SEL-487B Relay

Protection
Automation
Control

Instruction Manual

20210514

SCHWEITZER ENGINEERING LABORATORIES, INC.

PM487B-01

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Preface

Overview

This manual provides information and instructions for installing, setting, configuring, and operating the SEL-487B Relay. The manual is for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples.

Manual Overview

The SEL-487B Instruction Manual consists of three volumes:

➤ User's Guide

➤ Applications Handbook

➤ Reference Manual

In addition, the SEL-487B Instruction Manual contains a comprehensive *Index* that encompasses the entire manual and a *Glossary* that lists and defines technical terms used throughout the manual.

Read the sections that pertain to your application to gain valuable information about using the SEL-487B. For example, to learn about relay protection functions, read the protection sections of this manual and skim the automation sections. You can concentrate on the operation sections or on the automation sections of this manual as your job needs and responsibilities dictate. An overview of each manual section and section topics follows.

User's Guide

Preface. Describes manual organization and conventions used to present information.

Section 1: Introduction and Specifications. Introduces SEL-487B features; summarizes relay functions and applications; lists relay specifications, type tests, and ratings.

Section 2: Installation. Discusses the ordering configurations and interface features (control inputs, control outputs, and analog inputs, for example); provides information about how to design a new physical installation and secure the relay in a panel or rack; details how to set relay board jumpers and make proper rear-panel connections (including wiring to CTs and PTs); explains basic connections for the relay communications ports and how to install optional communications cards (such as the Ethernet card).

Section 3: PC Software. Introduces how to use the ACSELERATOR QuickSet® SEL-5030 Software Program.

Section 4: Basic Relay Operations. Describes how to perform fundamental operations such as applying power and communicating with the relay, setting and viewing passwords, checking relay status, viewing metering data, reading event reports and SER (Sequential Events Recorder) records, and operating relay control outputs and control inputs.

Section 5: Front-Panel Operations. Describes the LCD display messages and menu screens; shows you how to use front-panel pushbuttons and read targets; provides information about local substation control and how to make relay settings via the front panel.

Section 6: Testing and Troubleshooting. Describes techniques for testing, troubleshooting, and maintaining the SEL-487B; includes the list of status notification messages and a troubleshooting chart.

Appendix A: Firmware and Manual Versions. Lists the current firmware versions and details differences between the current and previous versions.

Appendix B: Firmware Upgrade Instructions. Provides information about upgrading firmware in your SEL-487B.

Applications Handbook

Section 1: System Configuration Guideline and Application Examples. Provides general guidelines for implementing the relay in single-relay and three-relay applications; provides CT and disconnect auxiliary contact requirements for proper differential protection application. The section also provides application examples for the following busbar layouts:

- Single bus and tie breaker, three-relay application
- Single bus and tie breaker, single-relay application
- Breaker-and-a half
- Single bus and transfer bus with buscoupler
- Double bus with buscoupler
- Double bus and transfer bus with two busbars
- Double and transfer bus (outboard CTs)
- Double and transfer bus (inboard CTs)

Use the worksheets provided on the SEL-487B *Product Literature CD* to collect and organize data before configuring and setting the relay.

Section 2: Monitoring and Metering. Describes how to use the substation dc battery monitors; provides information on viewing metering quantities for voltages and currents.

Section 3: Analyzing Data. Explains how to obtain raw data and filtered data event reports, event summaries, history reports, and SER reports; discusses how to enter SER trigger and alias settings.

Section 4: SEL Communications Processor Applications. Provides examples of how to use the SEL-487B with the SEL-2020, SEL-2030, and SEL-2032 Communications Processors for total substation automation solutions.

Section 5: Direct Network Communications. Explains how to use DNP3 (serial and LAN/WAN) and other Ethernet protocols such as Telnet, FTP, and IEC 61850.

Reference Manual

Section 1: Protection Functions. Describes the protection, monitoring, and control elements in the SEL-487B and how the relay processes these elements.

Section 2: SELOGIC Control Equation Programming. Describes SELOGIC® control equations and how to apply these equations; discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers; provides a tutorial for converting older format SELOGIC control equations to new free-form equations.

Section 3: Communications Interfaces. Explains the physical connection of the SEL-487B to various communications network topologies.

Section 4: SEL Communications Protocols. Describes the various SEL software protocols and how to apply these protocols to substation integration and automation; includes details about SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS® communications.

Section 5: DNP3 Communications. Explains how to use DNP3 (serial and LAN/WAN) and other Ethernet protocols such as Telnet, FTP, and IEC 61850.

Section 6: IEC 61850 Communications. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

Section 7: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 8: Settings. Provides a list of all SEL-487B settings and defaults. The organization of the settings is the same as for the settings organization in the relay and in the ACSELERATOR QuickSet software.

Appendix A: Relay Word Bits. Contains a summary of Relay Word bits.

Appendix B: Analog Quantities. Contains a summary of analog quantities.

SEL-487B Relay Command Summary. Contains a listing of SEL-487B commands.

CD-ROM

The CD-ROM contains the SEL-487B Instruction Manual in an electronic form that you can search easily.

Conventions

The SEL-487B Instruction Manual uses certain conventions that identify particular terms and help you find information. To benefit fully from reading this manual, take a moment to familiarize yourself with these conventions.

Typographic Conventions

There are three ways to communicate with the SEL-487B:

- Using a command line interface on a PC terminal emulation window, such as Microsoft® HyperTerminal®.
- Using the front-panel menus and pushbuttons.
- Using ACSELERATOR QuickSet SEL-5030 Software.

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions.

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
{CLOSE}	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
`RELAY RESPONSE` `MAIN > METER`	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.
U.3.1 A.3.1 R.3.1	Page numbers include a reference to the volume, section, and page number. U stands for User's Guide A stands for Applications Handbook R stands for Reference Manual
SELOGIC control equations	SEL trademarks and registered trademarks contain the appropriate symbol on first reference in a section. In the SEL-487B Instruction Manual, certain SEL trademarks appear in small caps. These include SELOGIC control equations, MIRRORED BITS communications, and ACSELERATOR QuickSet software program.
Modbus®	Registered trademarks of other companies include the registered trademark symbol with the first occurrence of the term in a section.

Commands

You can simplify the task of entering commands by shortening any ASCII command to the first three characters (upper- or lowercase); for example, **ACCESS** becomes **ACC**.

Always send a carriage return **<CR>** character, or a carriage return character followed by a line feed character **<CR><LF>**, to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a **<CR>**. For example, to send the **ACCESS** command, type the following:

ACC <Enter>

Safety Information

This manual uses three kinds of hazard statements, formatted as follows:

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury or equipment damage.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

Notes

Margin notes present valuable or important points about relay features or functions. Use these notes as tips to easier and more efficient operation of the relay.

Step-by-Step Procedures

The SEL-487B Instruction Manual contains many step-by-step procedures. These procedures lead you easily and efficiently through complex tasks. Each procedure lists required equipment, as well as the basic knowledge you need to perform the steps in the procedure. Throughout the procedure, the documentation references other SEL-487B Instruction Manual sections where you can find more information.

Read the entire procedure before performing the listed steps. Read each step again before you perform it. The following text shows sample steps. Steps include explanations, text references, table references, and figure references to further illustrate the step.

Step 1. Press **<Ctrl+T>** to use the serial communications terminal in the ACSELERATOR software.

Step 2. Press **<Enter>** to see if the communications link is active between the software and the relay.

You should see the Access Level 0 = prompt in the terminal window.

Step 3. Open the **Communication** menu and click **Port Parameters**.

Step 4. Confirm that you have entered the correct passwords in the **Level One Password** dialog box and the **Level Two Password** dialog box.

Step 5. On the **Settings** menu, click **Read**.

The relay sends all configuration and settings data to ACSELERATOR.

Step 6. Click the **+** mark next to the **Group** you want to program on the **Settings** tree view.

This example uses **Group 1**, as shown in *Figure 1.2*.

Figure Reference

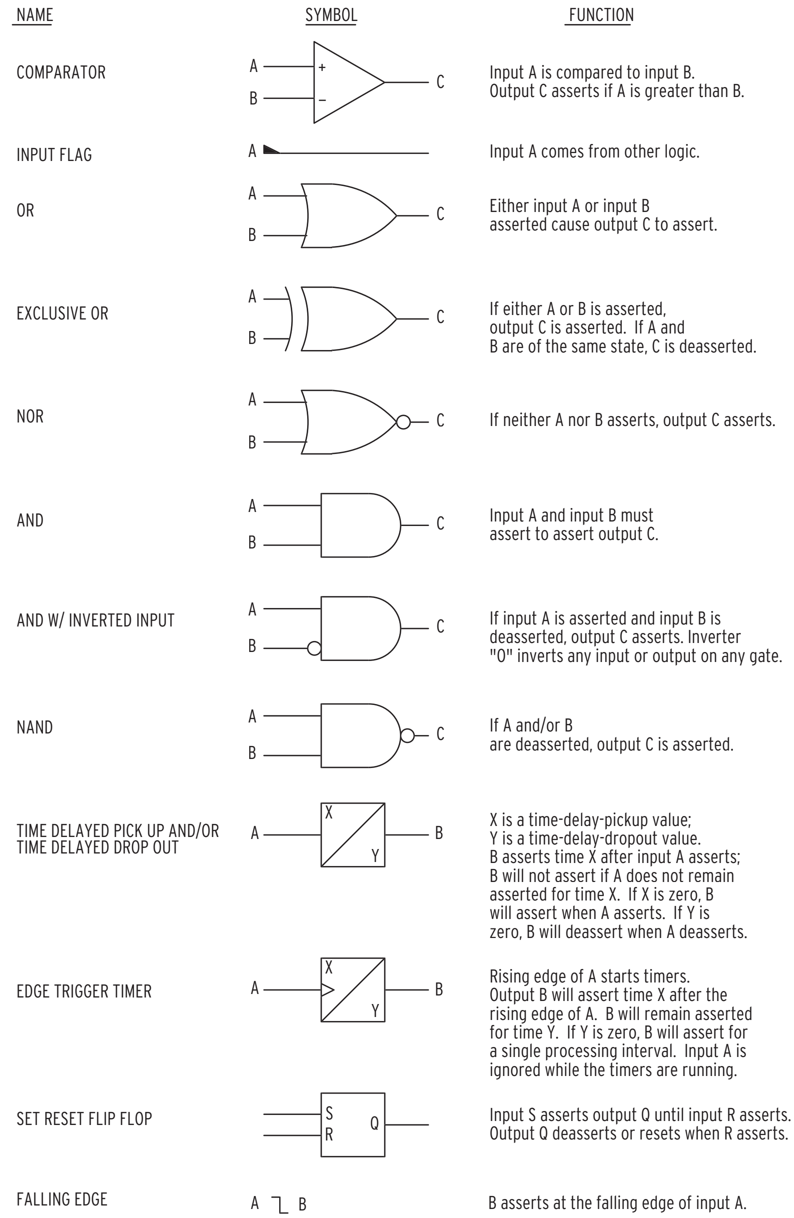
Sample Step-by-Step Instructions

Numbers

This manual displays numbers as decimal values. Hexadecimal numbers include the letter h appended to the number. Alternatively, the prefix 0X or 0x can also indicate a hexadecimal number. For instance, 11 is the decimal number eleven, but 11h and 0X11 are hexadecimal representations of the decimal value seventeen.

Logic Diagrams

Logic diagrams in this manual follow the conventions and definitions shown below.



SEL-487B Cautions, Warnings, and Dangers

The following hazard statements appear in the body of this manual in English. See the following table for the English and French translation of these statements.

English	French
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.	⚠ATTENTION Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.
⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Otherwise, equipment damage can result.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de mettre en marche.
⚠CAUTION Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.	⚠ATTENTION Ne pas installer de cavalier sur les positions A ou D sur le connecteur J18 de la carte principale. Une défaillance du relais pourrait survenir si un cavalier était installé sur les positions J18A et J18D.
⚠CAUTION Setting E87ZSUP := Y enables the zone supervision in all six zones. If you do not enter any supervision conditions for a particular zone, be sure to enter a 1 at the SELOGIC control equation prompt.	⚠ATTENTION Le réglage E87ZSUP := Y autorise la supervision de zone des six zones. Si vous n'entrez aucune condition de supervision pour une zone particulière, assurez-vous d'entrer un 1 au message de l'équation de commande SELOGIC.
⚠CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use Standard null-modem cables with this equipment.	⚠ATTENTION Des problèmes sévères d'alimentation et de masse pourraient survenir sur les ports de communication suite à l'usage de câbles autres que ceux fournis par SEL. Ne jamais utiliser des câbles standards de type modem nul avec cet équipement.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.

English	French
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING Do not look into the fiber (laser) ports/connectors.	⚠AVERTISSEMENT Ne pas regarder vers l'extremité des ports ou connecteurs de fibres pour laser.
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	⚠AVERTISSEMENT Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠WARNING Incorporated components, such as LEDs, transceivers, and laser emitters, are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes), émetteurs-récepteurs ou émetteurs pour rayon laser ne peuvent pas être entretenus par l'usager. Retourner ces unités à SEL pour toute réparation ou remplacement.
⚠WARNING Do not use Relay Word bit 51PnnT in any trip equation if inverse-time overcurrent protection is not required.	⚠AVERTISSEMENT Ne pas utiliser le bit de "Relay Word" 51PnnT dans une équation de déclenchement si la protection de type temps-courant à temps inverse n'est pas requise.
⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessuers ou la mort.

Section 1
Introduction and Specifications

Overview

The SEL-487B Relay provides bus current differential protection, circuit breaker failure protection, and backup overcurrent protection. Equipped with four interface boards, the relay has a total of 103 inputs (74 common inputs and 29 independent inputs) and 40 outputs. It is configurable in either a three-relay or a single-relay application. The relay has 18 analog current inputs and 3 analog voltage inputs. For buses with no more than six terminals, use one SEL-487B in a single-relay application. For buses with as many as 18 terminals, use three SEL-487B relays in a three-relay application; each relay provides up to six dedicated zones of protection.

The SEL-487B has separate protection and automation SELOGIC® control equation programming areas with extensive protection and automation programming capabilities. You can organize automation SELOGIC control equation programming into 10 blocks of 100 program lines each. With the flexibility of the expanded SELOGIC control equations, the relay is suitable for custom protection and control schemes.

Communications interfaces include standard SEL ASCII and enhanced MIRRORED BITS® communications protocols. Establish Ethernet connectivity with the optional Ethernet card. With the Ethernet card, you can employ the latest industry communications tools, including Telnet, FTP, IEC 61850, and DNP3 (Serial and LAN/WAN) protocols.

Included with the SEL-487B is the ACSELERATOR QuickSet® SEL-5030 Software program. Use the ACSELERATOR QuickSet software to assist you in setting, controlling, and acquiring data from the relays both locally and remotely. ACSELERATOR Architect is included with purchase of the optional Ethernet card with IEC 61850 protocol support. ACSELERATOR Architect enables you to view and configure IEC 61850 settings via a GUI interface, tightly integrated with ACSELERATOR QuickSet.

Combining the simple and robust hardware design with extensive self-testing provides relay reliability and enhances relay availability.

This section introduces the SEL-487B and provides information on the following topics:

- Functional Overview
- Models and Options
- Applications
- Specifications

Functional Overview

The SEL-487B contains many protection, automation, and control features. *Figure 1.1* presents a simplified functional overview of the relay.

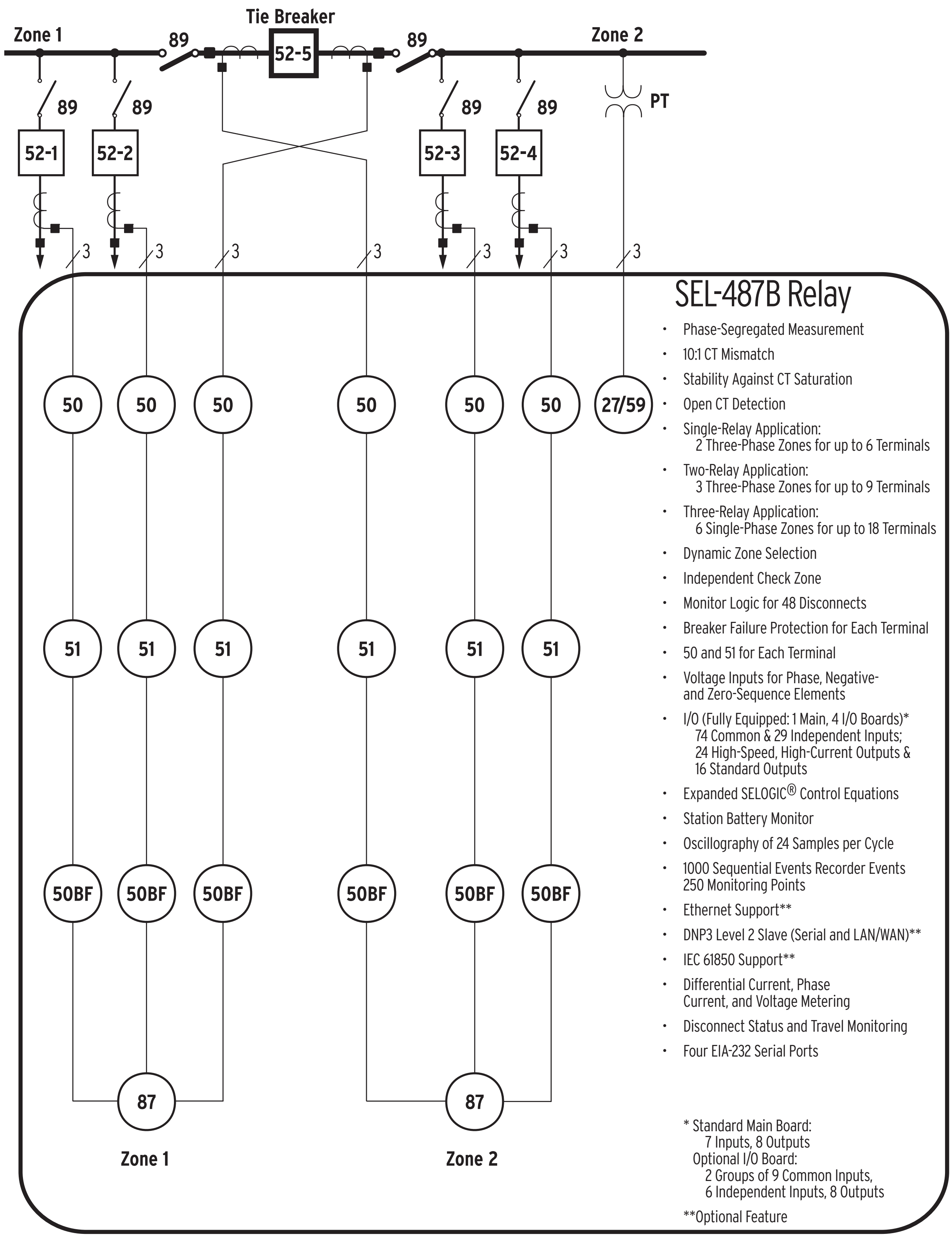


Figure 1.1 SEL-487B Relay Basic Functions in a Double-Bus Application

The SEL-487B features include the following:

Bus Protection. The SEL-487B provides differential protection for the following: single bus, double bus, double bus with transfer, breaker-and-a-half, triple bus arrangements, generators and motors, shunt capacitor banks, autotransformers and reactors.

Second Trip Criterion. Each of the six elements includes a second trip criterion. This criterion consists of the OR combination of a directional element in parallel with a fault detection element.

Check Zone Capability. If your protection philosophy calls for an overall check zone, configure any one of the six zones as a check zone or use the available independent check zone.

Voltage Elements. Phase, negative-, and/or zero-sequence elements are available as additional trip criteria for trip supervision.

Breaker Failure. Select the type of breaker failure protection (internal or external) on a terminal-by-terminal basis. Internal breaker failure protection provides breaker failure trip and breaker retrip for 18 terminals. Open-phase detection ensures current-element reset in less than one cycle. For the external breaker failure protection, select the external breaker failure option. With this option, the relay accepts inputs from breaker failure relays installed in the feeder protection panels.

Differential Protection. Innovative algorithms switch the relay to a high-security mode during through-fault conditions. While in the high-security mode, the algorithm does not block the differential elements, thus avoiding unnecessary time delays for clearing faults evolving from external to internal faults.

Overcurrent Elements. Each of the 18 terminals provides one level of phase instantaneous (50) and one level of time-overcurrent (51) protection.

CT Open-Circuit Detection. Use the independent sensitive differential element in each zone to detect CT open circuit, short circuit, or incorrect CT polarity.

Minimum CT Requirement. The relay requires primary CTs that shall reproduce the primary current without saturation for at least 2 ms after external fault inception.

Dynamic Station Configuration. Wire the disconnect (89) auxiliary contacts to the relay to assign the current inputs dynamically to the correct differential measuring element. Instead of disabling bus protection during disconnect switching, use this feature to provide bus protection during switching operations, when the safety of personnel is at high risk.

CT Ratio Mismatch. Mismatched CTs of ratios as high as 10:1 can be installed. For example, this means you can install the new feeder with a CT ratio of 2000/5 to existing bus systems that all have CT ratios of 200/5.

Expanded SELogic Control Equations. Modify and set custom relay applications with PLC-style (programmable logic controller, IEC 61131-3) SELogic control equation programming that includes math and comparison functions. Use counters and multifunction timers for greater application flexibility, i.e., perform advanced PLC functions within the relay. The SEL-487B has separate protection and automation SELogic control equation programming areas. These programming areas provide ample protection programming capability and 10 blocks of 100-line automation programming capability (1000 lines).

Alias Settings. Use as many as 200 aliases to rename any digital or analog quantity in the relay. The aliases are now available for use in customized programming, making the initial programming and maintenance much easier.

Metering. View metering primary or secondary information for phase currents and angles of all 18 terminals, phase voltages and angles, CT polarities, as well as the operating and restraint values from all protection zones.

Oscillography and Event Reporting. Record raw currents of all 18 current terminals and 3 voltages in a single report. Investigate relay internal logic points and power system performance with event report phasor analysis.

Sequential Events Recorder (SER). Record 1000 system entries from 250 monitoring points, including settings changes, power ups, and Relay Word bit elements that you select. Set element names to easily understood aliases.

Digital Relay-to-Relay Communication. Use MIRRORED BITS communications to monitor internal element conditions between relays within a substation and between substations using communication channels (SEL fiber-optic transceivers to send a direct transfer trip, for example).

Ethernet Communications Capability. Implement control and data gathering capabilities via substation LANs (local area networks) and company WANs (wide area networks) with the optional Ethernet card. Employ the FTP protocol for system data acquisition.

Increased Security. The SEL-487B divides control and settings into seven relay access levels; the relay has separate breaker, protection, automation, and output access levels, among others. Set unique passwords for each access level.

Computer Software. Use the rules-based settings editor, the ACSELERATOR software, to develop settings offline.

Settings Reduction. Internal relay programming shows only the settings for the functions and elements you have enabled.

Options and Standard Features

For ease of ordering and future expansion, the SEL-487B is available in a 9U chassis size (U is one rack unit in height—44.45 mm or 1.75 inches) that supports up to four additional expansion I/O boards, or, for applications not requiring as many contact I/O points, in a 7U chassis size that supports up to two additional expansion I/O boards. For the three-relay application, three units are required. Features not labeled as ordering options are standard.

- Up to four optional I/O boards (9U chassis size supports a maximum of four optional I/O boards; 7U chassis size supports a maximum of two optional I/O boards)
  - INT4 with high-speed outputs: 18 common inputs (2 groups of 9), 6 independent inputs, 6 high-speed Form A outputs, 2 standard Form A outputs
  - INT4 with standard outputs: 18 common inputs (2 groups of 9) 6 independent inputs, 8 standard Form A outputs
- Power supply (ordering option)
  - 24/48 Vdc
  - 48/125 Vdc or 120 Vac
  - 125/250 Vdc or 120/230 Vac
- Secondary current inputs (ordering option)
  - 1 A nominal or 5 A nominal CT inputs
- Communications card (ordering option)
  - Ethernet card with combinations of 10 Mbps and 100 Mbps copper and fiber jacks on each of two ports providing FTP, Telnet, DNP3 LAN/WAN, and IEC 61850 protocols
  - Secondary voltage inputs (standard feature)
  - 300 V maximum per voltage input
- Secondary voltage inputs (standard feature)
  - 300 V maximum per voltage input
- Communications protocols (standard features)
  - SEL Compressed ASCII
  - SEL Fast Messaging (SEL Fast Meter, SEL Fast Operate, SEL Fast SER)
  - ASCII
  - Ymodem File Transfer
  - Enhanced MIRRORED BITS
  - DNP3 Level 2 Slave, Serial (ordering option)
  - DNP LAN/WAN (ordering option)
  - IEC 61850 (ordering option)
- Fixed terminal block for PT and CT inputs (standard feature)

Contact the SEL factory or your local Technical Service Center for ordering information (see *Technical Support on page U.6.38*). You can also view the latest ordering information on the SEL website at www.selinc.com.

Applications

Use the SEL-487B for most bus protection applications. For information on connecting the relay, see *Section 2: Installation*. See the *Applications Handbook* for thorough discussions of protection and automation applications using the SEL-487B. The figures in this subsection illustrate common relay applications. Each SEL-487B has 18 analog current inputs (I01 through I18) and three analog voltage inputs (V01, V02, and V03).

Single Busbar–Up to 6 Terminals

Use one SEL-487B for the application in *Figure 1.2*. In this application, the relay has two 3-phase bus-zones available. Wire the disconnect status to the relay to dynamically assign the terminal currents to the differential elements for each zone.

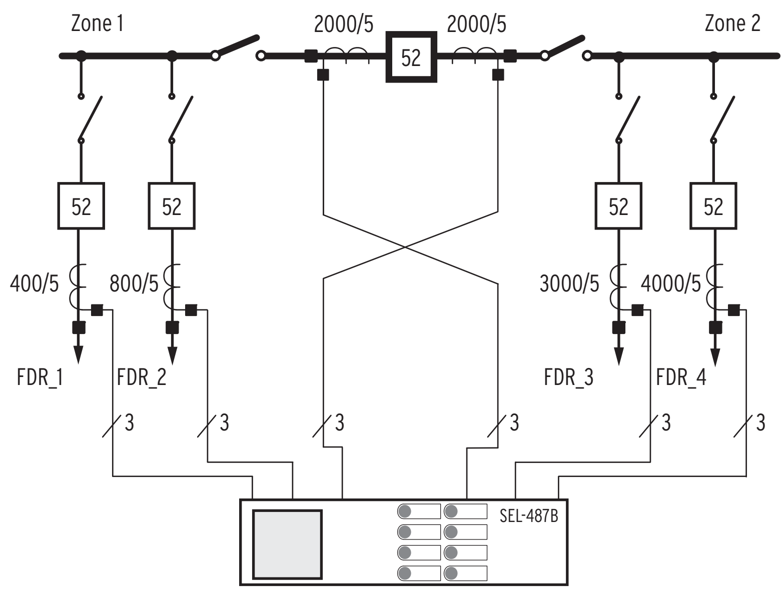


Figure 1.2 Single SEL-487B Protecting Double Bus Sections With Bus Tie Breaker

Breaker-and-a-Half Busbar Configuration

Figure 1.3 shows a station with a breaker-and-a-half busbar configuration. For this configuration, and with six or fewer terminals on either busbar, use one SEL-487B per busbar.

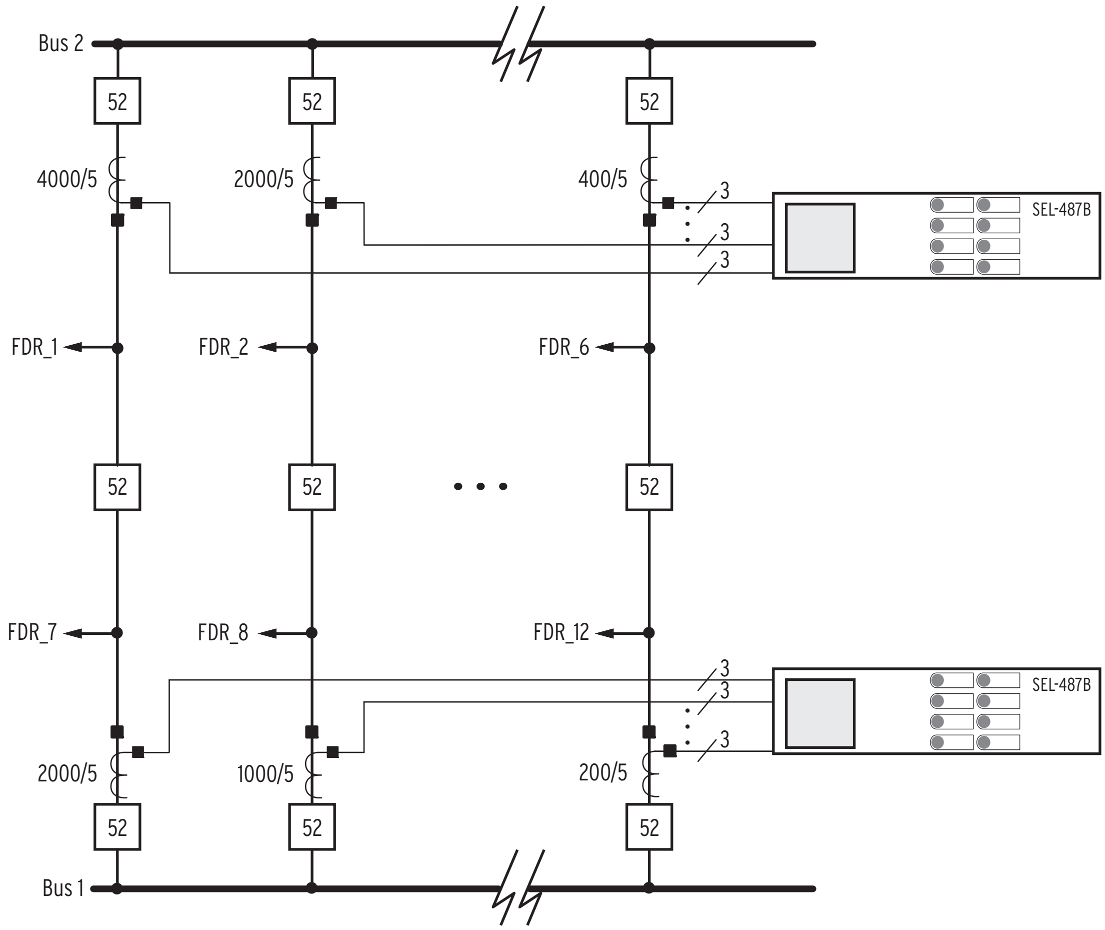


Figure 1.3 Two Single SEL-487B Relays Protecting the Two Busbars in a Breaker-and-a-Half Busbar Configuration

Triple Busbar—Up to 18 Terminals

Figure 1.4 shows a triple busbar layout (i.e., two main busbars and a transfer bus).

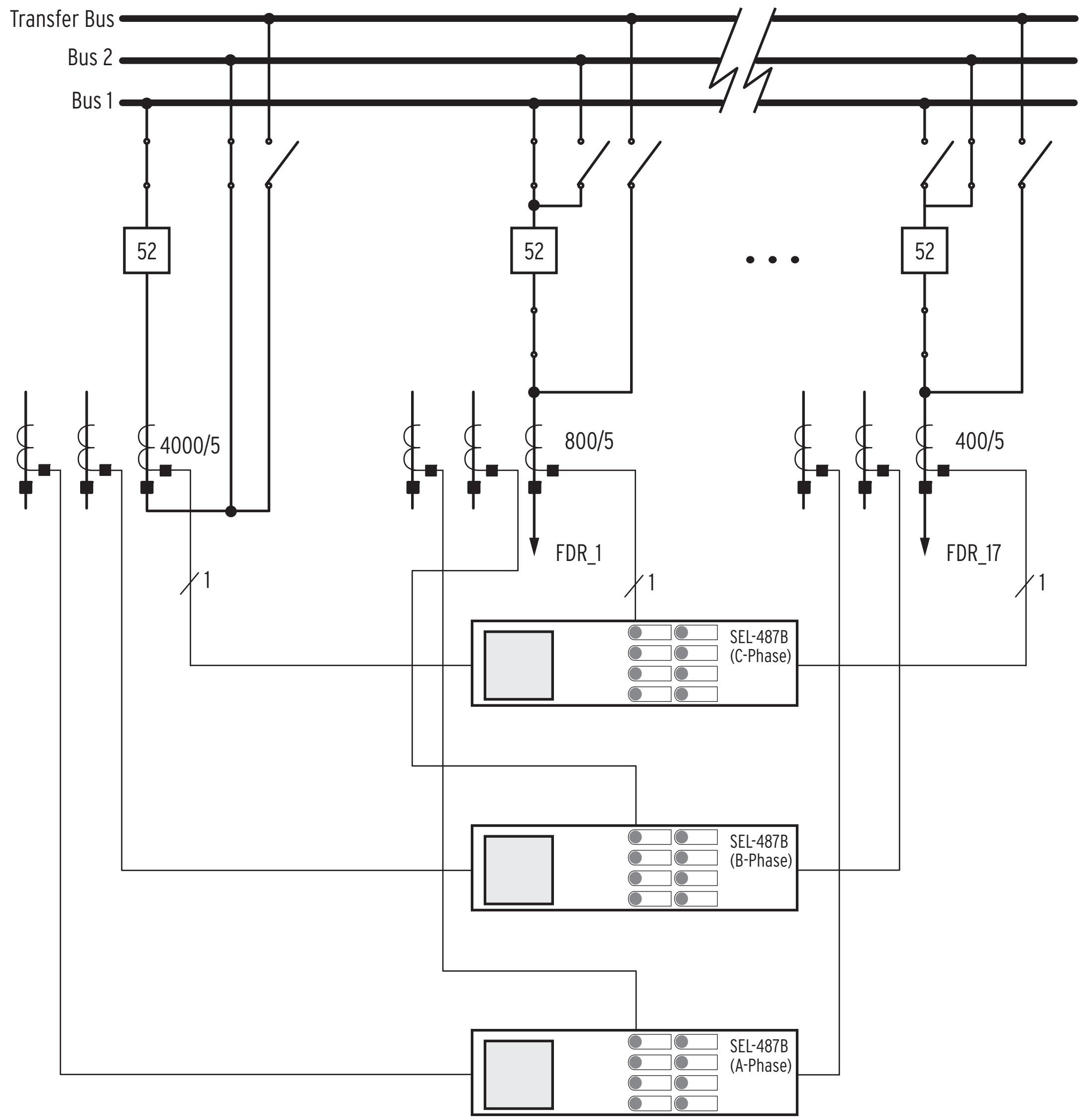


Figure 1.4 Three SEL-487B Relays Protect 2 Main Busbars and a Transfer Busbar, 1 Bus Coupler, and 17 Terminals

Optimize your SEL-487B by protecting both HV and LV busbars with three relays. *Figure 1.5* shows two HV busbars and two LV busbars. Using four zones for the four busbars (two HV and two LV) still leaves two zones available that can be configured as overall check zones, one for the HV and one for the LV busbars.

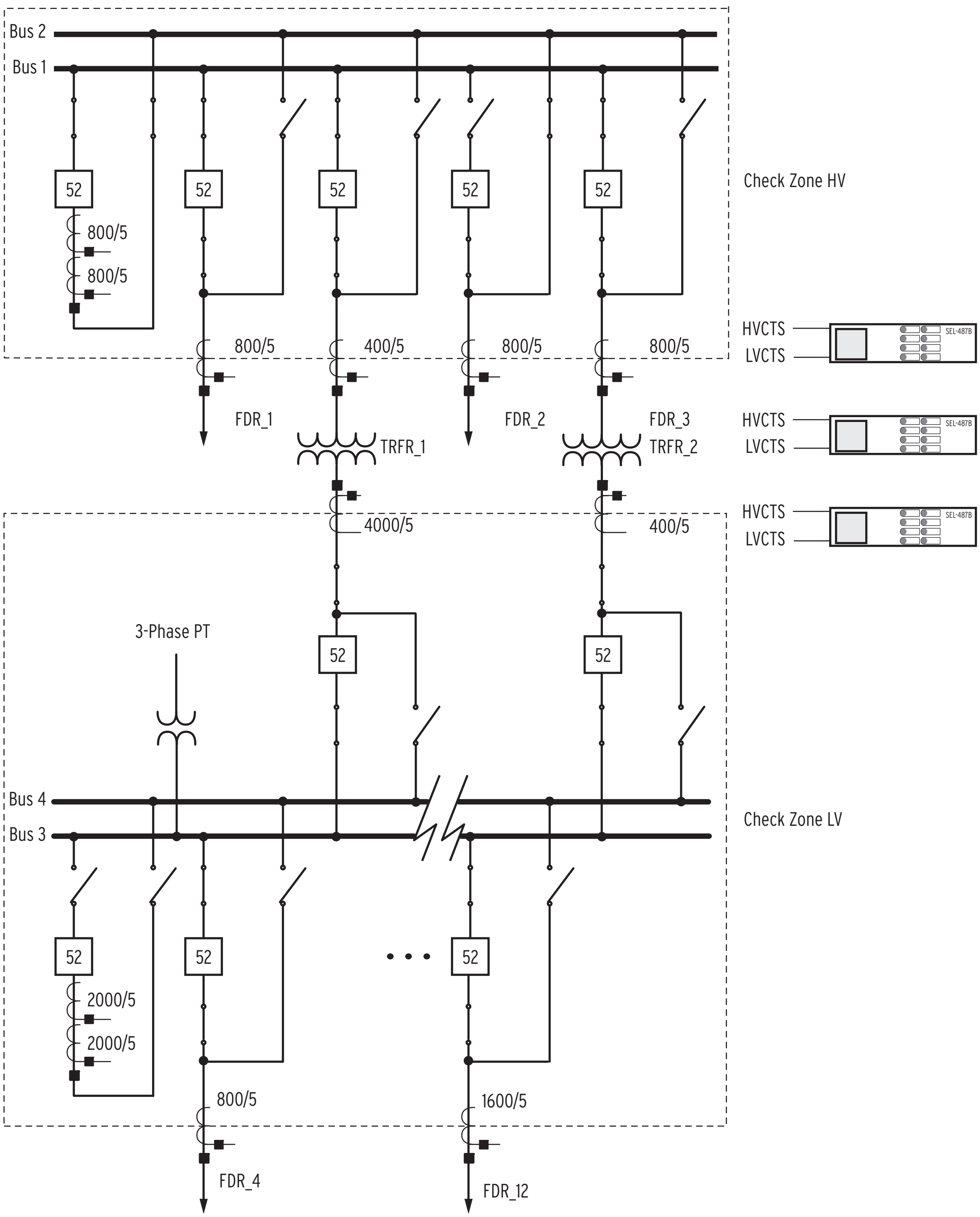


Figure 1.5 Three SEL-487B Relays Protect Both HV and LV Busbars

Table 1.1 Application Highlights

Application	Key Feature
High number of terminals and zones	Three-relay applications provide six zones of protection for as many as 18 terminals.
Complex busbar arrangements	Flexible zone selection logic uses the disconnect auxiliary contacts to dynamically assign the currents to the correct zones.
Wide range of bus applications	A variety of bus applications are available: single bus, double bus, double bus with transfer, breaker-and-a-half, triple bus arrangements.
High-speed tripping	The SEL-487B features fast differential elements and fast closing trip outputs with total clearing times of less than one cycle.
Minimum CT requirements	The differential elements are secure when the CTs reproduce the primary current without saturating for at least 2 ms after external fault inception.
Open CT detection	The open CT detection elements use delta IOP/IRT to reliably detect failed CTs within each differential zone.
Terminals with different CT ratios	The SEL-487B accepts a CT mismatch of 10:1 in any one zone or combination of zones; for example, 250/5 to 2500/5.
Fast resetting internal breaker failure protection	The SEL-487B includes breaker failure protection with retrip for each terminal. Open-phase detection ensures current-element reset in less than one cycle.
External breaker failure relays	Set any terminal to "external breaker failure" to still use the trip logic in the relay, but the breaker failure initiation is from an external breaker failure relay.
Backup overcurrent protection	Each terminal has instantaneous and inverse time-overcurrent elements.
Check zone as trip criterion	Configure any of the six zones as an overall check zone or use the available independent check zone.
Voltage as trip supervision	Choose from phase, negative-, or zero-sequence voltage to supervise the differential elements.
End-zone protection	Use SELOGIC control equations to configure end-zone protection for faults between the feeder circuit breaker and the CT.
Fault between tie breaker and CT	The SEL-487B includes logic to accelerate tripping for a fault between the tie breaker and CT. Further logic ensures the security of the healthy zone when the tie breaker is closed onto a fault.
Direct transfer trip	Use MIRRORED BITS communications to send a trip to the remote end of the line.
Auxiliary relays	The SEL-487B requires no auxiliary relays for zone selection.
SCADA applications analog and digital data acquisition for station-wide functions	The SEL-487B can acquire analog and digital data for station-wide functions.
Communications capability	These protocols are included in the relay: SEL Compressed ASCII, SEL Fast Messaging (SEL Fast Meter, SEL Fast Operate, SEL Fast SER), SEL ASCII, Enhanced MIRRORED BITS® communications, YMODEM File Transfer. Additionally, you can choose these optional protocols: Ethernet, IEC 61850, FTP, Telnet, DNP3 (Serial and/or LAN/WAN).
Customized protection and automation schemes	The SEL-487B includes separate protection and automation SELOGIC control equation programming areas. Use timers and counters in expanded SELOGIC control equations for complete flexibility.

Specifications

Important: Do not use the following specification information to order an SEL-487B. Refer to the actual ordering information sheets.

General

AC Current Inputs (Secondary Circuits)

Note: Current transformers are Measurement Category II.

Continuous Thermal Rating

5 A nominal:	15 A
1 A nominal:	3 A

Saturation Current (Linear) Rating

5 A nominal:	100 A
1 A nominal:	20 A

One-Second Thermal Rating

5 A nominal:	500 A
1 A nominal:	100 A

One-Cycle Thermal Rating

5 A nominal:	1250 A-peak
1 A nominal:	250 A-peak

Burden Rating

5 A nominal:	≤0.5 VA at 5 A 2.51 VA at 15 A
1 A nominal:	≤0.1 VA at 1 A 1.31 VA at 3 A

Minimum A/D Current Limit (peak)

5 A nominal:	247.5 A
1 A nominal:	49.5 A
Sampling Rate:	Analog input signals shall be sampled at a rate of 24 samples per cycle.
Rated Voltage (U_e):	240 Vac
Rated Insulation Voltage (U_i):	300 Vac
Sampling Rate Analog inputs:	24 samples per cycle
Rotation:	ABC, ACB

AC Voltage Inputs

Rated Voltage Range:	0–300 V_{LN}
Ten-Second Thermal Rating:	600 Vac
Burden:	<0.1 VA @ 125 V

Power Supply

125/250 Vdc or 120/240 Vac

Rated Supply Voltage:	120/240 Vac 125/250 Vdc
Absolute Voltage Range:	85–300 Vdc 85–264 Vac
Rated Frequency:	50/60 Hz ± 5 Hz
Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-11:2008
Interruption:	250 ms @ 250 Vdc per IEC 60255-11:2008
Burden:	<35 W

48/125 Vdc or 120 Vac

Rated Supply Voltage:	120 Vac 48/125 Vdc
Absolute Voltage Range:	38–140 Vdc 85–140 Vac
Rated Frequency:	50/60 Hz ± 5 Hz
Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-11:2008
Interruption:	160 ms @ 125 Vdc per IEC 60255-11:2008
Burden:	<35 W

24/48 Vdc

Rated Supply Voltage:	24/48 Vdc
Absolute Voltage Range:	18–60 Vdc
Vdc Input Ripple:	15% per IEC 60255-11:2008
Interruption:	100 ms @ 48 Vdc per IEC 60255-11:2008
Burden:	<25 W

Operating Temperature

SEL-487B Without Ethernet Card:

–40° to +85°C (–40° to +185°F)

SEL-487B With Ethernet Card:

–40° to +75°C (–40° to +167°F)

Note: LCD contrast impaired for temperatures below –20° and above +70°C. Stated temperature ranges not applicable to UL applications.

Humidity

5% to 95% without condensation

Weight (Maximum)

9U Rack Unit:	19.1 kg (42 lbs)
7U Rack Unit:	16.1 kg (35 lbs)

Control Outputs

Main Board:	5 Form A and 3 Form C
Interface Boards:	High-speed contact option: 2 standard Form A 6 high-speed, high-current interrupting Form A Standard Contact Option: 8 standard Form A contacts

Standard

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (maximum voltage):	250 Vac, 330 Vdc
Pickup/Dropout Time:	6 ms, resistive load

Update Rate:	1/12 cycle

Break Capacity (10000 operations):

48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Cyclic Capacity (2.5 cycle/second):

48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

High-Speed High-Current Interrupting

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (maximum voltage):	250 Vac, 330 Vdc
Pickup Time:	10 µs, resistive load
Dropout Time:	8 ms, resistive load
Update Rate:	1/12 cycle

Break Capacity (10000 operations):

48 V	10.0 A	L/R = 40 ms
125 V	10.0 A	L/R = 40 ms
250 V	10.0 A	L/R = 20 ms

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

48 V	10.0 A	L/R = 40 ms
125 V	10.0 A	L/R = 40 ms
250 V	10.0 A	L/R = 20 ms

Note: Per IEC 60255-23:1994, using the simplified method of assessment.

Note: Make rating per IEEE® C37.90-1989.

Optoisolated Inputs

Main Board:	5 inputs with no shared terminals 2 inputs with shared terminals
INT4 Interface Board:	6 inputs with no shared terminals 18 inputs with shared terminals (2 groups of 9 inputs, with each group sharing one terminal)
Voltage Options:	24 V standard 48, 110, 125, 220, 250 V standard

DC Thresholds

24 Vdc:	Pickup 15.0–30.0 Vdc
48 Vdc:	Pickup 38.4–60.0 Vdc; Dropout below 28.8 Vdc
110 Vdc:	Pickup 88.0–132.0 Vdc; Dropout below 66.0 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout below 75 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout below 132 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout below 150 Vdc

AC Thresholds (Ratings met only when recommended control input settings are used—see *Table 2.1 on page 2.9*)

24 Vac:	Pickup 12.3–30.0 Vac
48 Vac:	Pickup 31.4–60.0 Vac; Dropout below 20.3 Vac
110 Vac:	Pickup 71.9–132.0 Vac; Dropout below 46.6 Vac
125 Vac:	Pickup 85.8–150.0 Vac; Dropout below 53.0 Vac
220 Vac:	Pickup 143.8–264 Vac; Dropout below 93.2 Vac
250 Vac:	Pickup 163.3–300 Vac; Dropout below 106 Vac
Current Drawn:	5 mA at nominal voltage 8 mA for 110 V option
Sampling Rate:	24 samples per cycle

Frequency and Rotation

System Frequency:	50/60 Hz
Phase Rotation:	ABC or ACB

Communications Ports

EIA-232:	1 Front and 3 Rear
Serial Data Speed:	300–57600 bps

Communications Card Slot for Optional Ethernet Card

Fiber Optic (Optional)

Ordering Options:	100BASE-FX
Mode:	Multi
Wavelength (nm):	1300
Source:	LED
Connector Type:	ST
Min. TX Pwr. (dBm):	–19
Max. TX Pwr. (dBm):	–14
RX Sens. (dBm):	–32
Sys. Gain (dB):	13

IRIG Time Input

Demodulated IRIG-B time code

Nominal Voltage:	5 Vdc + 10%
Maximum Voltage:	8 Vdc
Input Impedance:	333 ohms
Distance Between Relays for Cable With Capacitance of 28 pF/ft:	90 m (300 ft)

IRIG Time Output

Capable of driving 300 ohm termination with <200 ns propagation delay

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum:	1.0 Nm (9 in-lb)
Maximum:	2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes:

Connection Type	Minimum Wire Size	Maximum Wire Size
Grounding (Earthing) Connection	18 AWG ($0.8 mm^2$)	14 AWG ($2.5 mm^2$)
Current Connection	16 AWG ($1.5 mm^2$)	12 AWG ($4 mm^2$)
Potential (Voltage) Connection	18 AWG ($0.8 mm^2$)	14 AWG ($2.5 mm^2$)
Contact I/O	18 AWG ($0.8 mm^2$)	14 AWG ($2.5 mm^2$)
Other Connection	18 AWG ($0.8 mm^2$)	14 AWG ($2.5 mm^2$)

Type Tests

Electromagnetic Compatibility Emissions

Emissions: IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity:
IEC 60255-22-6:2001
Severity Level: 10 Vrms
IEC 61000-4-6:2008
Severity Level: 10 Vrms

Electrostatic Discharge Immunity:
IEC 60255-22-2:2008
Severity Level: 2, 4, 6, 8 kV contact: 2, 4, 8, 15 kV air
IEC 61000-4-2:2008
Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEEE C37.90.3-2001
Severity Level: 2, 4, 8 kV contact; 4, 8, 15 kV air

Fast Transient/Burst Immunity:
IEC 60255-22-4:2008
Severity Level: Class A: 4 kV, 5 kHz; 2 kV, 5 kHz on communication ports
IEC 61000-4-4:2011
Severity Level: 4 kV, 5 kHz

Magnetic Field Immunity:
IEC 61000-4-8:2009
Severity Level: 900 A/m for 3 seconds, 100 A/m for 1 minute
IEC 61000-4-9:2001
Severity Level: 1000 A/m

Power Supply Immunity:
IEC 60255-11:2008
IEC 61000-4-11:2004
IEC 61000-4-29:2000

Radiated Digital Radio Telephone RF Immunity:
ENV 50204:1995
Severity Level: 10 V/m at 900 MHz and 1.89 GHz

Radiated Radio Frequency Immunity:
IEC 60255-22-3:2007
Severity Level: 10 V/m
IEC 61000-4-3:2010
Severity Level: 10 V/m
IEEE C37.90.2-2004
Severity Level: 35 V/m

Surge Immunity:
IEC 60255-22-5:2008
Severity Level: 1 kV Line to Line, 2 kV Line to Earth
IEC 61000-4-5:2005
Severity Level: 1 kV Line to Line, 2 kV Line to Earth

Surge Withstand Capability Immunity:
IEC 60255-22-1:2007
Severity Level: 2.5 kV peak common mode, 1.0 kV peak differential mode
IEEE C37.90.1-2002
Severity Level: 2.5 kV oscillatory, 4 kV fast transient waveform

Environmental

Cold:
IEC 60068-2-1:2007,
Severity Level: 16 hours at –40°C

Damp Heat, Cyclic:
IEC 60068-2-30:2005
Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity 95%

Dry Heat:
IEC 60068-2-2:2007
Severity Level: 16 hours at +85°C

Vibration:
IEC 60255-21-1:1988
Severity Level: Class 1 Endurance, Class 2 Resonse
IEC 60255-21-2:1988
Severity Level: Class 1 – Shock Withstand, Bump, and Class 2 – Shock Response
IEC 60255-21-3:1983
Severity Level: Class 2 (Quake Response)

Safety

Dielectric Strength:
IEC 60255-5:2000
Severity Level: 2500 Vac on control inputs, control outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.
IEEE C37.90-2005
Severity Level: 2500 Vac on control inputs, control outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.

Impulse:
IEC 60255-5:2000
Severity Level: 0.5 Joule, 5 kV
IEEE C37.90-2005
Severity Level: 0.5 Joule, 5 kV

IP Code:
IEC 60529:2001 + CRGD:2003
Severity Level: IP30

Safety Agency Certifications

Product Safety:
C22.2 No 14
cUL Listed Protective Relay, Product Category NRGU7
UL 508
UL Listed Protective Relay, Product Category NRGU

Certifications

ISO 9001: This product was designed and manufactured under an ISO 9001 certified quality management system.

Event Reports

Maximum Duration:
16 events at 30 cycles,
32 events at 15 cycles,
8 events at 60 cycles,
or 4 events at 120 cycles

Resolution: 4-, 12-, and 24-samples/cycle

Event Summary

Storage: 100 summaries

Sequential Events Recorder

Sequential Events Recorder Storage:	1000 entries
Trigger Elements:	250 monitoring points
Processing Rate:	24 samples per cycle

Processing Specifications

AC Voltage and Current Inputs

24 samples per cycle, 3 dB low-pass analog filter cut-off frequency of 646 Hz, ±5%

Digital Filtering

Full-cycle cosine after low-pass analog filtering

Protection and Control Processing

12 times per power system cycle

Control Points

32 remote bits
32 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

Relay Element Pickup Ranges and Accuracies

Differential Elements

Number of Zones:	6
Number of Terminals:	
Three-relay Application:	18
Single-Relay Application:	6
Slope 1	
Setting Range:	15–90%
Accuracy:	±5% ±0.02 • I_{NOM}
Slope 2	
Setting Range:	50–90%
Accuracy:	±5% ±0.02 • I_{NOM}

Supervising Differential Element

Quantity:	6
Setting range:	0.10–4.00 pu
Accuracy:	±5% ±0.02 • I_{NOM}

Incremental Restraint and Operating Threshold Current Supervision

Setting range:	0.1–10.0 pu
Accuracy:	±5% ±0.02 • I_{NOM}

Sensitive Differential Current Alarm

Quantity:	6
Setting range:	0.05–1.00 pu
Accuracy:	±5% ±0.02 • I_{NOM}
Timer Setting Range:	50–6000 cycles

Instantaneous/Definite-Time Overcurrent Elements

Phase Current Setting Range:	
5 A Model:	OFF, 0.25–100.00 A secondary, 0.01 A steps
1 A Model:	OFF, 0.05–20.00 A secondary, 0.01 A steps
Accuracy (Steady State):	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Transient Overreach:	<5% of setting
Timer Setting Range:	0.00–99999.00 cycles, 1/6-cycle steps
Timer Accuracy:	±0.1% of settings ±1/6 cycle
Max. Operating Time:	1.5 cycles

Time-Overcurrent Elements

Pickup Range:	
5 A Model:	0.50–16.00 A secondary, 0.01 A steps
1 A Model:	0.10–3.20 A secondary, 0.01 A steps
Accuracy (Steady State):	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Time Dial Range:	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles, ±4% of curve time (for current between 2 and 30 multiples of pickup)
Reset:	1 power cycle or Electromechanical Reset Emulation time

Under/Overvoltage Elements (27, 59)

Processing Rate:	1/12 cycle
Phase Under/Overvoltage (2 Level/Phase)	
Setting Range:	1.0–200 V_{LN} in 0.1 steps
Accuracy:	±5% of setting, ±0.5 V
Transient Overreach:	<5% of pickup
Maximum Delay:	1.5 cycles
Zero- and Negative-Sequence Overvoltage Elements	
Setting Range:	1.0–200 V in 0.1 steps
Accuracy:	±5% of setting, ±1 V
Transient Overreach:	<5% of setting
Maximum Delay:	1.5 cycles

Breaker Failure Instantaneous Overcurrent

Setting Range:	
5 A Model:	0.50–50 A, 0.01 A steps
1 A Model:	0.10–10.0 A, 0.01 A steps
Accuracy:	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Transient Overreach:	<5% of setting
Maximum Pickup Time:	1.5 cycles
Maximum Reset Time:	<1 cycle
Timers Setting Range:	0–6000 cycles, 1/12-cycle steps (BFPU*nn*, RTPU*nn*) 0–1000 cycles, 1/12-cycle steps (BFISP*nn*, BFIDO*nn*)
Time Delay Accuracy:	1/12 cycle, ±0.1% of setting

Disconnect Monitor

Number:	48
Timer Setting Range:	0–99999 cycles, 1 cycle step

Breaker Status Monitor

Number: 18

Coupler Security Logic

Number: 4

Timer Setting Range: 0–1000 cycles, 1/12 cycle step

Control Input Timers

Setting Range:

Pickup: 0.00–1 cycle

Dropout: 0.00–1 cycle

Station DC Battery System Monitor Specifications

Operating Range: 0–350 Vdc

Input Sampling Rate: 24 samples per cycle

Processing Rate: 1/6 cycle

Maximum Operating Time: ≤ 1.5 seconds (element DC1R)
≤1.5 cycles (all elements but DC1R)

Setting Range:

DC Settings: OFF, 15–300 Vdc, 1 Vdc steps

AC Ripple Setting: 1–300 Vac, 1 Vac steps

Pickup Accuracy: ±10%, ±2 Vdc (DC1RP), ±3%, ±2 Vdc (all elements but DC1RP)

Metering Accuracy

All metering accuracies are based on an ambient temperature of 20°C and nominal frequency.

Instantaneous Differential Metering per Zone (Steady State)

IOP, IRT: ±3.0%, ±0.02 • I_{NOM}

Per-Phase Instantaneous Metering (Steady State)

V01, V02, and V03: > 30 V ±1%

I01, I02, . . ., I18: ±1.5% ±0.004 • I_{NOM}, ±2.0°

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Section 2
Installation

Overview

The first steps in applying the SEL-487B Relay are installing and connecting the relay. This section describes common installation features and particular installation requirements for the physical configurations of the SEL-487B. You can order the relay in panel-mount or rack-mount versions, in a 9U horizontal orientation, with up to four interface boards, or in a 7U version, with up to two interface boards. To install and connect the relay safely and effectively, you must be familiar with relay configuration features, options, and relay jumper configuration. You should plan relay placement, cable connection, and relay communication carefully.

Consider the following when installing the SEL-487B:

- Shared configuration attributes
  - Relay size
  - Front-panel templates
  - Rear panels
  - Connector types
  - Secondary circuits
  - Control inputs
  - Control outputs
  - Main board I/O
  - Time inputs
  - Battery-backed clock
  - Communications interfaces
- Plug-in boards
  - I/O interface board(s) (if applicable)
  - Communications card (if applicable)
- Jumpers
  - Main board jumpers
  - Password and circuit breaker jumpers
  - I/O interface board jumpers
- Front-panel labels
  - Removing and changing configurable front-panel labels
  - Creating laser-printed labels

- Relay placement
  - Physical location
  - Rack mounting
  - Panel mounting
- Connection
  - Rear-panel layout
  - Rear-panel symbols
  - Screw terminal connectors
  - Grounding
  - Power connections
  - Monitor connections (dc battery)
  - Secondary circuit connections
  - Control circuit connections
  - Time input connections
  - Replacing the lithium battery
  - Communications ports connections
- AC/DC connection diagrams

This section contains drawings of typical ac and dc connections to the SEL-487B (*AC/DC Connection Diagrams on page U.2.38*). Use these drawings as a starting point for planning your particular relay application. It is also very important to limit access to the SEL-487B settings and control functions by using passwords. For information on relay access levels and passwords, see *Section 7: ASCII Command Reference in the Reference Manual*.

Shared Configuration Attributes

There are common or shared attributes among the many possible configurations of the SEL-487B. This section discusses the main shared features of the relay.

Relay Size

SEL produces the SEL-487B in a 9U panel-mount or rack-mount version, horizontal orientation, or in a 7U panel-mount or rack-mount version. The 9U version is capable of supporting up to a maximum of four optional I/O boards, and the 7U version is capable of supporting up to a maximum of two optional I/O boards.

Front-Panel Templates

The front-panel template is shown in *Figure 2.1*. The SEL-487B front panel has three pockets for slide-in labels: one pocket for the **TARGET** LED label and two pockets for the Operator Control labels. *Figure 2.1* and *Figure 2.2* show the front-panel pocket areas and openings; dashed lines denote the pocket areas.

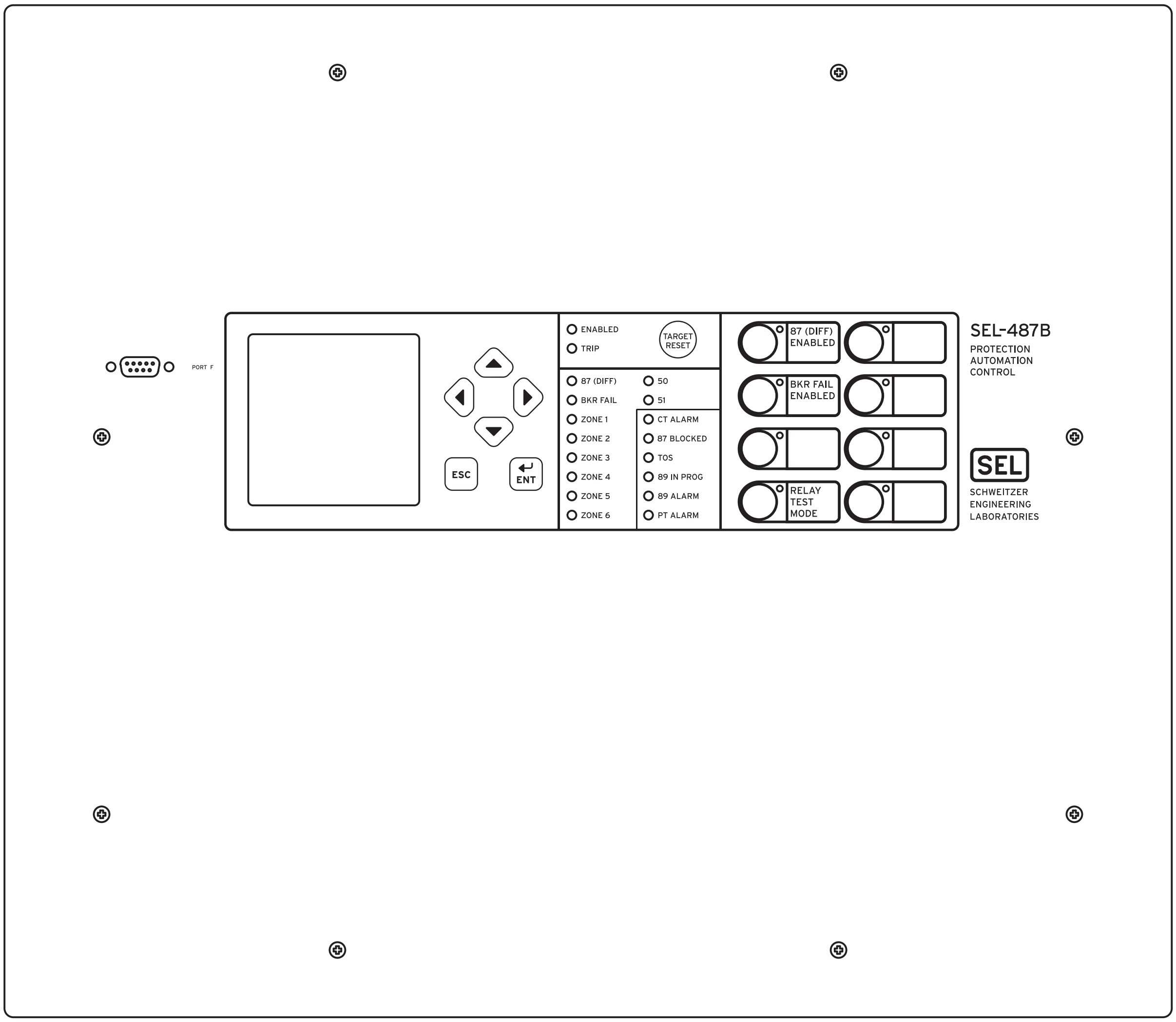


Figure 2.1 Front-Panel Diagram, Panel-Mount Option, 9U Version, Showing the Front Panel With LCD, Navigation Pushbuttons, Programmable LEDs, Reset, and Programmable Pushbuttons

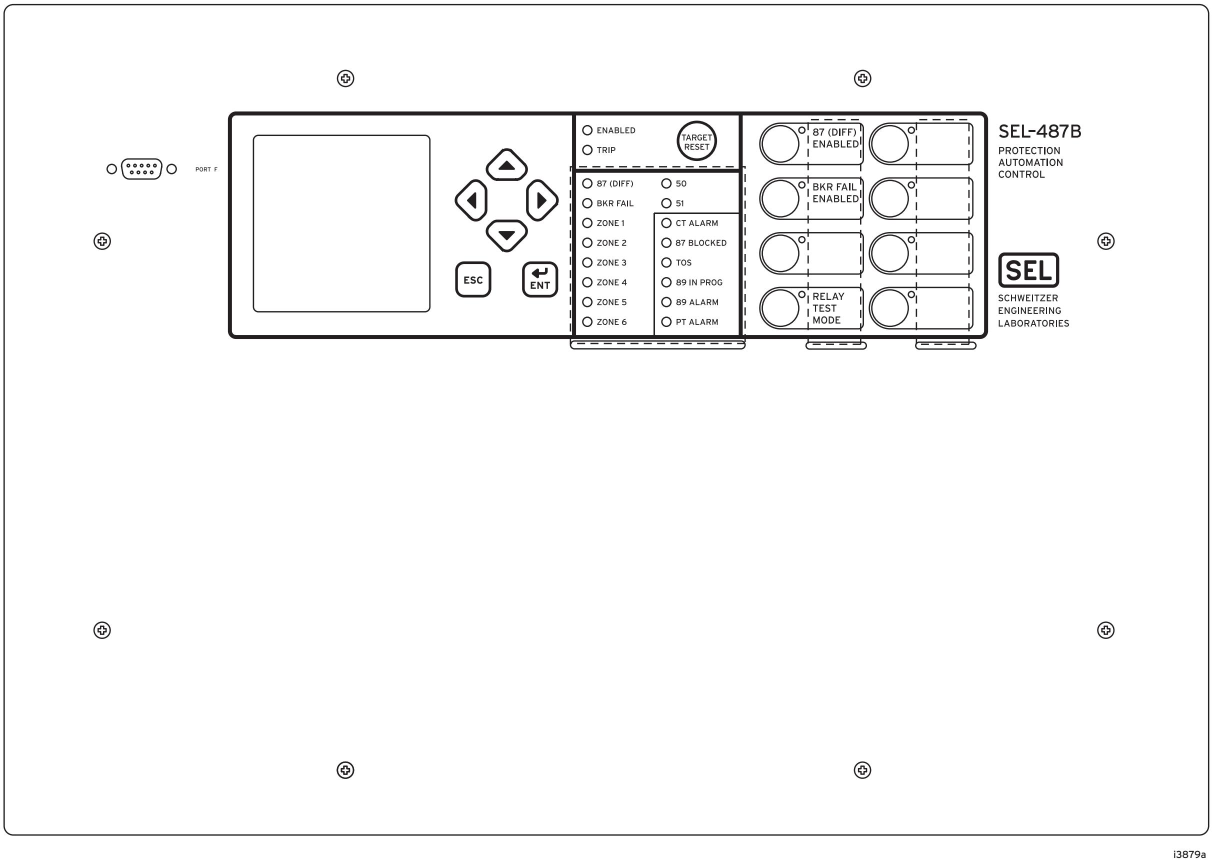


Figure 2.2 Front-Panel Diagram, Panel-Mount Option, 7U Version, Showing the Front Panel With LCD, Navigation Pushbuttons, Programmable LEDs, Reset, and Programmable Pushbuttons

Rear Panels

Figure 2.3 and *Figure 2.4* show examples of a rear panel with fixed terminal block analog inputs. Note that Connectorized® analog inputs are not available.

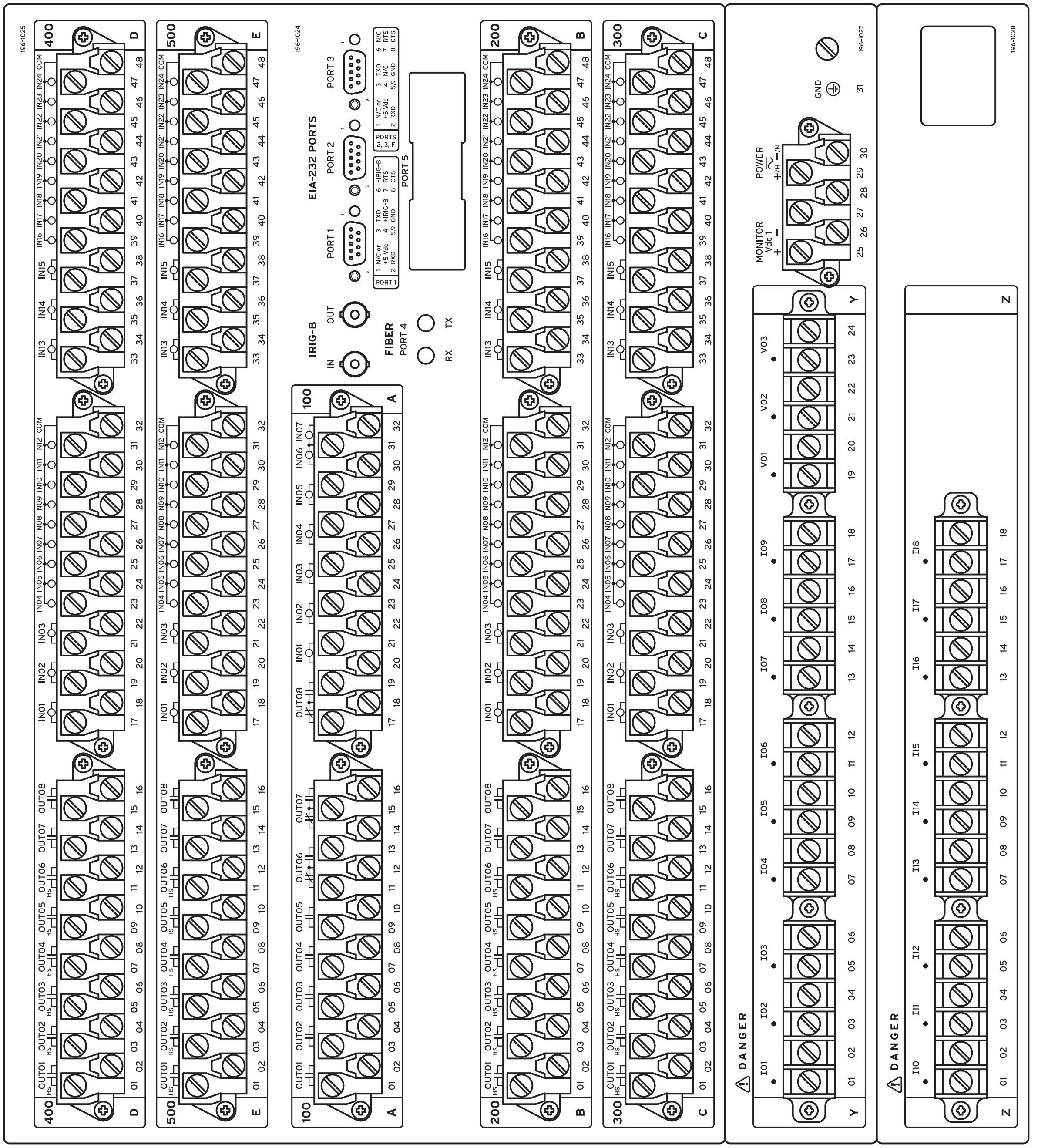


Figure 2.3 Rear-Panel Diagram of SEL-487B With Four Interface Boards (9U Version)

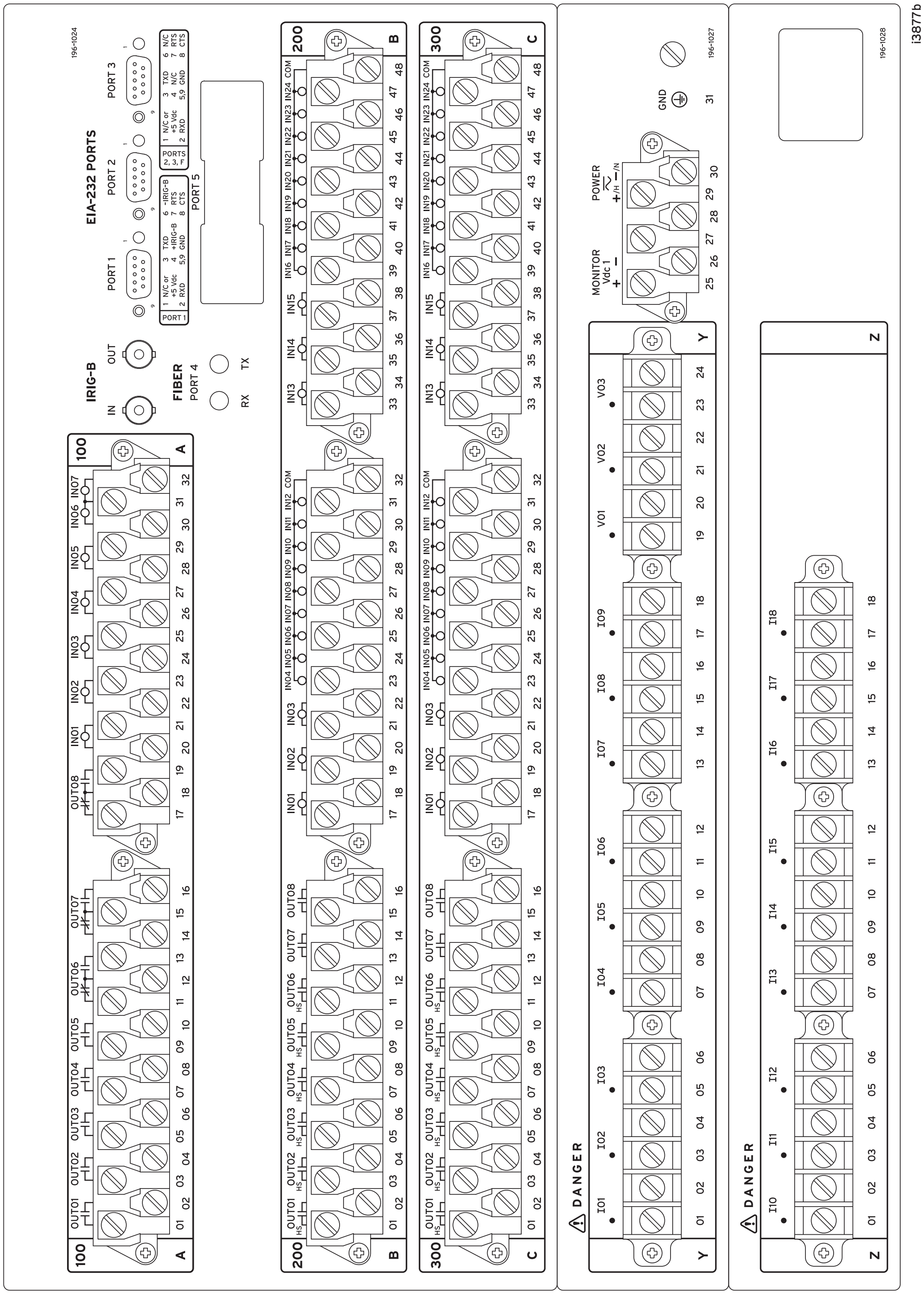


Figure 2.4 Rear-Panel Diagram of SEL-487B With Two Interface Boards (7U Version)

Connector Types

Screw Terminal Connectors–I/O and Battery Monitor/Power

Connection to the relay I/O and Battery Monitor/Power terminals on the rear panel is through screw terminal connectors. You can remove the entire screw terminal connector from the back of the relay to disconnect relay I/O, dc battery monitor, and power without removing each wire connection. The screw terminal connectors are keyed (see *Figure 2.18*), so you can replace the screw terminal connector on the rear panel only where you removed the screw terminal connector. In addition, the receptacle key prevents you from inverting the screw terminal connector. This feature makes relay removal and replacement easier.

Secondary Circuit Connectors

Fixed Terminal Blocks

Connect PT and CT inputs to the fixed terminal blocks in the bottom two rows of the relay rear panel. You cannot remove these terminal blocks from the relay rear panel. These terminals offer a secure high-reliability connection for PT and CT secondaries.

Secondary Circuits

The SEL-487B presents a low burden to the CT and PT secondaries (see *Specifications on page U.1.11*). The relay accepts 18 analog current inputs from the power system. CT inputs are labeled as follows: I01, I02, through I18. Because the relay impedance is low, the current elements can be wired in series with current elements from other relays. *Figure 2.5* shows the CT connections of the A-phase unit in a three-relay application. Current Input IA01 enters the relay at Terminal Y01 and leaves the relay at Terminal Y02 for input to other relays.

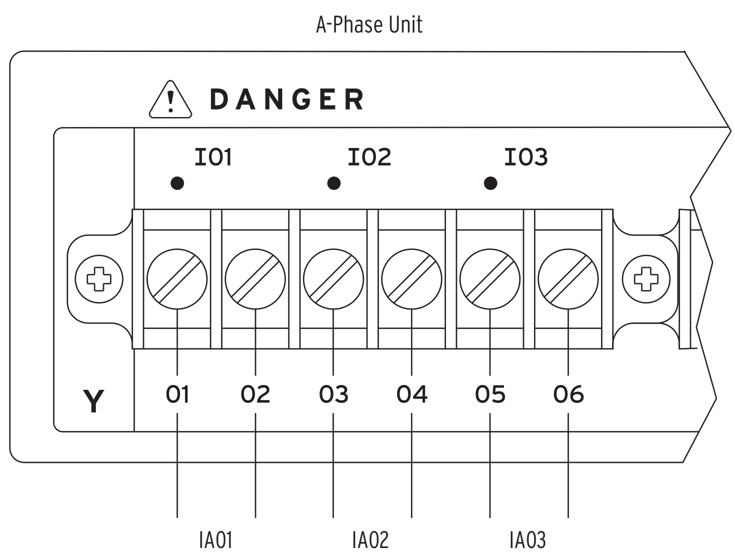


Figure 2.5 CT Connections for a Three-Relay Application

Figure 2.6 shows the CT connections if the SEL-487B is the last relay in the CT circuit. For a single-relay application, Current Input IA enters the relay at Terminal Y01, Input IB at Terminal Y03, and Input IC at Terminal Y05. Form the wye or star point by connecting Terminals Y02, Y04, and Y06 together and include the return wire to the CT on any one of these three terminals.

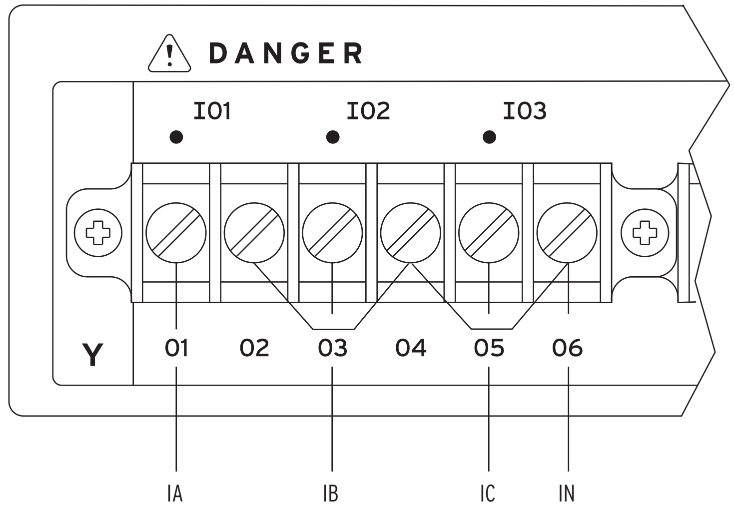


Figure 2.6 CT Connections for a Single-Relay Application When the SEL-487B Is the Last in the CT Circuit

Figure 2.7 shows the CT connections for a single-relay application when other devices are connected downstream of the SEL-487B. Current Input IA enters the relay at Terminal Y01 and leaves the relay at Terminal Y02 for input to other devices. B-phase and C-phase are wired similarly.

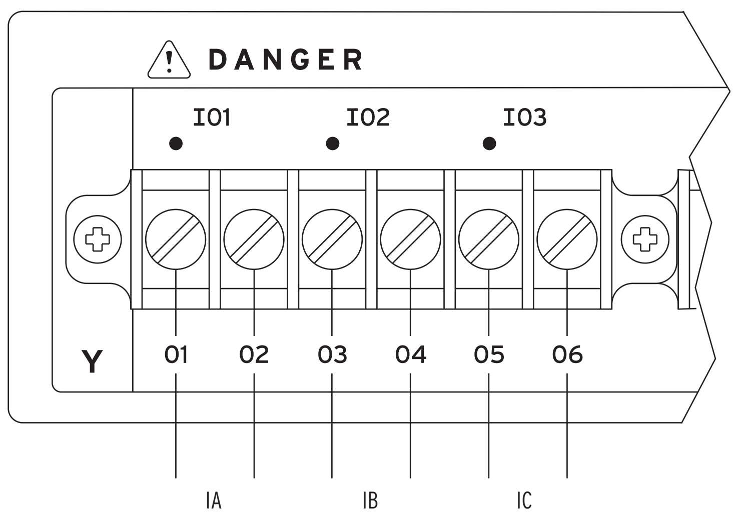


Figure 2.7 CT Connections for a Single-Relay Application When the SEL-487B Is in Series With Other Relays

For 5 A relays, the rated nominal input current, I_{NOM}, is 5 A. For 1 A relays, the rated nominal input current, I_{NOM}, is 1 A. Continuous input current for both relay types is $3 \cdot I_{NOM}$.

The relay also accepts one set of three-phase, six-wire potentials from power system PT secondaries at inputs V01, V02, and V03. The nominal line-to-neutral input voltage for the PT inputs is 67 volts with a maximum voltage rating of 300 volts. The PT inputs and elements are independent of each other for both the single-relay or three-relay applications.

Control Inputs

Inputs into the relay are high-impedance control inputs. Use these inputs for monitoring change-of-state conditions of power system equipment. These high-isolation control inputs are ground-isolated circuits and are not polarity sensitive, i.e., you cannot damage these inputs with a reverse polarity connection. For more information on control input specifications, see *Specifications on page U.1.11*. Inputs can be independent or common. Independent inputs have two separate ground-isolated connections, with no internal connections among inputs. Common inputs share one input leg in common; all input legs of common inputs are ground isolated. Each group of common inputs is isolated from all other groups. Nominal current drawn by these inputs is 8 mA or less with 6 voltage options covering a wide range of voltages, as published in the *Specifications*. You can debounce the control input pickup delay and dropout delay separately for each input as a global setting that applies to all the inputs.

AC Control Signals

Optoisolated control inputs can be used with ac control signals, within the ratings shown in *Optoisolated Inputs on page U.1.12*. Specific pickup and dropout time-delay settings are required to achieve the specified ac thresholds, as shown in *Table 2.1*.

NOTE: Only the Optoisolated Control Inputs on the INT4 I/O interface board can be used to detect ac control signals. Direct-coupled control inputs can only be used with dc control signals.

It is possible to mix ac and dc control signal detection on the same INT4 I/O interface board, provided that the two signal types are not present on the same set of combined inputs. Use standard debounce time settings (usually the same value in both the pickup and dropout settings) for the inputs being used with dc control voltages.

Table 2.1 Required Settings for Use With AC Control Signals[a]

Global Settings	Description	Entry[b]	Relay Recognition Time for AC Control Signal State Change
IN201PU–IN224PU, IN301PU–IN324PU, IN401PU–IN424PU, IN501PU–IN524PU	Pickup Delay	0.1250 cycles	0.625 cycles maximum (assertion)
IN201DO–IN224DO, IN301DO–IN324DO, IN401DO–IN424DO, IN501DO–IN524DO	Dropout Delay	1.0000 cycle	1.1875 cycles maximum (deassertion)

[a] First set Global setting EICIS := Y to gain access to the individual input pickup and dropout timer settings (only available for installed INT4 I/O interface boards).
[b] These are the only setting values that SEL recommends for detecting ac control signals. Other values may result in inconsistent operation.

The recognition times listed in *Table 2.1* are only valid when:

➤ The ac signal applied is at the same frequency as the power system.

➤ The signal is within the ac threshold pickup ranges defined in *Optoisolated Inputs on page U.1.12*.

➤ The signal contains no dc offset.

The SEL-487B samples the optoisolated inputs 24 times per cycle.

Control Outputs

Control outputs from the relay include standard outputs and high-speed (high-current interrupting) outputs. An MOV (metal-oxide varistor) protects against excess voltage transients for each contact. Each output is individually isolated except Form C outputs, which share a common connection between the NC (normally closed) and NO (normally open) contacts. The relay updates control outputs 12 times per cycle. Updating of relay control outputs does not occur when the relay is disabled. When the relay is re-enabled, the control outputs assume the state that reflects the present protection processing.

Standard Control Outputs

NOTE: You can use ac or dc circuits with standard control outputs.

The standard control outputs are dry Form A contacts. Ratings for standard outputs are 30 A make, 6 A continuous, and 0.5 A or less break (depending on circuit voltage). Standard contact outputs have a maximum voltage rating of 250 Vac/330 Vdc. Maximum break time is 6 ms (milliseconds) with a resistive load. The maximum pickup time for the standard control outputs is 6 ms. *Figure 2.8* shows a representative connection for a Form A Standard control output on the main board I/O terminals.

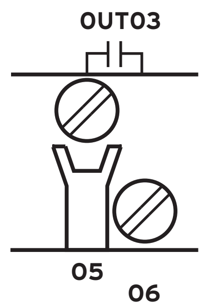


Figure 2.8 Standard Control Output Connection

See *Control Outputs on page U.1.11* for complete standard control output specifications.

High-Speed, High-Current Interrupting Control Outputs

Available only on the interface boards, high-speed, high-current interrupting control outputs are not polarity dependent and are capable of interrupting high-current, inductive loads. High-speed control outputs use an IGBT (Insulated Gate Bipolar Junction Transistor) in parallel with a mechanical contact to interrupt (break) highly inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients. With any high-speed output, break time varies according to the L/R (circuit inductive/resistive) ratio. As the L/R ratio increases, the time needed to interrupt the circuit also fully increases. The reason for this increased interruption delay is that circuit current continues to flow through the output MOV after the output deasserts, until all of the inductive energy dissipates. Maximum dropout (break) time is 8 ms with a resistive load. The other ratings of these control outputs are similar to the standard control outputs, except that the high-speed outputs can break current as great as 10 A. High-speed contact outputs have a maximum voltage rating of 250 Vac/330 Vdc. The maximum pickup time for the high-speed control outputs is 10 µs with resistive load. *Figure 2.9* shows a representative connection for a Form A high-speed control output on the interface board I/O terminals. High-speed contacts are marked HS (High Speed) to distinguish them from the standard contacts.

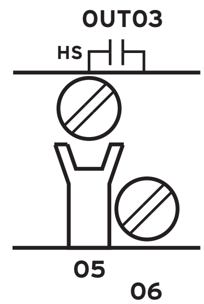


Figure 2.9 High-Speed Control Output Connection

See *Specifications on page U.1.11* for complete high-speed control output specifications.

Main Board I/O

The SEL-487B has 9U and 7U chassis options with I/O interface on the main board. See *Figure 2.3* and *Figure 2.15* for representative views of the 9U chassis rear panel and *Figure 2.4* and *Figure 2.16* for representative views of the 7U chassis rear panel.

Every SEL-487B configuration includes the main board I/O and features these connections:

- Five Standard Form A outputs
- Three Standard Form C outputs
- Seven high-isolation control inputs (five independent and two common)

Time Inputs

The SEL-487B has two high-accuracy time-keeping IRIG-B connections, one for receiving the signal and one for providing the signal to other relays. With this capability, the user can synchronize event reports from the three relays to within 10 µs of each other. Any one of the three units can be the reference relay; by connecting the IRIG-B signal to the IRIG-B terminal labeled IN, the relay becomes the reference relay. Connect the IRIG-B terminal labeled OUT from the reference relay to the IRIG-B terminal labeled IN of the next relay, and so on. If there is no IRIG-B available, the relays generate the synchronizing signal internally to synchronize the three relays relative to each other, although not to an absolute time reference. You can provide IRIG-B time code format signals to the relay from many sources (SEL-2030 Communications Processor, for instance). See *Section 3: Analyzing Data in the Applications Handbook* and *Configuring Timekeeping on page U.4.49* for more information on the use and benefits of high-accuracy time keeping.

IRIG-B

The IRIG-B serial data format consists of a 1-second frame containing 100 pulses divided into fields. The relay decodes the second, minute, hour, and day fields and sets the internal time clock upon detecting valid time data in the IRIG time mode. See *TIME Input Connections on page U.2.34* for information on enabling IRIG-B time keeping.

Battery-Backed Clock

If relay input power is lost or removed, a lithium battery powers the relay clock providing date and time backup. The battery is a 3 V lithium coin cell, Ray-O-Vac® No. BR2335 or equivalent. If power is lost or disconnected, the battery discharges to power the clock. At room temperature (25°C, 77°F), the battery will operate for approximately 10 years at rated load. When the SEL-487B is operating with power from an external source, the self-discharge rate of the battery only is very small. Thus, battery life can extend well beyond the nominal 10-year period. The battery cannot be recharged. *Figure 2.11* shows the clock battery location (at the front of the main board). If the relay does not maintain the date and time after power loss, replace the battery. See *Replacing the Lithium Battery on page U.2.35*.

Communications Interfaces

The SEL-487B has several communications interfaces you can use to communicate with other IEDs (intelligent electronic devices) via EIA-232 ports: PORT 1, PORT 2, PORT 3, and PORT F. See *Section 3: Communications Interfaces in the Reference Manual* for more information and options for connecting your relay to the communications interfaces.

An optional communications card provides Ethernet capability for the SEL-487B. A communications card gives the relay access to popular Ethernet networking standards including TCP/IP, FTP, Telnet, DNP3, and IEC 61850 over local area and wide area networks. The Ethernet card with IEC 61850 support is only available at purchase as a factory-installed option. For information on DNP3 applications, see *Section 5: DNP3 Communications in the Reference Manual*. For more information on IEC 61850 applications, see *Section 6: IEC 61850 Communications in the Reference Manual*.

Other Shared Configuration Attributes

Each SEL-487B also features a battery monitor connection and ground detection. See *Connection on page U.2.24* for information on these relay interface features.

Plug-In Boards

The SEL-487B supports up to four interface boards. There are ordering options for the number of I/O boards, as well as the overall chassis size. A 9U chassis ordering option provides support for up to four additional interface boards. A 7U chassis option provides support for up to two additional interface boards. Both chassis sizes are available in rack- or panel-mount versions.

Plug-in communications cards are also available for the SEL-487B. The optional Ethernet card allows you to use TCP/IP, FTP, Telnet, DNP LAN/WAN, and IEC 61850 applications on an Ethernet network. This card is only available at the time of purchase of a new SEL-487B as a factory-installed option or as a factory-installed conversion to an existing relay.

I/O Interface Boards

When the 9U chassis size is ordered, you can choose up to four INT4 interface boards for a total of 96 inputs and 32 outputs (all four boards installed). When the 7U chassis size is ordered, you can choose up to two INT4 interface boards for a total of 48 inputs and 16 outputs (both boards installed). In addition to the inputs and outputs provided by the INT4 interface boards, there are also 7 inputs and 8 outputs on the main board (described in *Shared Configuration Attributes on page U.2.2*). Refer to *Figure 2.3* for a view of the interface boards and the rear screw terminal connectors associated with the interface boards.

The I/O interface boards carry jumpers that identify the board location. See *Jumpers on page U.2.16* for more information on I/O board jumpers.

I/O Interface Board Inputs

The INT4 I/O interface board has two groups of nine (9) common contacts (18 total) and six (6) independent control inputs. All independent inputs are isolated from other inputs. These high-isolation control inputs are not polarity sensitive, i.e., you cannot damage these inputs with a reverse polarity connection.

Table 2.2 shows the I/O board input capacities and the I/O inputs on the main board. See *Optoisolated Inputs on page U.1.12* for complete control input specifications.

Table 2.2 I/O Interface Board Control Inputs

Board	Independent Contact Pairs	Common Contact Pairs
INT4	6	Two sets of 9
Main	5	2

I/O Interface Board Outputs

The INT4 I/O interface board is available with either six (6) high-speed and two (2) standard output contacts, or 8 standard contact outputs. *Table 2.3* shows the I/O board outputs; the table also shows the I/O outputs on the main board. See *Control Outputs on page U.1.11* for complete control output specifications.

Table 2.3 I/O Interface Boards Control Outputs

Board	Standard		High-Speed
	Form A	Form C	Form A
INT4 with high-speed outputs	2	0	6
INT4 with standard outputs	8	0	0
Main	5	3	0

Installing Optional I/O Interface Boards

When expanding the capability of the SEL-487B with additional I/O interface boards, perform the following steps:

⚠WARNING
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠DANGER
Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

Step 1. Remove the relay from service.

a. Follow your company's standard for removing a relay from service.

b. Disconnect power from the SEL-487B.

c. Retain the GND connection, if possible, and ground the equipment to an ESD mat.

Step 2. Remove the front panel from the SEL-487B.

Step 3. Disconnect the front-panel cable from the front panel.

Step 4. Disconnect all cables from the main board and I/O interface boards.

Step 5. Confirm proper installation of address jumpers on the interface board; see *Jumpers on page U.2.16*.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Step 6. Confirm the correct drawout tray keying before installing the additional interface board.

The relay chassis and the drawout trays for the 200, 300, 400, and 500-addresses slots are keyed (see *Figure 2.10*). The keys are two round plug-in/plug-out discs on the bottom of the drawout tray. The 200-address slot keys go to the left, the 300-address slot keys second to the left, 400-address next, 500-address to the right (when viewed from the top and front of the drawout tray).

Step 7. If the drawout tray keying does not match the tray keying of the target position, move a key on the bottom of the drawout tray to the correct position. (Refer to *Figure 2.10*.)

a. Pry the key from the tray.

b. Reinsert the key in the proper position.

Repeat this step for the second key.

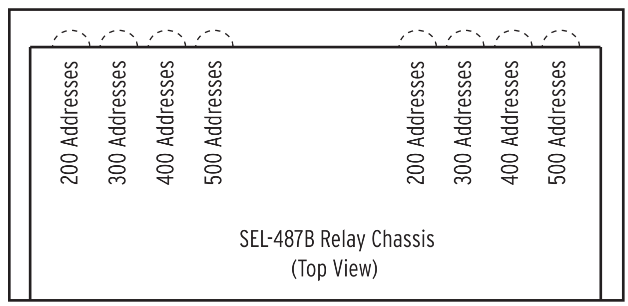


Figure 2.10 Chassis Key Positions for I/O Interface Boards

Step 8. Install the I/O interface board:

a. Position the I/O board edges into the left-side and right-side internally mounted slots.

b. Slide the I/O interface board into the SEL-487B by pushing the front edge of the board drawout tray.

c. Apply firm pressure to fully seat the I/O interface board.

Step 9. If this is a new I/O interface board installation, remove the INTERFACE BOARD EXPANSION SLOT self-sticking label from the rear panel by lifting a corner of the label and peeling away the label from the rear panel.

Step 10. Inspect the screw terminal connector receptacles on the rear of the I/O interface board.

Refer to *Figure 2.19* for the corresponding key positions inside the receptacle.

SEL supplies three new screw terminal connectors with new I/O interface boards.

If the keys inside the I/O interface board receptacles are not in the positions shown in *Figure 2.19*:

a. Grasp the key edge with long-nosed pliers to remove the key.

b. Reinsert the key in the correct position.

c. With long-nose pliers, remove the webs of the screw terminal connectors in the positions that match the receptacle key (see *Figure 2.18*).

Step 11. Attach the screw terminal connector.

a. Mount the screw terminal connectors to the rear panel of the SEL-487B.

Refer to *Figure 2.3* for screw terminal connector placement.

b. Tighten the screw terminal connector mounting screws to between 0.9 Nm and 1.4 Nm (8 in-lb and 12 in-lb).

Step 12. Connect the internal interface cable(s) from the I/O board(s) and front-panel cable to the main board.

Step 13. Reconnect the internal power and analog cables.

Step 14. Reconnect front-panel cable to the front panel.

Step 15. Reattach the front panel.

Step 16. Apply power.

Step 17. Enter Access Level 2 (*Making Simple Settings Changes on page U.4.12*).

Step 18. Issue the **STA** command and answer **Y <Enter>** to accept the new hardware configuration (see *STATUS on page R.7.40*).

Step 19. Inspect the relay targets to confirm that the relay reads the added I/O interface board(s).

You can see the new control inputs in the target listings by using a terminal, the ACSELERATOR QuickSet® SEL-5030 software program, or the front panel.

Step 20. Use a communications terminal to issue one of the following commands.

➢ **TAR OUT201 <Enter>** (for the 200-addresses slot)

➢ **TAR OUT301 <Enter>** (for the 300-addresses slot)

➢ **TAR OUT401 <Enter>** (for the 400-addresses slot)

➢ **TAR OUT501 <Enter>** (for the 500-addresses slot)

Step 21. Alternatively, from the front-panel MAIN MENU, select RELAY ELEMENTS, SEARCH.

a. Type **OUT <Enter>**.

b. Use the {Down Arrow} pushbutton to confirm that the Relay Word bits from the new interface board are present and available for you to use.

Step 22. Follow your company's standard procedure to return the relay to service.

Communications Card

You can add other communications protocols to the SEL-487B by purchasing the Ethernet card option. Factory-installed in the rear relay Port 5, the Ethernet card provides Ethernet ports for industrial applications that processes data traffic between the SEL-487B and a LAN (local area network).

Jumpers

The SEL-487B contains jumpers that configure the relay for certain operating modes. The jumpers are located on the main board and on each of the I/O interface boards.

Main Board Jumpers

The jumpers on the main board of the SEL-487B perform the following functions:

- ➤ Temporary/emergency password disable
- ➤ Circuit breaker control enable
- ➤ Rear serial port +5 Vdc source enable

Figure 2.11 shows the positions of the main board jumpers. The main board jumpers are in two locations. The password disable jumper and circuit breaker control jumper are at the front of the main board. The serial port jumpers are near the rear-panel serial ports; each serial port jumper is directly in front of the serial port that it controls.

Password and Circuit Breaker Jumpers

You can access the password disable jumper and circuit breaker control jumper without removing the main board from the relay cabinet. Remove the SEL-487B front cover to view these jumpers (use appropriate ESD precautions). The password and circuit breaker jumpers are on jumper header J18 on the front of the main board.

⚠CAUTION
Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.

The J18 header is denoted A, B, C, and D from right to left (position A is on the right). Position B is the password disable jumper; position C is the circuit breaker control enable jumper. Positions A and D are not used. *Figure 2.12* shows the jumper header with the circuit breaker/control jumper in the ON position and the password jumper in the OFF position; these are the normal jumper positions for an in-service relay. *Table 2.4* lists the J18 jumper positions and functions.

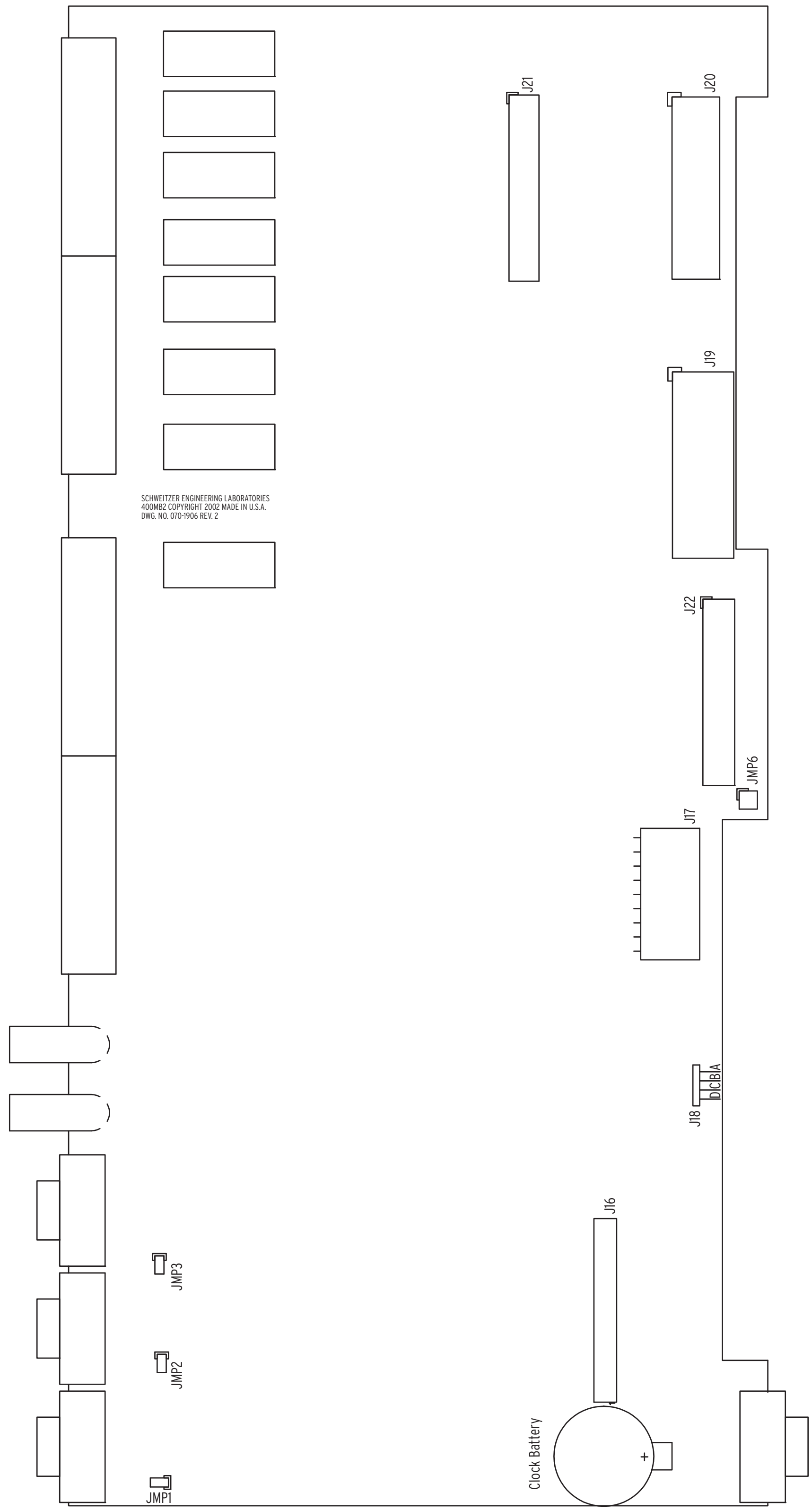


Figure 2.11 Major Component Locations on the SEL-487B Main Board

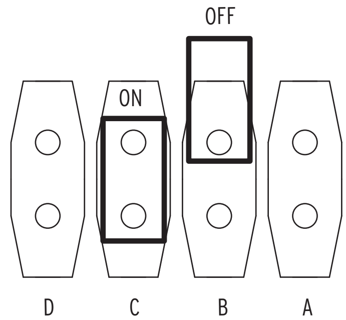


Figure 2.12 J18 Header-Password and Breaker Jumpers

Table 2.4 Main Board Jumpers[a]

Jumper	Jumper Location	Jumper Position	
J18A	Front	OFF	For SEL use only
J18B	Front	OFF ON	Enable password protection (normal and shipped position) Disable password protection (temporary or emergency only)
J18C	Front	OFF ON	Disable control outputs (shipped position) Enable control outputs, including circuit breaker OPEN (normal position)
J18D	Front	OFF	For SEL use only

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.

The password disable jumper, J18B, is for temporary or emergency suspension of the relay password protection mechanisms. The SEL-487B ships with password disable jumper J18B OFF (passwords enabled). For temporary unprotected access to a particular access level, use the **PAS *n* DISABLE** command (*n* is the access level: *n* = 1, B, P, A, O, 2). For more information on this command and setting passwords, see *PASSWORD on page R.7.27*. The circuit breaker control enable jumper, Jumper J18C, supervises the **OPEN *nn*** command, the **PULSE OUT*nnn*** command, and front-panel local bit control. To use these functions you must install Jumper J18C. The relay checks the status of the circuit breaker control jumper when you issue **OPEN *nn***, **PULSE OUT*nnn***, and when you use the front panel to open circuit breakers, control a local bit, or pulse an output. Jumper J18C is usually installed on a long-term basis after you have completed relay commissioning and installation tests. The SEL-487B ships with circuit breaker jumper J18C OFF (control outputs disabled). After commissioning tests, move jumper J18C to ON for proper control output operation.

Serial Port Jumpers

Place jumpers on the main board to connect +5 Vdc to Pin 1 of each of the three rear-panel EIA-232 serial ports. The maximum current available from this Pin 1 source is 0.5 A. The Pin 1 source is useful for powering an external modem. *Table 2.5* describes the JMP1, JMP2, and JMP3 positions. Refer to *Figure 2.11* for the locations of these jumpers. The SEL-487B ships with JMP1, JMP2, and JMP3 OFF (no +5 Vdc on Pin 1).

Table 2.5 Main Board Jumpers—JMP1, JMP2, and JMP3[a]

Jumper	Jumper Location	Jumper Position	Pin Connections
JMP1	Rear	OFF ON	Serial Port 3, Pin 1 = not connected Serial Port 3, Pin 1 = +5 V
JMP2	Rear	OFF ON	Serial Port 2, Pin 1 = not connected Serial Port 2, Pin 1 = +5 V
JMP3	Rear	OFF ON	Serial Port 1, Pin 1 = not connected Serial Port 1, Pin 1 = +5 V

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.

Changing Serial Port Jumpers

⚠WARNING
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠DANGER
Contact with instrument terminals can cause electrical shock that can result in injury or death.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

You must remove the main board to access the serial port jumpers. To change the JMP1, JMP2, and JMP3 jumpers in an SEL-487B, perform the following steps:

Step 1. Remove the relay from service.
- a. Follow your company's standard for removing a relay from service.
- b. Disconnect power from the SEL-487B.
- c. Retain the GND connection, if possible, and ground the equipment to an ESD mat.

Step 2. Remove the front panel from the SEL-487B.

Step 3. Disconnect the front-panel cable at the front panel.

Step 4. Disconnect the power cable, interface board cable(s), and input board analog cable from the main board.

Step 5. Remove rear-panel EIA-232 ports mating connectors.
- a. Unscrew the keeper screws.
- b. Disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 6. Carefully pull out the drawout assembly containing the main board.

Step 7. Locate the jumper you want to change.

Jumpers JMP1, JMP2, and JMP3 are located at the rear of the main board, directly in front of **PORT 3**, **PORT 2**, and **PORT 1**, respectively (see *Figure 2.11*).

Step 8. Install or remove the jumper as needed.

See *Table 2.5* for jumper position descriptions.

Step 9. Reinstall the SEL-487B main board.

Step 10. Reconnect the power cable, the interface board cable(s), and the input board analog cable.

Step 11. Reconnect any serial cables that you removed in the disassembly process to the EIA-232 ports.

Step 12. Reconnect the front-panel cable to the front panel.

Step 13. Reattach the front panel.

Step 14. Follow your company's standard procedure to return the relay to service.

I/O Interface Board Jumpers

Jumpers on the INT4 I/O interface board identify the I/O board control address (see *I/O Interface Boards on page U.2.12* for more information on these boards). The jumpers on these I/O interface boards are at the front of each board, as shown in *Figure 2.13*.

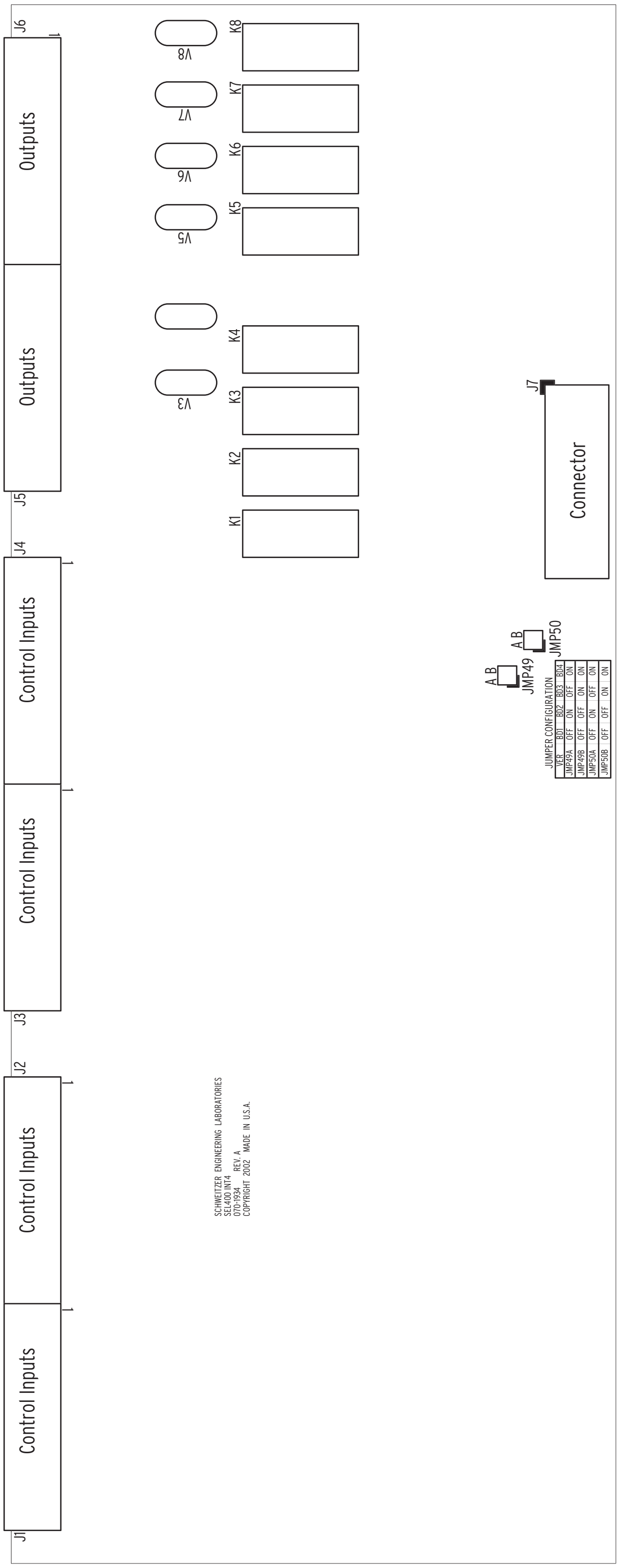


Figure 2.13 Major Component Locations on the SEL-487B INT4 I/O Board

To confirm the positions of your I/O board jumpers, you can remove the front panel and inspect the jumper placements visually. *Table 2.6* lists the four jumper positions for I/O interface boards. Refer to *Figure 2.13* for the locations of these jumpers.

The I/O board control address has a hundreds-series prefix attached to the control inputs and control outputs for that particular I/O board chassis slot.

Table 2.6 I/O Board Jumpers

Description	JMP49A	JMP49B	JMP50A	JMP50B
Position A (Main Board) 1xx I/O	N/A	N/A	N/A	N/A
Position B (Expansion I/O) 2xx I/O	OFF	OFF	OFF	OFF
Position C (Expansion I/O) 3xx I/O	ON	OFF	ON	OFF
Position D (Expansion I/O) 4xx I/O	OFF	ON	OFF	ON
Position E (Expansion I/O) 5xx I/O	ON	ON	ON	ON

See *Figure 2.3* for board location details.

Changing I/O Interface Board Jumpers

⚠WARNING
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠DANGER
Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Change the I/O interface board jumpers only when you move the slot position of an I/O board. You must remove the I/O interface boards to access the jumpers. To change JMP49A, JMP49B, JMP50A, and JMP50B on an interface board, perform the following steps:

Step 1. Remove the relay from service.
  a. Follow your company's standard for removing a relay from service.
  b. Disconnect power from the SEL-487B.
  c. Retain the GND connection, if possible, and ground the equipment to an ESD mat.

Step 2. Disconnect the front-panel cable from the front panel.

Step 3. Remove the front panel from the SEL-487B.

Step 4. Disconnect the interface board cable from the main board.

Step 5. Pull out the drawout assembly containing the I/O interface board.

Step 6. Locate the jumper you want to change.

Jumpers JMP49A, JMP49B, JMP50A, and JMP50B are located at the front of the I/O board to the left of the interface board connector (see *Figure 2.13*).

Step 7. Install or remove the jumper as needed.

See *Table 2.6* for jumper position descriptions.

Step 8. Reinstall the SEL-487B I/O interface board.

Step 9. Reconnect the interface board cable.

Step 10. Reconnect the front-panel cable to the front panel.

Step 11. Reattach the front panel.

Step 12. Follow your company's standard procedure to return the relay to service.

Step 13. At relay power up, confirm that the relay does not display a Status Warning about I/O board addresses.

For information on this Status Warning, see *Relay Self-Tests on page U.6.34*.

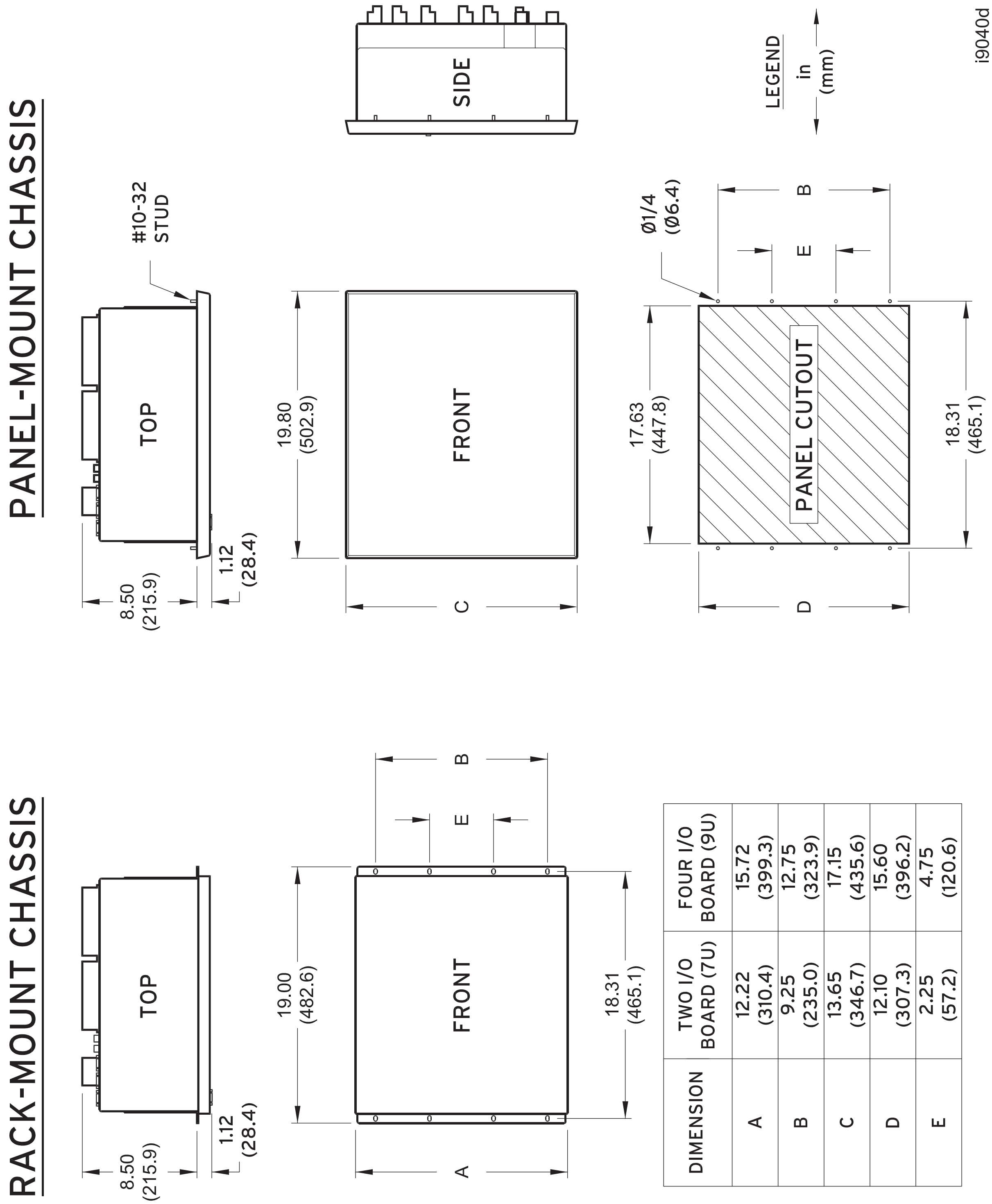
Relay Placement

Use the following guidelines for proper physical installation of the SEL-487B.

Physical Location

You can mount the SEL-487B in a sheltered indoor environment (a building or an enclosed cabinet) that does not exceed the temperature and humidity ratings for the relay.

This rating allows mounting the relay indoors or in an outdoor (extended) enclosure where the relay is protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity are controlled. You can place the relay in extreme temperature and humidity locations. The relay operates in –40° to +85°C (–40° to +185°F) temperatures (see *Operating Temperature on page U.1.11*). With no condensation present, the relay operates in humidity ranging from 5 percent to 95 percent.



DIMENSION	TWO I/O BOARD (7U)	FOUR I/O BOARD (9U)
A	12.22 (310.4)	15.72 (399.3)
B	9.25 (235.0)	12.75 (323.9)
C	13.65 (346.7)	17.15 (435.6)
D	12.10 (307.3)	15.60 (396.2)
E	2.25 (57.2)	4.75 (120.6)

Figure 2.14 Relay Chassis Dimensions

Panel Mounting

Place the panel-mount versions of the SEL-487B in a switchboard panel. See the drawings in *Figure 2.14* for panel cut and drill dimensions. Use the supplied mounting hardware to attach the relay.

Connection

The SEL-487B is available with a main board and 1, 2, 3 or 4 INT4 interface boards. The INT4 interface board is available to expand the control inputs and control outputs only; no analog expansion is available. There are two relay size options: a 9U chassis capable of supporting up to the maximum of four interface boards, or a 7U chassis capable of supporting up to two interface boards. This subsection presents a representative sample of relay rear-panel configurations and the connections to these rear panels. When connecting the SEL-487B, refer to your company plan for wire routing and wire management. Be sure to use wire that is appropriate for your installation with an insulation rating of at least 90°C.

Rear-Panel Layout

Figure 2.15 and *Figure 2.16* show the rear panel of the relay with only the main board installed, and *Figure 2.3* and *Figure 2.4* show the rear panel of the relay fully equipped. For clarity, the figures do not show a communications card installed in PORT 5.

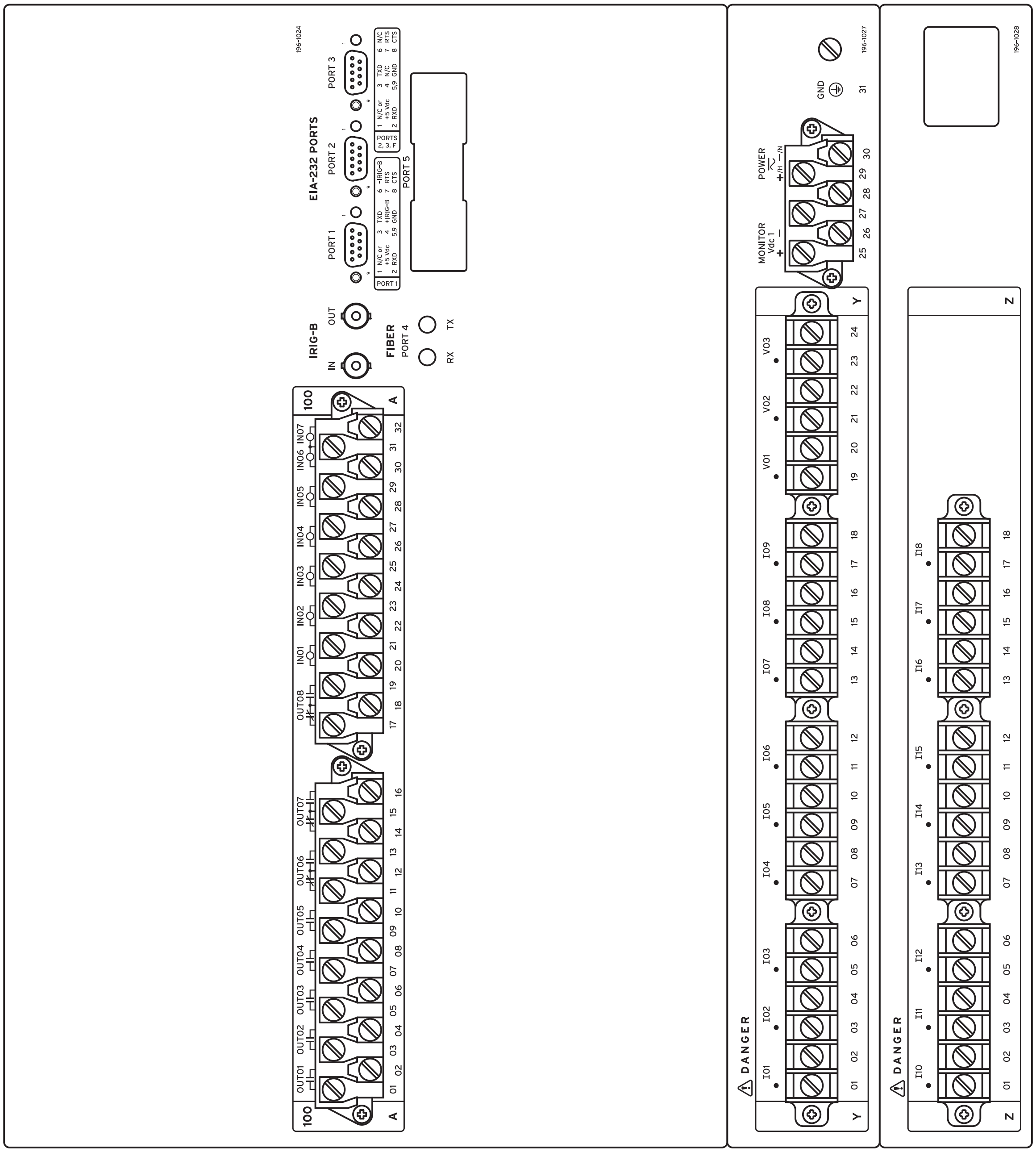


Figure 2.15 Rear Panel With Only Main Board (9U Version)

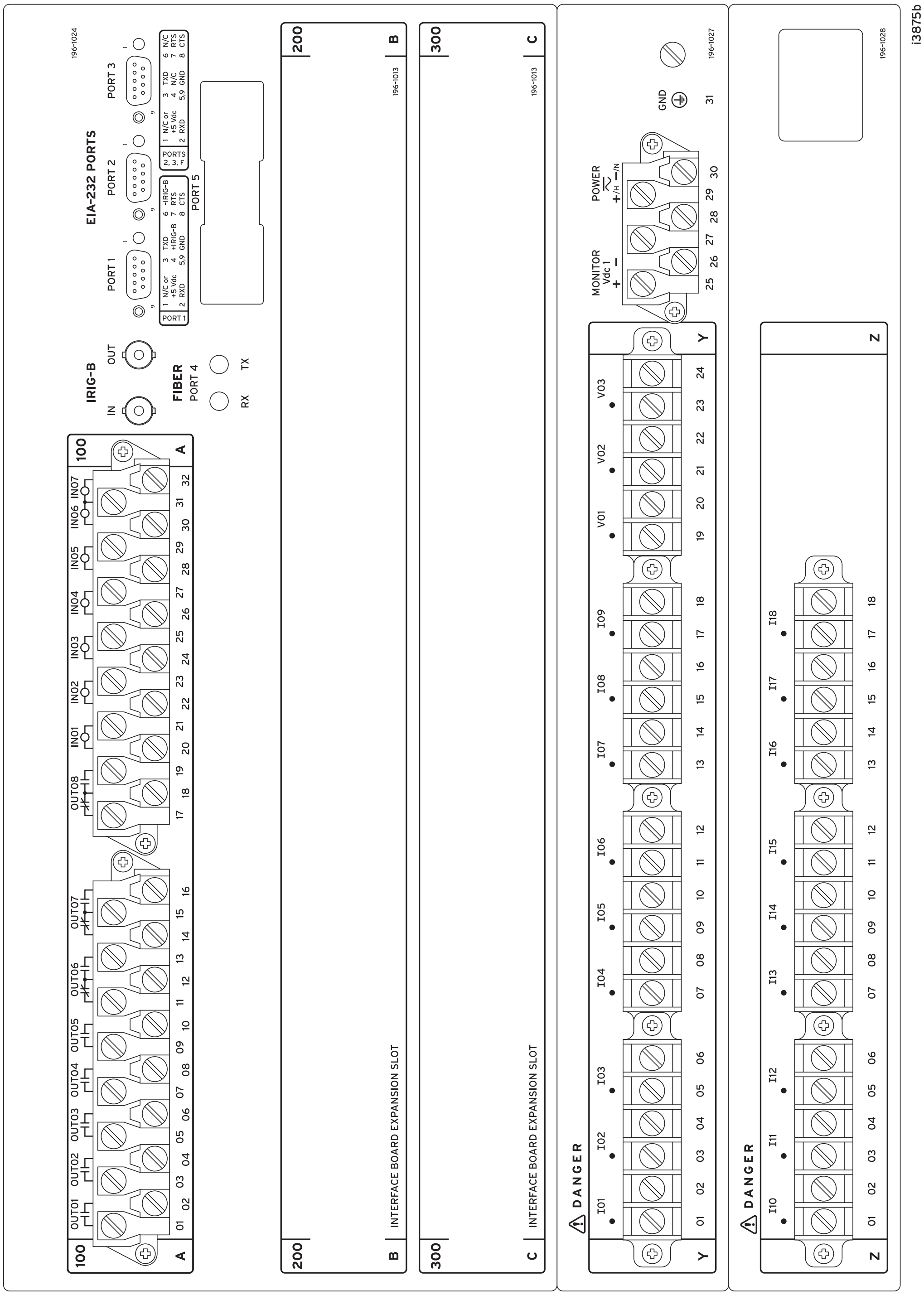


Figure 2.16 Rear Panel With Only Main Board (7U Version)

Rear-Panel Symbols

Figure 2.17 shows important safety symbols and their descriptions. These safety symbols appear on the rear of the relay. Observe proper safety precautions when you connect the relay at terminals marked by these symbols. In particular, the danger symbol located on the rear panel corresponds to the following: **Contact with instrument terminals can cause electrical shock that can result in injury or death**. Be careful to limit access to these terminals.

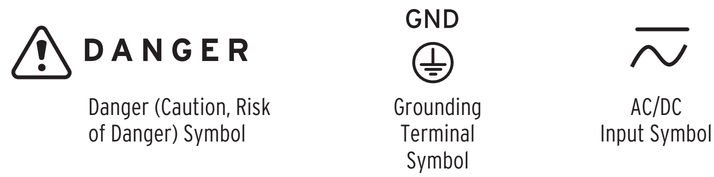


Figure 2.17 Rear-Panel Symbols

Screw Terminal Connectors

Terminate connections to the SEL-487B screw terminal connectors with ring-type crimp lugs. Use a #8 ring lug with a maximum width of 9.1 mm (360 in). The screws in the rear-panel screw terminal connectors are #8-32 binding head, slotted, nickel-plated brass screws. Tightening torque for the terminal connector screws is 1.0 Nm to 2.0 Nm (9 in-lb. to 18 in-lb). You can remove the screw terminal connectors from the rear of the SEL-487B by unscrewing the screws at each end of the connector block. Remove the connector by pulling the connector block straight out. Note that the receptacle on the relay circuit board is keyed; you can insert each screw terminal connector in only one location on the rear panel. To replace the screw terminal connector, confirm that you have the correct connector, push the connector firmly onto the circuit board receptacle, and reattach the two screws at each end of the block.

Changing Screw Terminal Connector Keying

You can rotate a screw terminal connector so that the connector wire dress position is the reverse of the factory-installed position (for example, wires entering the relay panel from below instead of from above). In addition, you can move similar function screw terminal connectors to other locations on the rear panel. To move these connectors to other locations, you must change the screw terminal connector keying. Inserts in the circuit board receptacles key the receptacles for only one screw terminal connector in one orientation. Each screw terminal connector has a missing web into which the key fits (see *Figure 2.18*). If you want to move a screw terminal connector to another circuit board receptacle or reverse the connector orientation, rearrange the receptacle keys to match the screw terminal connector block. Use long-nosed pliers to move the keys. *Figure 2.19* shows the factory default key positions.

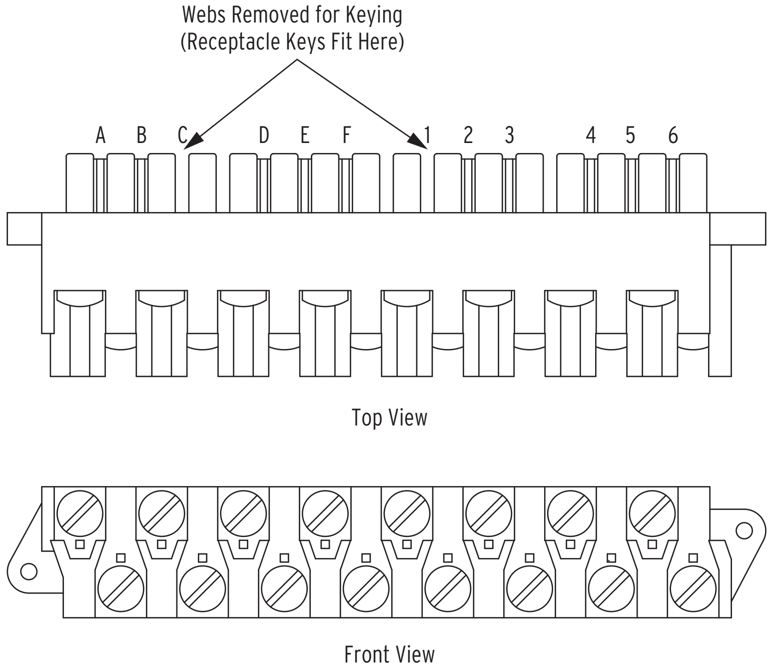


Figure 2.18 Screw Terminal Connector Keying

Grounding

Connect the grounding terminal (#Y31) labeled GND on the rear panel to a rack frame ground or main station ground for proper safety and performance. This protective earthing terminal is in the lower right side of the relay panel (see *Figure 2.15*). The symbol that indicates the grounding terminal is shown in *Figure 2.17*. Use 10 AWG (6 mm^2) to 12 AWG (4 mm^2) wire, less than 6.6 feet (2 m) in length for this connection. This terminal connects directly to the internal chassis ground of the SEL-487B.

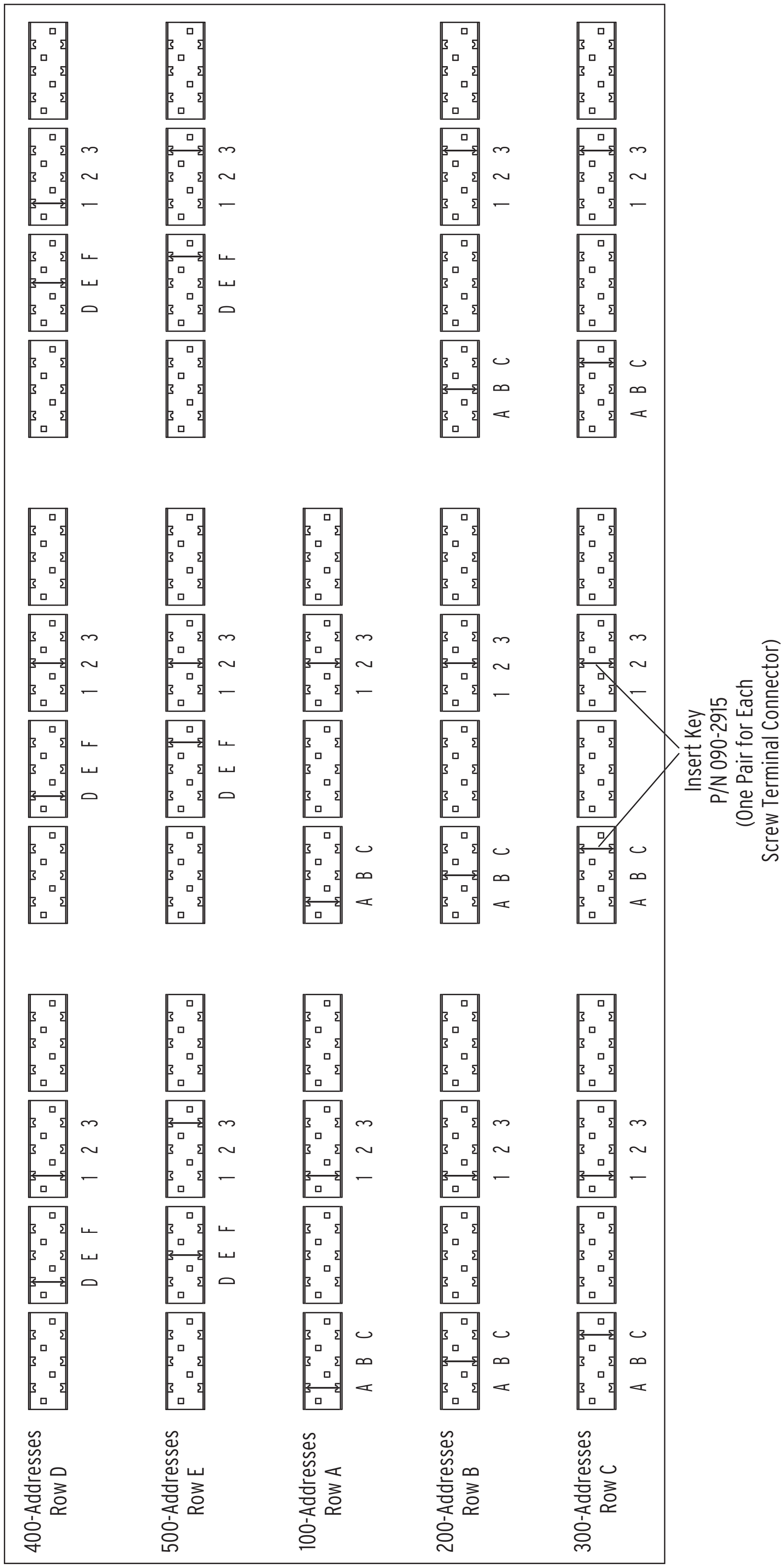


Figure 2.19 Rear-Panel Receptacle Keying

Power Connections

The terminals labeled POWER on the rear panel (Y29 and Y30) must connect to a power source that matches the power supply characteristics that your SEL-487B specifies on the rear-panel serial number label. (See *Power Supply on page U.1.11*, for complete power input specifications.)

NOTE: The combined voltages applied to the POWER and MONITOR terminals must not exceed 600 V (rms or dc).

The POWER terminals are isolated from chassis ground. Use 16 AWG to 14 AWG (1.5 mm^2 to 2 mm^2) size wire to connect to the POWER terminals. Connection to external power must comply with IEC 60947-1 and IEC 60947-3 and must be identified as the disconnect device for the equipment. Place an external disconnect device, either a switch/fuse combination or circuit breaker in the POWER leads for the SEL-487B; this device must interrupt both the hot (H/+) and neutral (N/-) power leads. The current rating for the power disconnect circuit breaker or fuse must be 20 A maximum. Be sure to locate this device within 9.8 feet (3.0 m) of the relay.

Operational power is internally fused by power supply fuse F1. *Table 2.7* lists the SEL-487B power supply fuse requirements. Be sure to use fuses that comply with IEC 127-2. You can order the SEL-487B with one of three operational power input ranges listed in *Table 2.7*. Each of the three supply voltage ranges represents a power supply ordering option. As noted in *Table 2.7*, model numbers for the relay with these power supplies begin with 0487B0*n*, where *n* is 2, 4, or 6, to indicate low, medium, and high voltage input power supplies, respectively. Note that each power supply range covers two widely used nominal input voltages. The SEL-487B power supply operates from 30 Hz to 120 Hz when ac power is used for the POWER input.

Table 2.7 Fuse Requirements for the SEL-487B Power Supply

Nominal Power Supply Voltage Rating	Power Supply Voltage Range	Fuse F1	Fuse Description
24/48 V	18–60 Vdc	T6.3AH250V	5x20 mm, time-lag, 6.3 A, high-break capacity, 250 V
48/125 V	38–140 Vdc or 85–140 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high-break capacity, 250 V
125/250 V	85–300 Vdc or 85–264 Vac (30–120 Hz	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high-break capacity, 250 V

The SEL-487B accepts dc power input for all three power supply models. The 48/125 Vdc supply also accepts 120 Vac; the 125/250 Vdc supply also accepts 120/240 Vac. When connecting a dc power source, connect the source with the proper polarity, as indicated by the + (Terminal Y29) and – (Terminal Y30) symbols on the power terminals. When connecting an ac power source, the + Terminal Y29 is hot (H), and the – Terminal Y30 is neutral (N). Each model of the SEL-487B internal power supply exhibits low power consumption and a wide input voltage tolerance. For more information on the power supplies, see *Power Supply on page U.1.11*.

Power Supply Fuse Replacement

⚠WARNING
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠DANGER
Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

You can replace a blown fuse in an SEL-487B power supply, or you can return the SEL-487B to SEL for fuse replacement. If you decide to replace the fuse, perform the following steps to replace the power supply fuse:

Step 1. Remove the relay from service.

a. Follow your company standard for removing a relay from service.

b. Turn off power to the SEL-487B.

c. Remove the relay from the rack or panel.

d. Retain the GND connection, if possible, and ground the equipment to an ESD mat.

Step 2. Remove the front panel from the SEL-487B.

Step 3. Disconnect the front-panel cable from the front panel.

Step 4. Disconnect the interface board cable(s) from the main board and the I/O interface board(s).

Step 5. Disconnect the power cables, input board analog cable, and interface board cable(s) from the main board.

Step 6. Remove the rear-panel EIA-232 ports mating connectors.

a. Unscrew the keeper screws.

b. Disconnect any serial cables connected to the PORT 1, PORT 2, and PORT 3 rear-panel receptacles.

Step 7. Pull out the drawout tray containing the I/O interface board(s).

Step 8. Pull out the drawout tray containing the main board.

Step 9. Locate the power supply.

Fuse F1 is at the rear of the power supply circuit board. See *Figure 2.20*.

Step 10. Examine the power supply for blackened parts or other damage.

If you can see obvious damage, reinstall all boards and contact SEL to arrange return of the relay for repair.

Step 11. Remove the spent fuse from the fuse clips.

Step 12. Replace the fuse with an exact replacement.

See *Table 2.7* for the proper fuse for your power supply.

Step 13. Reinstall the SEL-487B main board and the I/O interface board(s).

Step 14. Reattach the power cable, the interface board cable(s), and the input board analog cable.

Step 15. Reconnect any serial cables that you removed in the disassembly process to the EIA-232 ports.

Step 16. Reconnect the front-panel cable to the front panel.

Step 17. Reattach the front panel.

Step 18. Follow your company's standard procedure to return the relay to service.

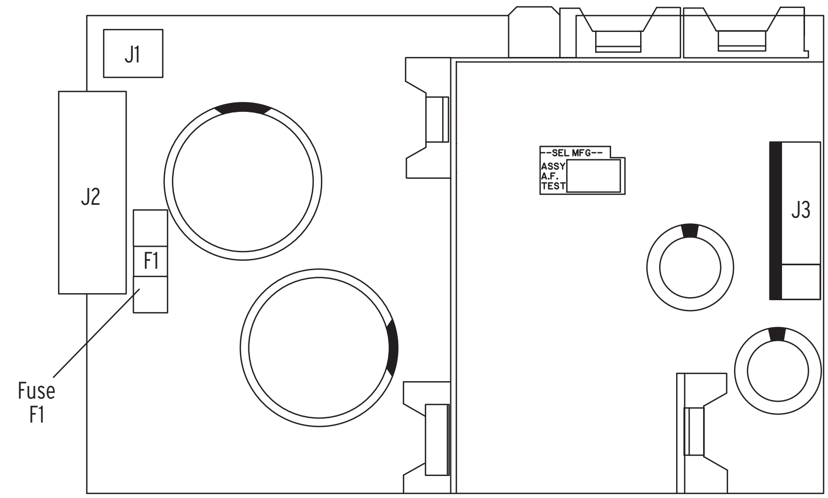


Figure 2.20 PS30 Power Supply Fuse Location

Monitor Connections (DC Battery)

Each SEL-487B monitors one dc battery system. For information on the battery monitoring function, see *Station DC Battery System Monitor on page A.2.1*. Connect the positive lead of the Battery System to Terminal Y25 and the negative lead of the Battery System to Terminal Y26. (Usually the Battery System is also connected to the rear panel POWER input terminals.) For the three-unit application and when there are two battery systems at a station, connect the second battery system to any one of the other two relays (also Terminals Y25 and Y26).

Secondary Circuit Connections

Each SEL-487B has 18 current inputs and 3 voltage inputs. *Shared Configuration Attributes on page U.2.2* describes these inputs in detail. The alert symbol and the word DANGER on the rear panel indicate that you should use all safety precautions when connecting secondary circuits to these terminals. To verify these connections, use SEL-487B metering (see *Examining Metering Quantities on page U.4.31*). You can also review metering data in an event report that results when you issue the **TRIGGER** command.

Fixed Terminal Blocks

⚠DANGER
Contact with instrument terminals can cause electrical shock that can result in injury or death.

NOTE: The combined voltages applied to the POWER and MONITOR terminals must not exceed 600 V (rms or dc).

Connect the secondary current circuits to the first 18 terminals on the Y terminal block (Terminals Y01–Y18) and on the Z terminal block (Terminals Z01–Z18).

Connect the voltage inputs to Terminals Y19–Y24 on the Y terminal block. Note the polarity dots above the odd-numbered terminals (Y01 and Y03–Y23, Z01 and Z03–Z17) for the analog inputs.

Control Circuit Connections

You can configure the SEL-487B with many combinations of control inputs and control outputs. See *Main Board I/O on page U.2.11* and *I/O Interface Boards on page U.2.12* for information about I/O configurations. This subsection provides details about connecting these control inputs and outputs. Refer to *Figure 2.3* for representative rear-panel screw terminal connector locations.

Control Inputs

No control input on the relay is polarity sensitive, which means you cannot damage these inputs with a reverse polarity connection. Note that the main board I/O control inputs have one set of two inputs that share a common input leg. These inputs are IN106 and IN107 found on Terminals A30, A31, and A32. To assign the functions of the control inputs, see *Operating the Relay Inputs and Outputs on page U.4.40*, or the **SET G** command in *SET on page R.7.32* for more details. You can also use the ACSELERATOR software to set and verify operation of the inputs.

Control Outputs

The SEL-487B has two types of outputs:

- ➤ Standard outputs (for example: main board OUT104)
- ➤ High-speed (high-current-interrupting) outputs, optionally on the INT4 interface board (for example: INT4 board OUT01). See *Control Outputs on page U.2.9* for more information.

You can connect the standard outputs in either ac or dc circuits. Connect the high-speed (high-current interrupting) outputs to dc circuits only. The screw terminal connector legends alert you about this requirement by showing HS marks on the high-speed (high-current interrupting) contacts. Form A contacts comprise the majority of the control outputs. Two pairs of Form C contacts are on the main board. The INT4 I/O interface board is available with six high-speed and two standard output contacts, or optionally, with eight standard output contacts.

Alarm Output

The SEL-487B monitors internal processes and hardware in continual self-tests. If the relay senses an out-of-tolerance condition, the relay declares a Status Warning or a Status Failure. The relay signals a Status Warning by pulsing the HALARM Relay Word bit (hardware alarm) to a logical 1 for five seconds. For a Status Failure, the relay latches the HALARM Relay Word bit at logical 1. To provide remote alarm status indication, connect the b contact of OUT108 to your control system remote alarm input. *Figure 2.21* shows the configuration of the a and b contacts of control output OUT108.

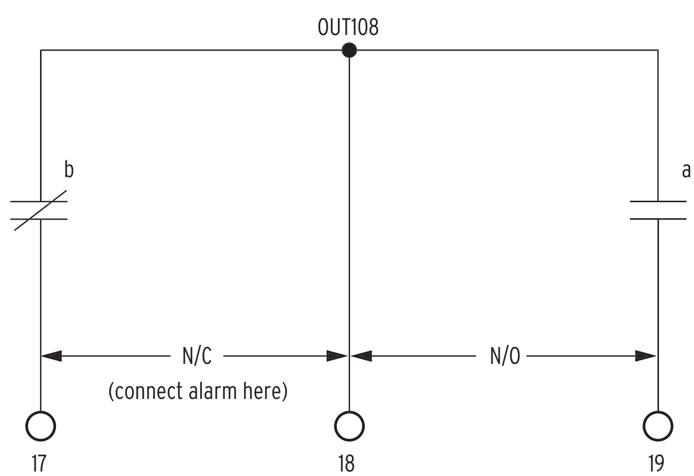


Figure 2.21 Control Output OUT108

Default settings for Output OUT 107 and Output OUT108 are as follows:

OUT107 := **TNS_SW #RELAY TEST MODE**

OUT108 := **NOT (SALARM OR HALARM)**

TNS_SW is a test function programmed to Pushbutton PB4, labeled **{RELAY TEST MODE}**. Output OUT107 asserts when the relay is in the test mode. When the relay is operating normally, the NOT HALARM signal is at logical 1 and the b contact of control output OUT108 is open. When a Status Warning condition occurs, the relay pulses the NOT HALARM signal to logical 0 and the b contact of OUT108 closes momentarily to indicate an alarm condition. For a Status Failure, the relay disables all control outputs and the OUT108 b contact closes to trigger an alarm. Also, when relay power is off, the OUT108 b contact closes to generate a power-off alarm. See *Relay Self-Tests on page U.6.34* for information on relay self-tests.

The relay pulses the SALARM Relay Word bit for software programmed conditions; these include settings changes, access level changes, and alarming after three unsuccessful password entry attempts.

Tripping and Closing Outputs

To assign the control outputs for tripping, see *Setting Outputs for Tripping on page U.4.46*. In addition, you can use the **SET O** command; see *SET on page R.7.32*, for more details.

TIME Input Connections

IRIG-B Input Connection

⚠**WARNING**
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠**DANGER**
Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

⚠**CAUTION**
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

The SEL-487B accepts a demodulated IRIG-B signal through two types of rear-panel connectors. These IRIG-B inputs are the BNC connector labeled IRIG-B and Pin 4 (+) and Pin 6 (–) of the DB-9 rear panel serial port labeled **PORT 1**. When you use the **PORT 1** input, ensure that you connect Pins 4 and 6 with the proper polarity. See *Communications Ports Connections on page 2.35* for other DB-9 connector pinouts and additional details.

These inputs accept the dc shift time code generator output (demodulated) IRIG-B signal with positive edge on the time mark. For more information on IRIG-B and the SEL-487B, see *Time Inputs on page 2.11*.

The BNC IRIG-B input and the **PORT 1** IRIG-B input circuit are internally connected to provide a single demodulated IRIG-B source for time signal processing. For this reason, you must only use one IRIG-B input (BNC or serial port) as the time signal source to the SEL-487B.

Where distance between the SEL-487B and the IRIG-B sending device exceeds the cable length recommended for conventional EIA-232 metallic conductor cables, you can use transceivers to provide isolation and to establish communication to remote locations.

Conventional fiber-optic and telephone modems do not support IRIG-B signal transmission. The SEL-2810 Fiber-Optic Transceiver/Modem includes a channel for the IRIG-B time code. These transceivers enable you to synchronize time precisely from IRIG-B time code generators (such as the SEL-2032 Communications Processor) over a fiber-optic communications link.

For ease of connection or for runs up to 300 feet from the IRIG-B generator to the SEL-487B, use the BNC IRIG-B input to connect the IRIG-B input of the SEL-487B to the IRIG-B generation equipment. Make this connection with a 50 Ω coaxial cable assembly.

Replacing the Lithium Battery

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.

You can replace a bad lithium battery in the SEL-487B. Perform the following steps to replace the lithium battery.

Step 1. Remove the relay from service.

a. Follow your company standard procedure for removing a relay from service.

b. Disconnect power from the SEL-487B.

c. Remove the relay from the rack or panel.

d. Retain the GND connection, if possible, and ground the equipment to an ESD mat.

Step 2. Remove the front panel from the SEL-487B.

Step 3. Disconnect the front-panel cable from the front panel.

Step 4. Disconnect the power cable, interface board cable(s), and input board analog cable from the main board.

Step 5. Pull out the drawout tray containing the main board.

Step 6. Locate the lithium battery.

The lithium battery is at the front of the main board. See *Figure 2.11*.

Step 7. Remove the spent battery from beneath the clip of the battery holder.

Step 8. Replace the battery with an exact replacement.

Use a 3 V lithium coin cell, Ray-O-Vac® No. BR2335 or equivalent. The positive side (+) of the battery faces up.

Step 9. Reinstall the SEL-487B main board drawout tray.

Step 10. Reattach the power cable, interface board cable(s), and input board analog cable.

Step 11. Reconnect the front-panel cable to the front panel.

Step 12. Reattach the front panel.

Step 13. Set the relay date and time via the communications ports or front panel (See *Making Simple Settings Changes on page U.4.12*).

Step 14. Follow your company's standard procedure to return the relay to service.

Communications Ports Connections

The SEL-487B has three rear-panel EIA-232 serial communications ports labeled **PORT 1**, **PORT 2**, and **PORT 3** and one front-panel port, **PORT F**. For information on serial communications, see *Establishing Communication on page U.4.4*.

In addition, the rear panel features a **PORT 5** for an optional factory-installed Ethernet communications card. For additional information about communications topologies and standard protocols that are available in the SEL-487B, see *Section 4: SEL Communications Processor Applications in the*

Applications Handbook, *Section 5: Direct Network Communication in the Applications Handbook*, *Section 5: DNP3 Communications in the Reference Manual*, and *Section 8: IEC 61850 Communications in the Reference Manual.*

Serial Ports

The SEL-487B serial communications ports use EIA-232 standard signal levels in a D-subminiature 9-pin connector. To establish communication between the relay and a DTE device (a computer terminal, for example) with a D-subminiature 9-pin connector, use an SEL Cable C234A.

Figure 2.22 shows the configuration of SEL Cable C234A that you can use for basic ASCII and binary communication with the relay. A properly configured ASCII terminal, terminal emulation program, or the ACSELERATOR software along with the C234A cable provide communication with the relay in most cases. See *Section 3: Communications Interfaces in the Reference Manual* for a list of hardware interfaces to the SEL-487B.

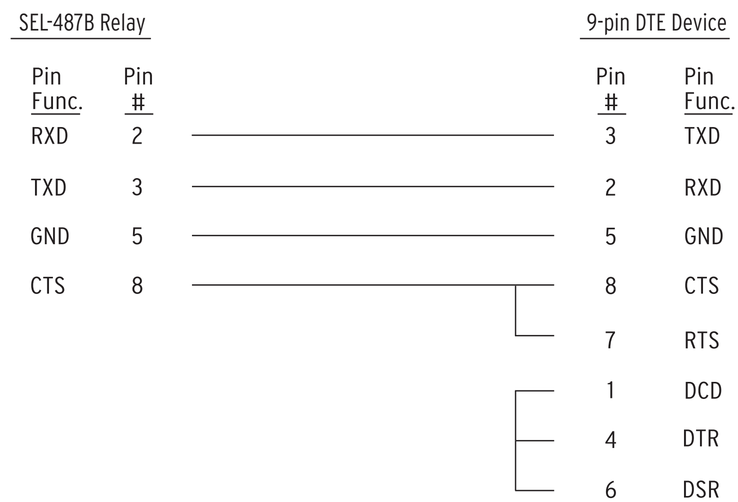


Figure 2.22 SEL-487B to Computer-D-Subminiature 9-Pin Connector

Serial Cables

Using an improper cable can cause numerous problems or failure to operate, so be sure to specify the proper cable for application of your SEL-487B. Several standard SEL communications cables are available for use with the relay. The following list provides rules and practices you should follow for successful communication using EIA-232 serial communications devices and cables:

- ➤ Route communications cables well away from power and control circuits. Switching spikes and surges in power and control circuits can cause noise in the communications circuits if power and control circuits are not adequately separated from communications cables.
- ➤ You should keep the length of the communications cables as short as possible to minimize communications circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions.

- ➤ EIA-232 communications cable lengths should never exceed 15.24 m (50 feet), and you should always use shielded cables for communications circuit lengths greater than 3.048 m (10 feet).
- ➤ Modems provide communication over long distances and give isolation from ground potential differences that are present between device locations. (Examples are the SEL-28xx-series transceivers.)
- ➤ Lower data speed communication is less susceptible to interference and will transmit greater distances over the same medium than higher data speeds. You should use the lowest data speed that provides an adequate data transfer rate.

Network Connections

The optional Ethernet card for the SEL-487B can use either the connection on Port A or Port B to operate on a network. These ports work together to provide a primary and backup interface, as described in *Network Port Fail-Over Operation on page R.3.9*. The following list describes the Ethernet card port options.

- ➤ 10/100BASE-T. 10 Mbps or 100 Mbps communications using CAT 5 cable (category 5 twisted-pair) and an RJ-45 connector
- ➤ 100BASE-FX. 100 Mbps communications over multimode fiber-optic cable using an ST connector

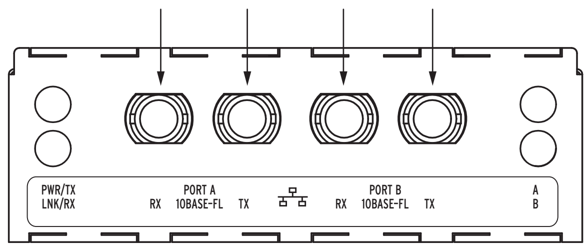


Figure 2.23 Example Ethernet Panel With Fiber-Optic Ports

Ethernet Card Rear-Panel Layout

Rear-panel layouts for the three Ethernet card port configurations are shown in *Figure 2.24–Figure 2.26*.

⚠CAUTION
Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

⚠WARNING
Do not look into the fiber (laser) ports/connectors.

⚠WARNING
Do not look into the end of an optical cable connected to an optical output.

⚠WARNING
Do not perform any procedures or adjustments that this instruction manual does not describe.

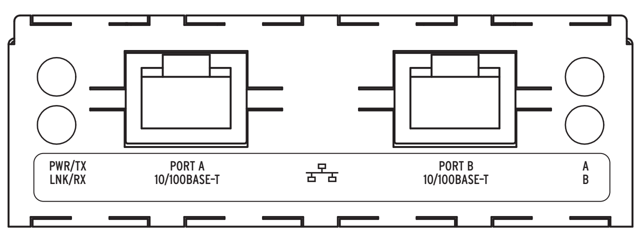


Figure 2.24 Two 10/100BASE-T Port Configuration

⚠WARNING
During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.

⚠WARNING
Incorporated components, such as LEDs, transceivers, and laser emitters, are not user serviceable. Return units to SEL for repair or replacement.

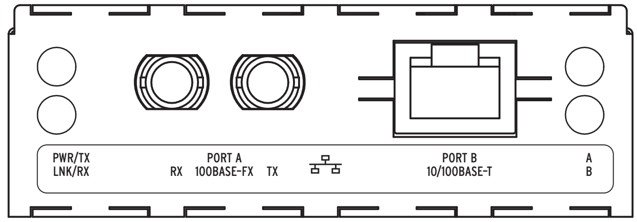


Figure 2.25 100BASE-FX and 10/100BASE-T Port Configuration

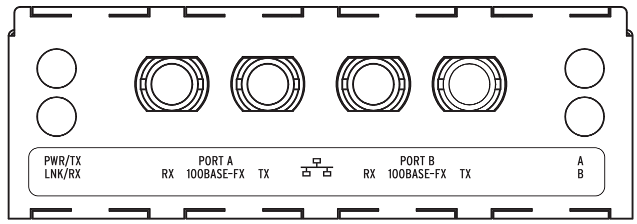


Figure 2.26 Two 100BASE-FX Port Configuration

Twisted-Pair Networks

NOTE: Use caution with UTP cables as these cables do not provide adequate immunity to interference in electrically noisy environments unless additional shielding measures are employed.

While Unshielded Twisted Pair (UTP) cables dominate office Ethernet networks, Shielded Twisted Pair (STP) cables are often used in industrial applications. The SEL-487B Ethernet card is compatible with standard UTP cables for Ethernet networks as well as STP cables for Ethernet networks.

Typically UTP cables are installed in relatively low-noise environments including offices, homes, and schools. Where noise levels are high, you must either use STP cable or shield UTP using grounded ferrous raceways such as steel conduit.

Several types of STP bulk cable and patch cables are available for use in Ethernet networks. If noise in your environment is severe, you should consider using fiber-optic cables. We strongly advise against using twisted-pair cables for segments that leave or enter the control house.

If you use twisted-pair cables, you should use care to isolate these cables from sources of noise to the maximum extent possible. Do not install twisted-pair cables in trenches, raceways, or wireways with unshielded power, instrumentation, or control cables. Do not install twisted-pair cables in parallel with power, instrumentation, or control wiring within panels, rather make them perpendicular to the other wiring.

You must use a cable and connector rated as Category 5 (CAT 5) to operate the twisted-pair interface (10/100BASE-T) at 100 Mbps. Because lower categories are becoming rare and because you may upgrade a 10 Mbps network to 100 Mbps, we recommend using all CAT 5 components.

Some industrial Ethernet network devices use 9-pin connectors for STP cables. The Ethernet card RJ-45 connectors are grounded so you can ground the shielded cable using a standard, externally shielded jack with cables terminating at the Ethernet card.

AC/DC Connection Diagrams

You can apply the SEL-487B to different power system busbar layouts. *Figure 2.27* shows one particular application scheme with connections that represent typical interfaces to the relay for a single zone layout. *Figure 2.28* depicts typical connections for a three-relay application.

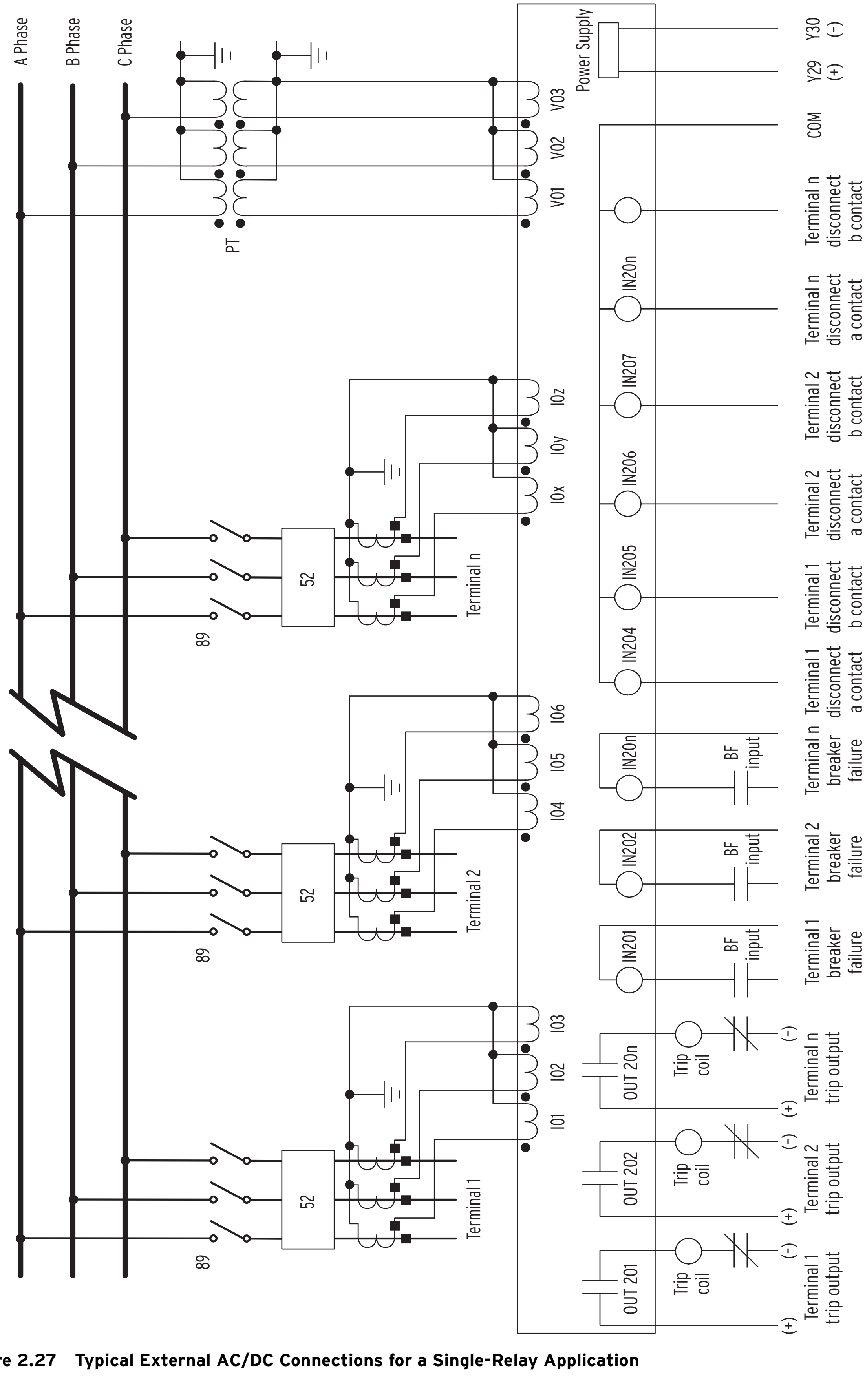


Figure 2.27 Typical External AC/DC Connections for a Single-Relay Application

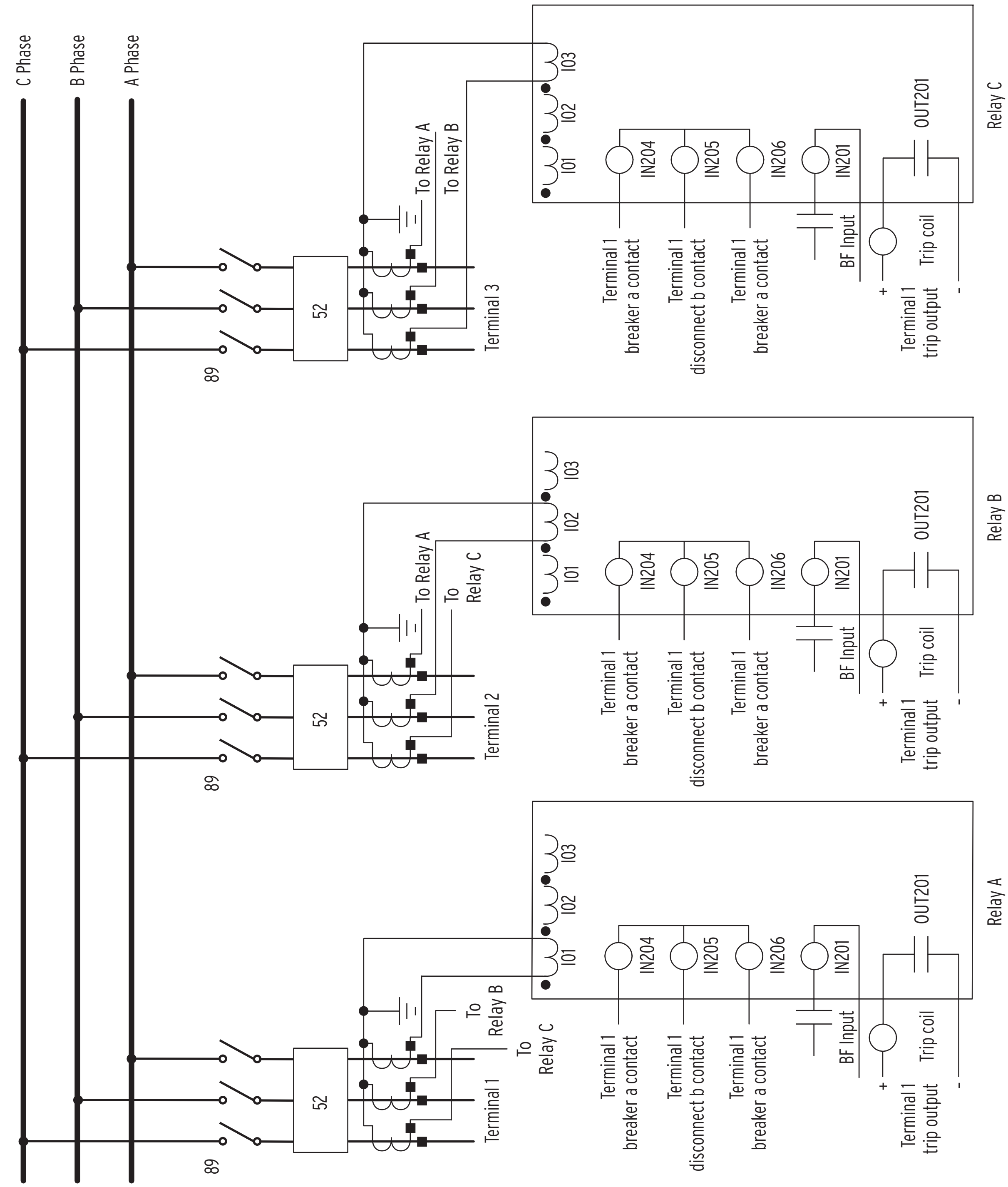


Figure 2.28 Typical External AC/DC Connections for a Three-Relay Application

Section 3
PC Software

Overview

The SEL-487B Relay includes a powerful relay settings, analysis, and measurement tool to aid you in applying and using the relay; this tool is the ACSELERATOR QuickSet® SEL-5030 software program. ACSELERATOR reduces engineering costs for relay settings, logic programming, and system analysis. ACSELERATOR makes it easier for you to do the following:

- Create and manage relay settings
  - Create settings for one or more SEL-487B relays
  - Store and retrieve settings with an IBM-compatible PC (personal computer)
  - Upload and download relay settings files to and from SEL-487B relays
- Analyze events
  - Use the integrated waveform and harmonic (single event reports) analysis tools
- Control the relay
  - Command relay operation through use of a GUI (graphical user interface) environment
  - Execute relay serial port commands in terminal mode
- Configure the serial port and passwords

SEL provides ACSELERATOR for easier, more efficient configuration of the relay settings. However, you do not have to use ACSELERATOR to configure the SEL-487B; you can use an ASCII terminal or a computer running terminal emulation software to access all relay settings and metering. ACSELERATOR gives you the advantages of rules-based settings checks, SELOGIC® control equation Expression Builder, and event analysis.

Communications Setup

ACSELERATOR uses the relay communications ports to communicate with the SEL-487B. Configure the ACSELERATOR **Communication Parameters** settings to communicate effectively with the relay. You can also use a basic terminal emulation any time you run ACSELERATOR. Use the **Communication** menu to view and clear a **Connection Log**.

Serial Communication Parameters

Use the **Communication Parameters** dialog box to configure relay communications settings.

Step 1. Select the **Communication** menu on the top ACSELERATOR toolbar.

Step 2. Click **Parameters** to open this dialog box.

Figure 3.1 shows the ACSELERATOR **Communication Parameters** dialog box.

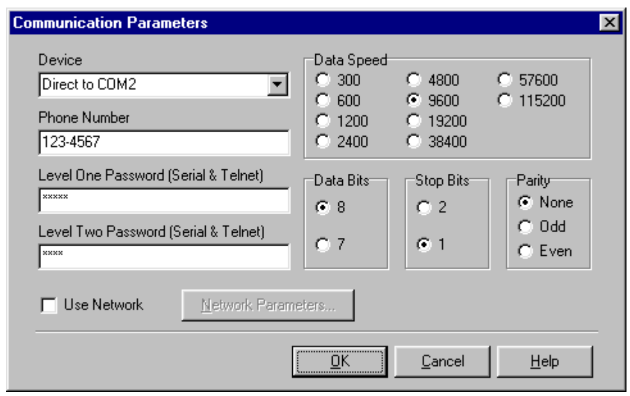


Figure 3.1 ACSELERATOR Communication Parameters Dialog Box

Serial Setup

You can use serial communication via relay Ports 1, 2, 3, and F (front panel). *Figure 3.1* shows the default serial port parameters (9600, 8, N, 1).

Step 1. Enter your relay Access Level One and Access Level Two passwords in the respective text boxes.

Step 2. If you choose a device from the **Device** drop-down list that is a telephone modem, enter the dial-up telephone number in the **Phone Number** text box.

Ethernet Card

Use the optional Ethernet card for FTP and Telnet network communications.

FTP Setup

Step 1. Access the **Network Parameters** dialog box.

a. Click the **Use Network** check box, as shown in *Figure 3.2*.

b. Click the **Network Parameters** command button.

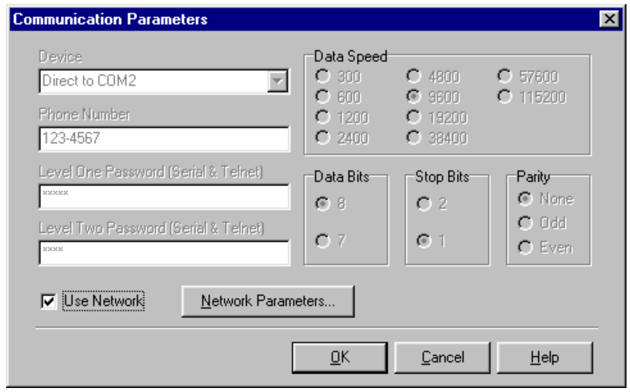


Figure 3.2 ACSELERATOR Communication Parameters Dialog Box With Network Parameters Active

Step 2. Click the **FTP File Transfer Options** option button to select FTP as the network communication protocol.

Step 3. Provide the access level command (**ACC**, **2AC**, for example) in the **User ID** text box.

Step 4. Provide the corresponding access level password in the **Password** text box to control the relay at a specific access level.

See *Changing the Default Passwords: Terminal on page U.4.9*.

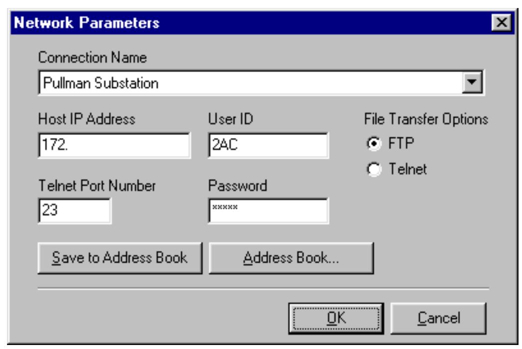


Figure 3.3 ACSELERATOR Network Parameters Dialog Box: FTP

Telnet Setup

Step 1. Access the **Network Parameters** dialog box.

a. Click the **Use Network** check box, as shown in *Figure 3.2*.

b. Click the **Network Parameters** command button.

2. Click the **Telnet File Transfer Options** button to select Telnet as the network communication protocol.

The Telnet session uses the relay passwords on the **Communication Parameters** dialog box (*Figure 3.1*). The default **Telnet Port Number** for accessing the relay is T1PNUM := 23. The default **Telnet Port Number** for communicating directly with the SEL-487B Ethernet card is T2PNUM := 1024. See *Section 5: Direct Network Communications in the Applications Handbook* for more information on Telnet.

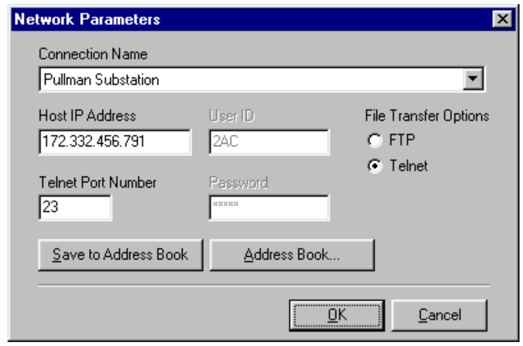


Figure 3.4 ACSELERATOR Network Parameters Dialog Box: Telnet

Terminal Mode

The terminal window is an ASCII interface between you and the relay. This is a basic terminal emulation with no file transfer capabilities. Many third-party terminal emulation programs are available with file transfer encoding schemes.

Step 1. Click the ACSELERATOR **Communication** menu.

Step 2. Click **Terminal** to start the terminal window.

Another convenient method to start the terminal is to type **<Ctrl+T>**.

Terminal Logging

When you check the **Terminal Logging** item in the **Communication** menu, ACSELERATOR records communications events and errors in a log.

Step 1. Click **Communication > Connection Log** to view the log.

Step 2. Clear the log by selecting **Communication > Clear Connection Log**.

Settings Database Management and Drivers

Database Manager

ACSELERATOR uses a relay database to save relay settings. ACSELERATOR contains sets of all settings files for each relay that you specify in the **Database Manager**. Choose appropriate storage backup methods and a secure location for storing your relay database files. Use the **File > Active Database** menu to retrieve a relay database from computer memory.

Relay Database

The default relay database file already configured in ACSELERATOR is **Relay.rdb**. This database contains example settings files for the SEL products with which you can use ACSELERATOR.

Step 1. Open the **Database Manager** to access the database.

a. Click on **File** in the ACSELERATOR top toolbar.

b. Select and click the **Database Manager** menu item.

You will see the dialog box similar to *Figure 3.5*.

Step 2. If you wish, you can enter descriptions of the database and/or relay in the **Database Description** and/or **Relay Description** text boxes.

A relay description would consist of special operating characteristics that describe the relay settings including the protection scheme settings and communications settings.

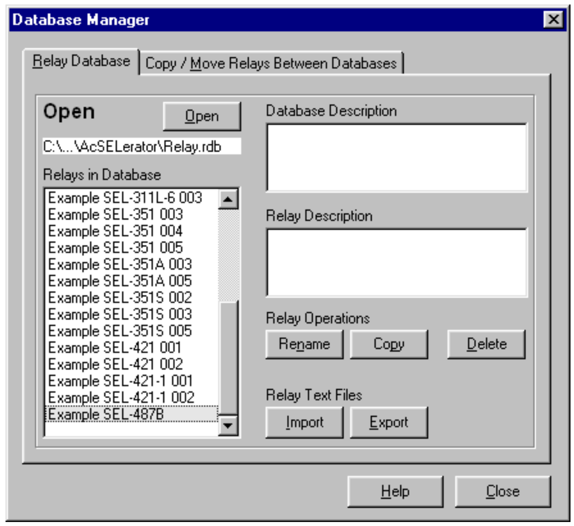


Figure 3.5 ACSELERATOR Database Manager Relay Database

Step 3. Highlight one of the relays listed in **Relays in Database.**

Step 4. Select the **Copy** option button to create a new collection of relay settings.

ACSELERATOR prompts you to provide a new name.

Step 5. Enter a new description in **Relay Description**.

Copy/Move Relays Between Databases

You can create multiple relay databases with the **Database Manager**; these databases are useful for grouping similar protection schemes or geographic areas.

Step 1. Select the **Copy/Move Relays Between Databases** tab to access the dialog box shown in *Figure 3.6*.

Step 2. Click the **Open B** option button to open a relay database.

Step 3. Type a filename.

Step 4. Click **Open**.

For example, **Relay2.rdb** is the B relay database in *Figure 3.6*.

Step 5. Highlight a relay in the A database.

Step 6. Select **Copy** or **Move.**

Step 7. Click the **>** button to create a new relay in the B database.

Reverse this process to take relays from the B database to the A database.

Copy creates an identical relay that appears in both databases. **Move** removes the relay from one database and places the relay in another database.

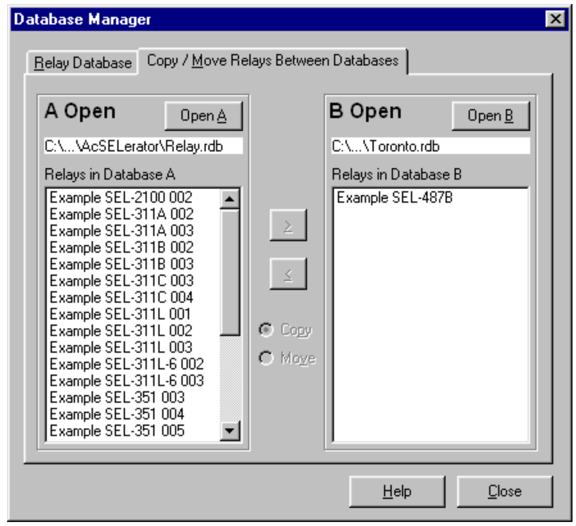


Figure 3.6 ACSELERATOR Database Manager Copy/Move

Create a New Database

Step 1. To create and copy an existing database of relays to a new database, select the **File > Database Manager** menu.

Step 2. Select **Copy/Move Relays Between Databases** on the **Database Manager** dialog box.

ACSELERATOR opens the last active database and assigns it as Database A (see *Figure 3.6*).

Step 3. Click on the **Open B** button.

ACSELERATOR prompts you for a file location.

Step 4. Type a new database name.

Step 5. Click on the **Open** button.

Step 6. Answer **Yes**.

The program creates a new empty database.

Step 7. Load relays into the new database as in *Copy/Move Relays Between Databases*.

Drivers

Relay settings folders in ACSELERATOR are closely associated with the ACSELERATOR relay driver that you used to create the settings. The relay settings and the ACSELERATOR drivers must match.

Step 1. Use one of the following methods to view the relay FID (firmware identification) number to determine the active ACSELERATOR drivers.

➤ Use the **STATUS** command from the serial port terminal emulation window.

➤ Type **ID <Enter>** in the computer emulation software window (**Ctrl+T** from ACSELERATOR).

Step 2. Locate and record the Z-number in the FID string.

The Z-number helps determine the proper ACSELERATOR relay settings driver version when creating or editing relay settings files.

Step 3. View the ACSELERATOR settings driver information at the bottom of the **Relay Editor** window (see *Figure 3.13*).

The first portion of the Z-number is the ACSELERATOR settings driver version number (see *Figure 3.7*).

Step 4. Compare the ACSELERATOR driver number and the relay FID number.

This ACSELERATOR driver Z-number and the corresponding part of the relay FID must match.

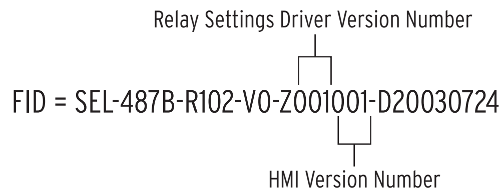


Figure 3.7 ACSELERATOR Software Driver Information in the FID String

ACSELERATOR reads the first portion of the Z-number (Z001XXX, for example) to determine the correct **Relay Editor** to display when you select **New**, **Open** or **Read**.

Step 5. View the bottom of the **Relay Editor** window to check the **Relay Editor** driver number (see *Figure 3.8*).

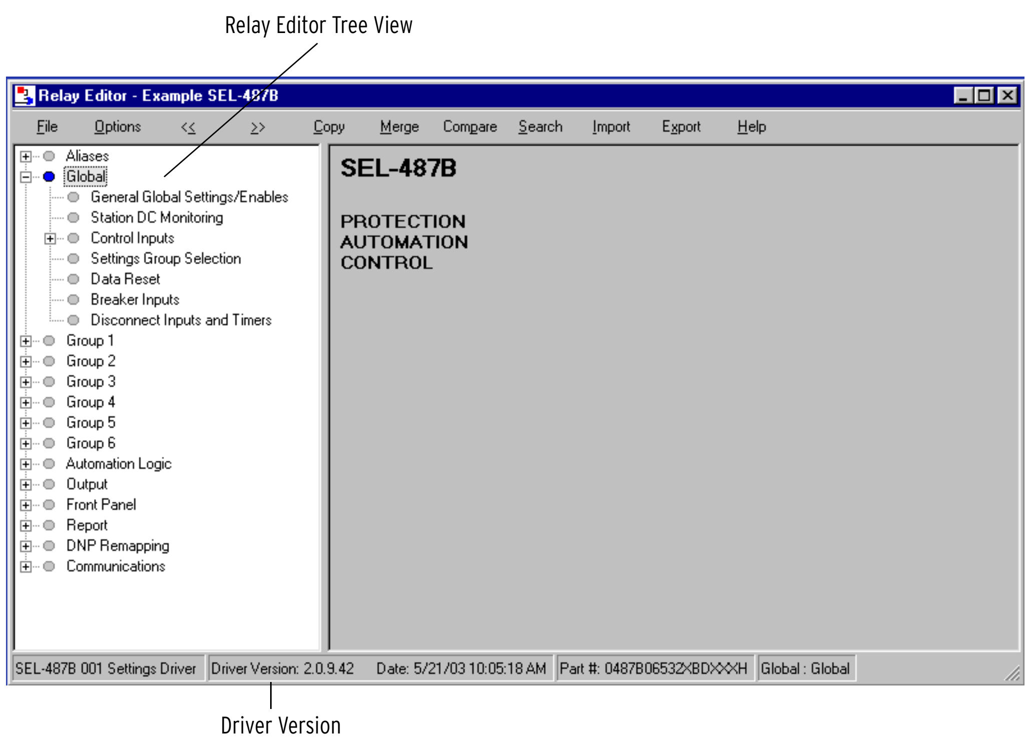


Figure 3.8 Relay Settings Driver Version Number

As SEL develops new drivers, you can update your existing ACSELERATOR with specific relay drivers for each SEL product that uses ACSELERATOR. Contact your local Technical Service Center or the SEL factory for the latest ACSELERATOR drivers.

Create and Manage Relay Settings

ACSELERATOR enables you to create settings for one or more SEL-487B relays. You can store existing relay settings downloaded from SEL-487B relays with ACSELERATOR, creating a library of relay settings (see *Database Manager on page U.3.4*). You can then modify and upload these settings from your settings library to an SEL-487B. ACSELERATOR makes setting the relay easy and efficient.

Collected Settings

ACSELERATOR arranges relay settings in easy-to-understand categories (for an explanation of settings organization, see *Making Simple Settings Changes on page U.4.12*). These categories of collected settings help you quickly set the relay. *Figure 3.9* is an example of relay settings categories in the **Relay Editor Settings** tree view.

ACSELERATOR shows all of the settings categories in the settings tree view. When you enable and disable settings categories, the tree view remains constant, but when you click on the tree view to access the settings in a disabled category, the disabled settings are dimmed. For example try the following steps:

Step 1. Select the **Global > General Global Settings/Enables** branch of the settings tree view.

Step 2. Observe that the **EGADVS Advanced Global Settings** are dim.

Step 3. If you select **Y** for **EDCMON**, then the **EGADVS Advanced Global Settings** become active.

Step 4. *Figure 3.9* illustrates this feature of ACSELERATOR.

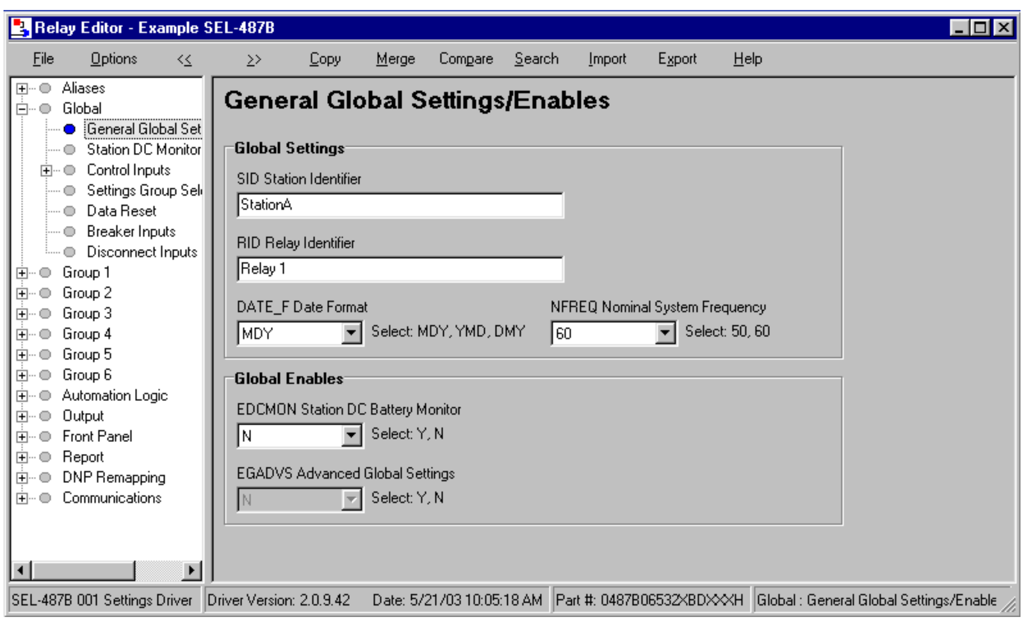


Figure 3.9 ACSELERATOR Sample Settings

Settings Menu

The **Settings** menu on the top ACSELERATOR toolbar is the starting point for all settings entries. The menu items in the **Settings** menu are the following:

- **New**
- **Open**
- **Read**

All of these menu items open the **Relay Editor** (see *Relay Editor on page U.3.10*).

New

Selecting the **New** menu item creates new relay settings files. ACSELERATOR makes the new settings files from the relay drivers that you specify in the **Relay Editor Selection** dialog box (see *Figure 3.10*). ACSELERATOR uses the Z-number in the relay FID string to create a particular version of relay settings.

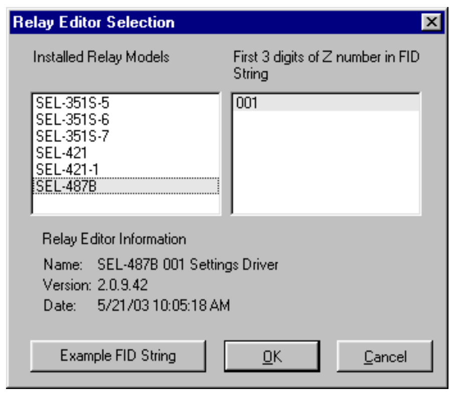


Figure 3.10 Selecting a Settings Driver in ACSELERATOR

After selecting the relay model and settings driver, ACSELERATOR presents the **Relay Part Number** dialog box. Use this dialog box to configure the **Relay Editor** to produce settings for a relay with options determined by the part number.

Open

The **Open** menu item opens an existing relay from the active database folder (see *Figure 3.11*). ACSELERATOR prompts you for a folder containing relay settings to load into the **Relay Editor**.

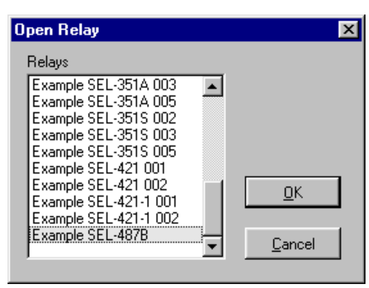


Figure 3.11 Opening Relay Settings in ACSELERATOR

Read

When you select the **Read** menu item, ACSELERATOR reads the relay settings from a connected relay. As ACSELERATOR reads data from the relay, you will see a dialog box similar to *Figure 3.12*. ACSELERATOR uses serial protocols at a serial port or FTP from an Ethernet port to read settings from SEL devices.

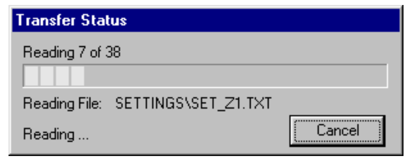


Figure 3.12 Reading Relay Settings in ACSELERATOR

Relay Editor

Use the **Relay Editor** to enter relay settings. *Figure 3.13* illustrates the important features of the editor. These features include the ACSELERATOR settings driver version number (the first three digits of the Z-number) in the lower left corner of the **Relay Editor**.

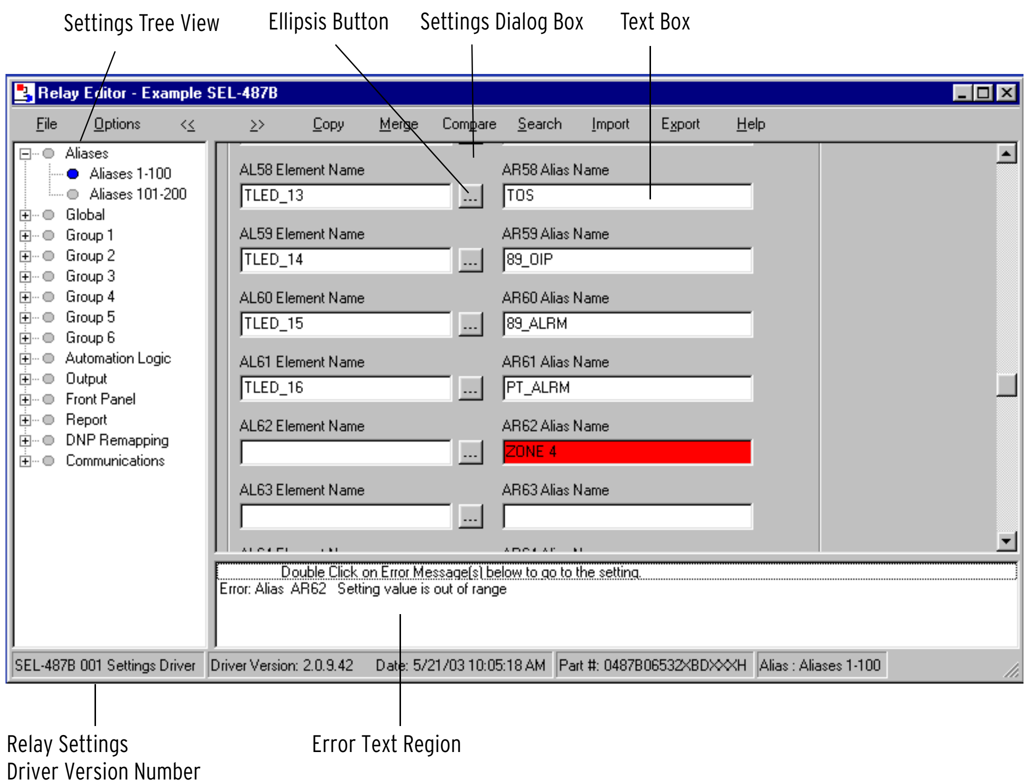


Figure 3.13 ACSELERATOR Relay Editor

Entering Settings

Step 1. Click the **+** marks to expand the **Settings Tree View** (see *Figure 3.13*).

Step 2. Click the circle buttons to select the settings class, instance, and category that you want to change.

Step 3. Use the **Tab** key to move to the setting text book and from setting to setting when entering and editing.

Step 4. The right-click mouse button performs two special functions when you are editing settings: **Previous Value** and **Default Value**.

Step 5. Use the following methods to edit the settings from ACSELERATOR.

- ➤ Restore previous values. Right click the mouse over the setting and select **Previous Value**.
- ➤ Restore default values. Right click in the setting dialog box and select **Default Value**.

If you enter a setting that is out of range or has an error, an error message appears at the bottom of the **Relay Editor** window. To correct the error, proceed to *Step 6*.

Step 6. Correct settings errors.

a. Double-click on the error listing in the **Relay Editor** window.

b. Enter a valid input for the setting where the error appears.

Relay Part Number

The relay part number determines the settings that ACSELERATOR displays and the functions that the software controls. When configuring ACSELERATOR to control a particular relay, you should confirm that the ACSELERATOR part number matches the relay part number so that you can access all of the settings you need for your relay.

Configuring the Relay Part Number

Step 1. Select the ACSELERATOR **Settings** menu.

Step 2. Click **New**, **Open**, or **Read** to start the **Relay Editor**; see *Settings Menu on page U.3.9*.

Step 3. Once in the **Relay Editor**, click the **Options** menu on the **Relay Editor** toolbar (see *Figure 3.14*).

Step 4. Point to **Part Number.**

Step 5. Click this option.

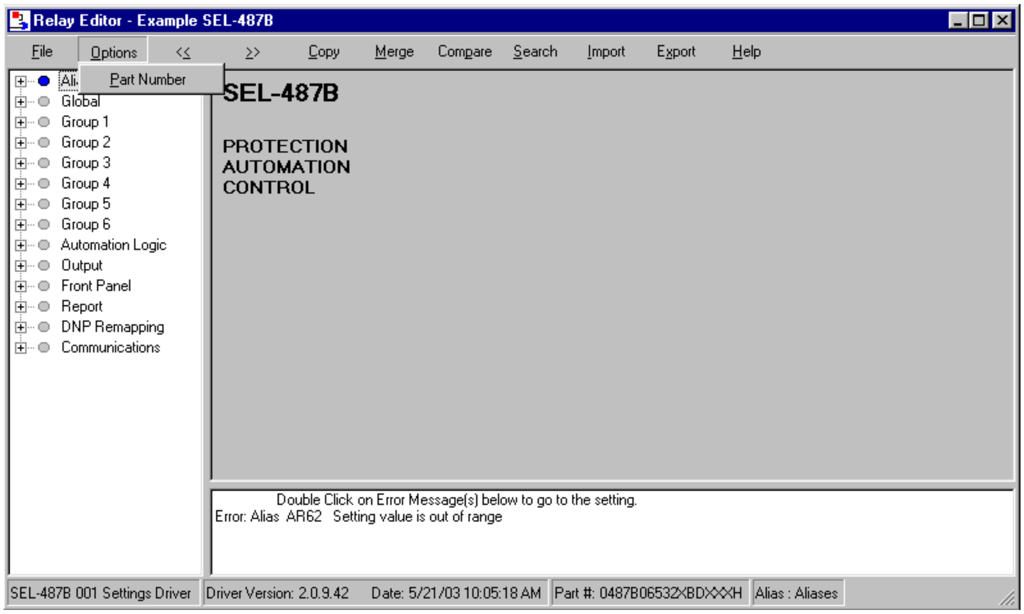


Figure 3.14 Retrieving the Relay Part Number

You will see the **Relay Part Number** dialog box, as shown in *Figure 3.15*.

Step 6. Use the arrows inside the text boxes to match corresponding portions of the **Relay Part Number** dialog box to your relay.

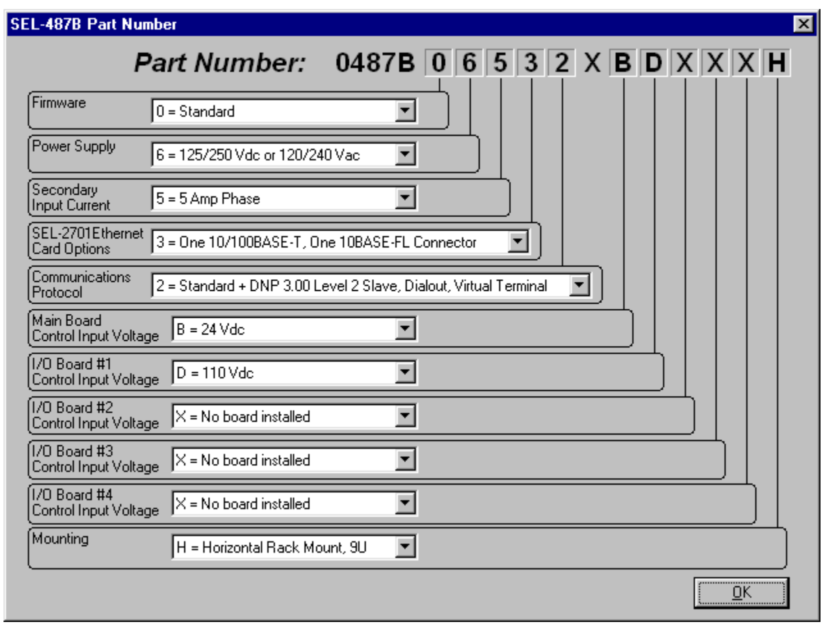


Figure 3.15 Setting the Relay Part Number in ACSELERATOR

Ellipsis Button

ACSELERATOR includes a feature called an **Ellipsis Button** (see *Figure 3.16*).

Figure 3.16 Ellipsis Button

The **Ellipsis Button** is a square button with three dots, as shown in *Figure 3.17*. Use the **Ellipsis Button** to build expressions or assist with entering settings in the relay. Whether the **Ellipsis Button** is an expression builder or a setting assistant depends on the selected relay function and is preprogrammed in the relay. For example, *Figure 3.17* shows the **Ellipsis Button** as a setting assistant, entering settings for the SER.

Step 1. Enter the SER settings by clicking on the **Report > SER Settings** in the **Tree View**.

Step 2. Click on the **SITM1 SER Points and Alias, Point 1** ellipsis button, which makes the **R1-SITM1** window available.

Step 3. Click on the Relay Word bit ellipsis button in the **R1-SITM1** window.

The software displays a list of Relay Word bits available in the relay that you can select to enter in the SER report.

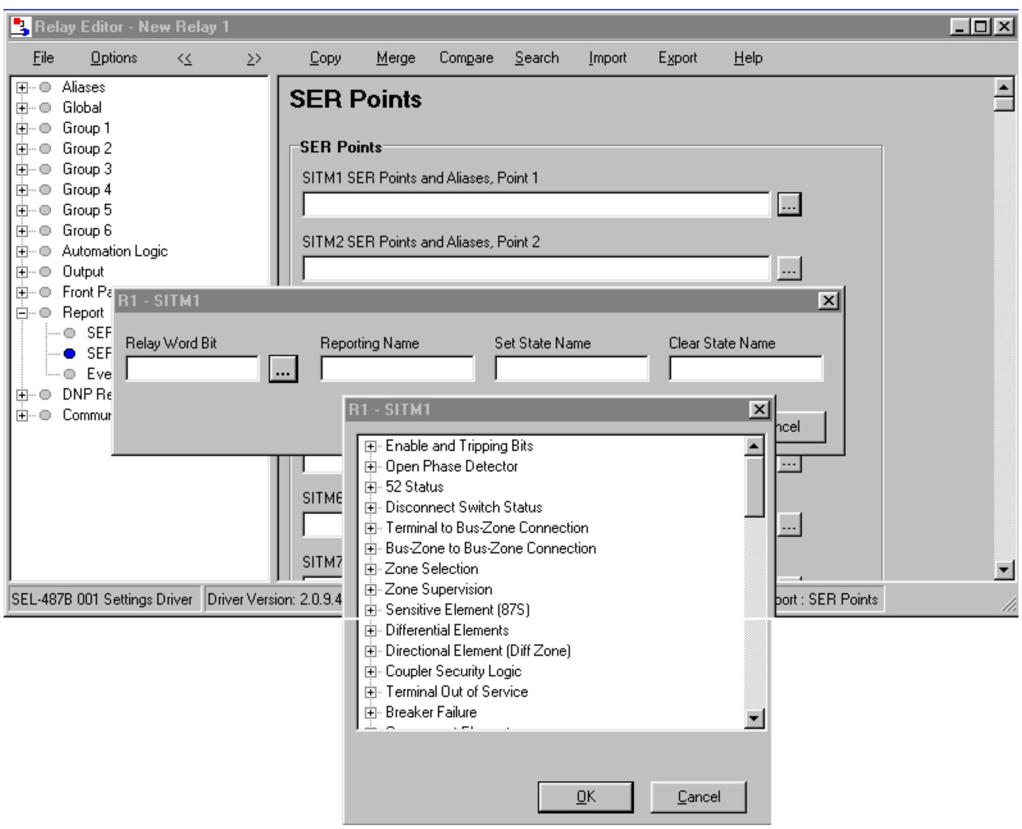


Figure 3.17 Location of Ellipsis Button

Expression Builder

The **Ellipsis Button** also includes an expression builder. SELOGIC control equations are a powerful means for customizing relay performance. Creating these equations can be difficult because of the large number of relay elements (Relay Word bits) and analog quantities in the relay. ACSELERATOR simplifies this process with the expression builder, a rules-based editor for programming SELOGIC control equations. The expression builder organizes relay elements, analog quantities, and SELOGIC control equation variables and focuses your equation decision making.

Expression Builder Organization

The **Expression Builder** dialog box is organized into two main parts representing the left side (LVALUE) and right side (RVALUE) of the SELOGIC control equation. (The LVALUE is fixed for all settings except Protection Free-Form SELOGIC and Automation Free-Form SELOGIC control equation settings; see *Fixed SELOGIC Control Equations on page R.2.4*.) *Figure 3.18* shows the two sides of the **Expression Builder**, with the SELOGIC control equation that you are constructing at the top of the dialog box. Note the dark vertical line and the equals sign (**:=**) separating the equation's left and right sides.

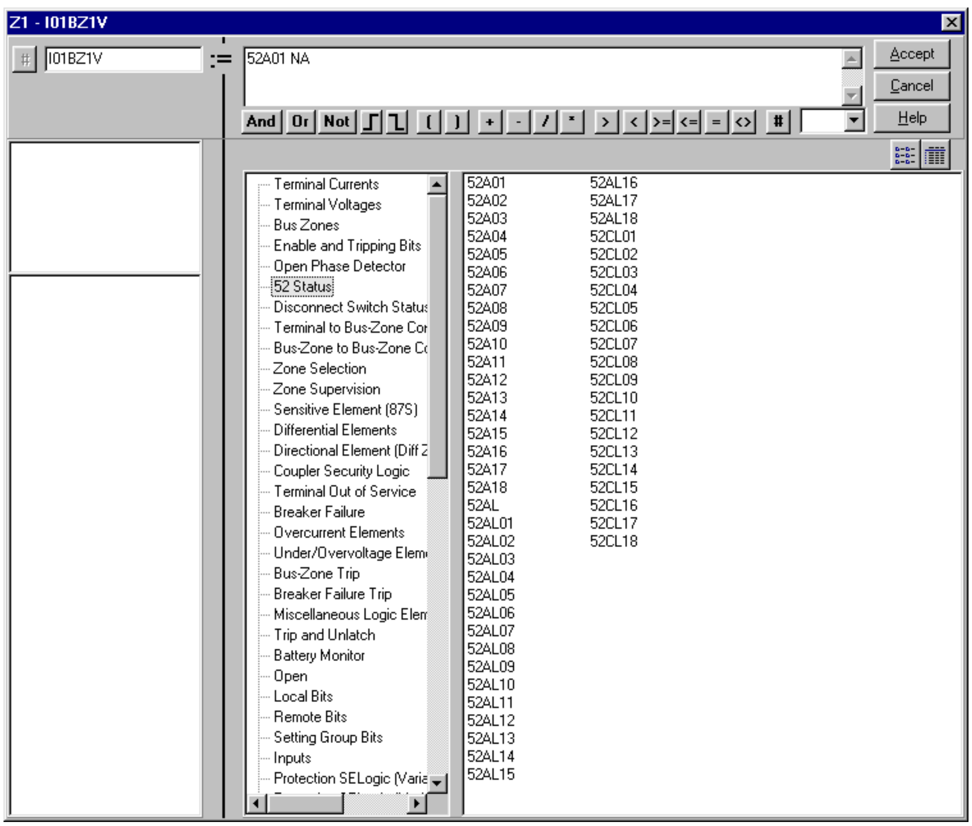


Figure 3.18 ACSELERATOR Expression Builder

Using the Expression Builder

Step 1. For Protection Free-Form SELOGIC and Automation Free-Form SELOGIC control equations, select the type of result (LVALUE) for the SELOGIC control equation to use the **Expression Builder**.

ACSELERATOR shows Relay Word bits available for use in compiling expressions. The program shows the relay elements for each type of SELOGIC control equation (e.g., Boolean Variables, Math Variables).

On the right side of the equation (RVALUE), you can select broad categories of relay elements, analog quantities, counters, timers, latches, Boolean variables, and math variables.

Step 2. Select a category in the RVALUE tree view.

The Expression Builder displays all elements for that category in the list box at the bottom right side. Directly underneath the right side of the equation, you can choose operations to include in the RVALUE. These operations include basic logic functions, rising and falling edge triggers, expression compares, and math functions. For more information on programming SELOGIC control equations, see *Section 2: SELOGIC Control Equation Programming in the Reference Manual*.

Analyze Events

Each SEL-487B provides event reports for analysis with oscillography software such as the SEL-5601 Analytic Assistant product. For stations with more that six terminals, the busbar protection requires three SEL-487B relays. Except for single-phase faults, all other faults involve at least two SEL-487B relays. For example, an A-phase to B-phase fault operates the differential element in the A-phase relay, as well as the differential element in the B-phase relay. For post-fault analysis, we need to consider two different event reports from two different relays. With the SEL-5601 Analytic Assistant, you can display events from three different relays in one window to make the fault analysis easier and more meaningful. Because the three different relays time-stamp the events with values from their individual clocks, we need to time-synchronize the three SEL-487B relays.

Time Synchronization

Each SEL-487B provides two IRIG-B connectors, labeled IN and OUT. Referring to the external source connections in *Figure 3.19*, connect the IRIG-B signals to the IN connection of Relay A to update the clock of Relay A. Connect the OUT connection of Relay A to the IN connector of Relay B to update the clock in Relay B. A similar connection between Relay B and Relay C updates the time in Relay C.

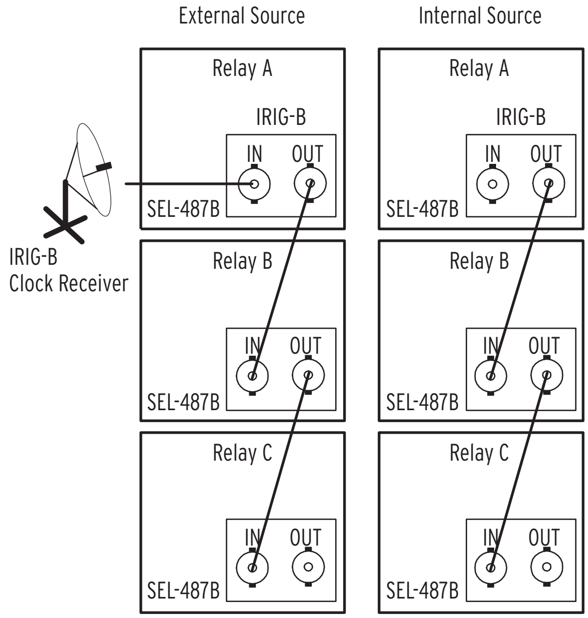


Figure 3.19 Time Synchronization Connections Between Three Relays

In the absence of an external IRIG-B signal, connect the relays as shown by the internal source connections in *Figure 3.19*. When connected this way, Relay B uses the clock of Relay A as time reference, and Relay C uses the clock of Relay B as time reference.

Because the event reports from the three relays could have the same number, be sure to enter a unique name for the RID setting of each relay. For example, at Eiger substation, label the three relays (Global settings) as follows:

Relay 1: SID = EIGER 275 KV BUSZONE, RID = A-PHASE

Relay 2: SID = EIGER 275 KV BUSZONE, RID = B-PHASE

Relay 3: SID = EIGER 275 KV BUSZONE, RID = C-PHASE

Assume a three-phase busbar fault occurs at the station. The following example shows how to download the event reports from the three relays and how to combine the three event reports into a single event report.

In this example we will do the following:

1. Use ACSELERATOR to identify the event reports of interest in each of the three relays.
2. Download the event reports from the relay.
3. Launch the SEL-5601 Analytic Assistant from ACSELERATOR.
4. Select as many as three events for analysis.
5. Select the analog channels and digital Relay Word bits from each of the three events.
6. Combine these selections into a single event report.

The following are the specific steps to download the event reports from three relays and to combine those reports into a single event report.

Step 1. Connect the communications cable to the A-phase relay.

Step 2. Launch ACSELERATOR.

NOTE: 24 and 12 samples/cycle events cannot be combined.

Step 3. Establish communications with the A-phase relay.

Step 4. Select **Analysis > View Event History**.

The software reads the available event reports as shown in *Figure 3.20*.

Step 5. Select the event report of interest from the available event reports in the relay.

Step 6. Select the type of event (12 samples/cycle or 24 samples/cycle) you want to download from the relay from the **Event Options**.

Step 7. After selecting the event type, press the **Get** button to retrieve the event.

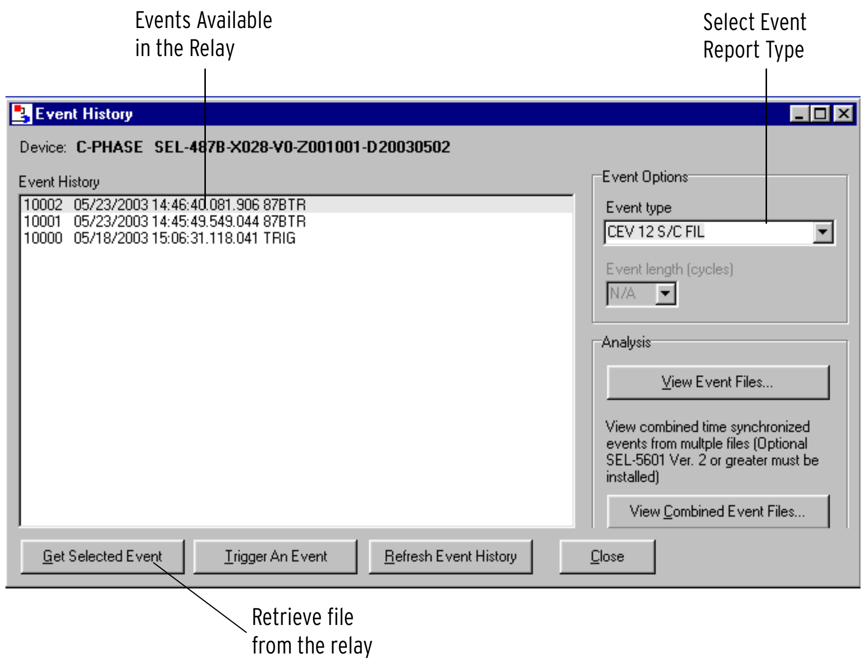


Figure 3.20 Screen for Retrieving Event Reports From the Relay

In this example, we select **Event Report 10003** and **12 samples/cycle event** type.

After pressing the **Get** button, the software downloads the event report to temporary memory and displays the screen as shown in *Figure 3.21*.

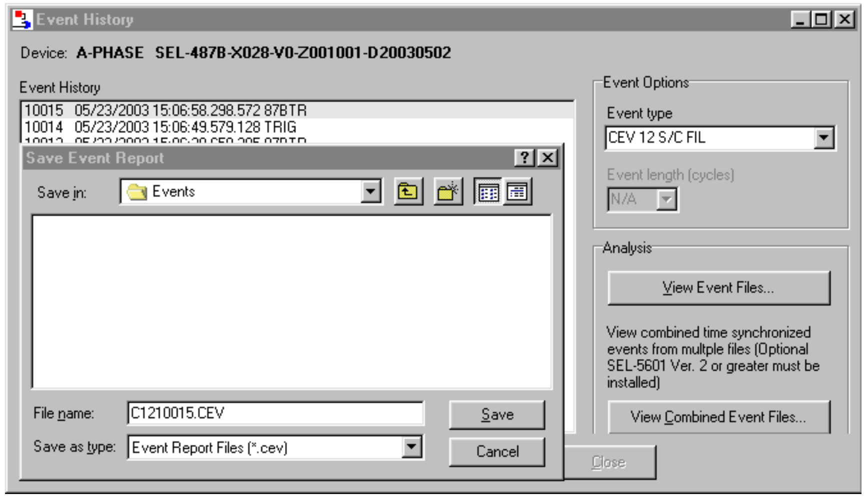


Figure 3.21 Event Report 10003 at 12 Samples/Cycle Selected for Download

The software selects the default events directory in which to save the event report.

Step 8. To avoid confusion between the three event reports from the three relays, change the file name from **C1210015.CEV** to a more descriptive name.

Figure 3.21 shows an example with the file name changed from **C1210015.CEV** to **A-PHASE_12-10015.CEV**.

Step 9. Press the **Save** button to save the file.

Step 10. Connect the communications cable to the B-phase relay.

Step 11. Ensure that the communication parameters are set properly.

Step 12. Press the **Refresh** button.

The software lists the available event reports in the B-phase relay from which you can select the event of interest.

Step 13. Change the file name to **B-PHASE_12-10001.CEV**.

Step 14. Press the **Save** button.

The software saves the file in the same directory as the **A-PHASE_12-10015.CEV** file.

Step 15. Connect the communications cable to the C-phase relay.

Step 16. Ensure that the communication parameters are set properly.

Step 17. Press the **Refresh** button.

The software lists the available event reports in the C-phase relay from which you can select the event of interest.

Step 18. Change the file name to **C-PHASE_12-10002.CEV.**

Step 19. Press the **Save** button.

The software saves the file in the same directory as the **A-PHASE_12-10015.CEV** file and the **B-PHASE_12-10001.CEV** file.

The three event reports from the three different relays are now retrieved and are available for analysis.

Step 20. Select the **View Combined Events** files to combine the three event reports into one event, as shown in *Figure 3.22*.

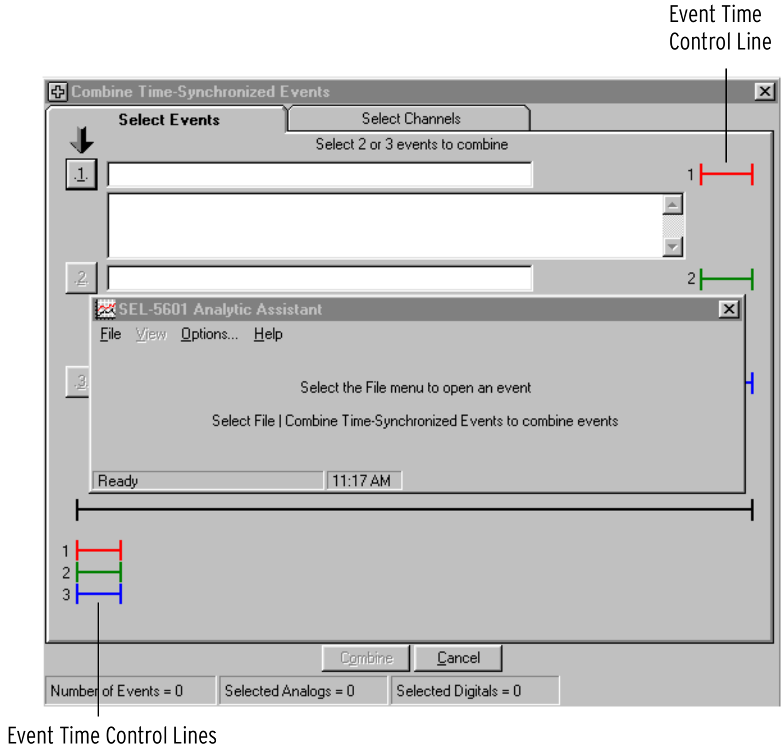


Figure 3.22 Combine Time-Synchronized Events Submenu Screen

Three placeholders are available for as many as three events. Next to each placeholder is a color-coded horizontal line called an event time control line. These event time control lines also appear at the bottom of the screen where they show the relative overall time relationship between the events, the trigger time of each event, and the number of cycles of each event. The event time control lines are color-coded with red (Event 1) on top, green (Event 2) in the center, and blue (Event 3) at the bottom. A flashing arrow points to a button for Event 1.

Step 21. Click on the button for Event 1.

The software selects the directory where you last stored an event report.

Step 22. Click on the event you want to analyze.

Step 23. Click on the **Open** button, as shown in *Figure 3.23*.

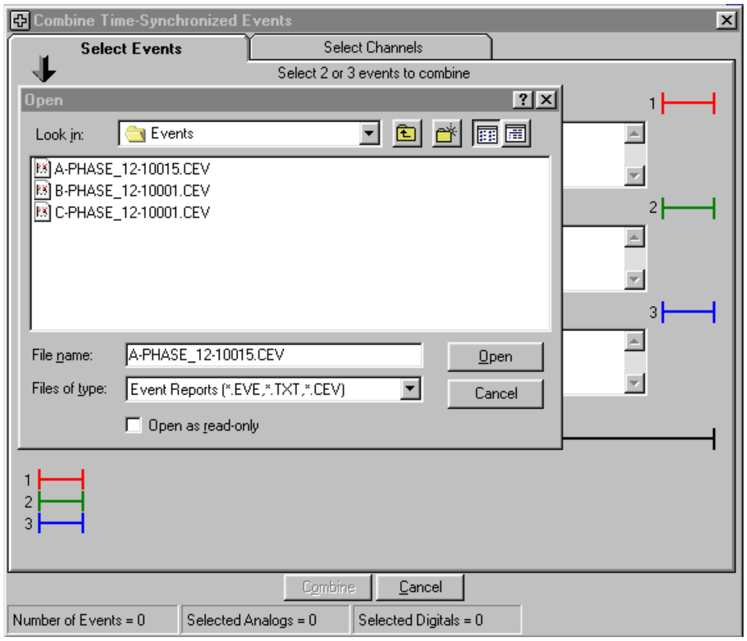


Figure 3.23 Selection of the First Event Report

The software reads the selected event report and places the event report in the first placeholder, as shown in *Figure 3.24*.

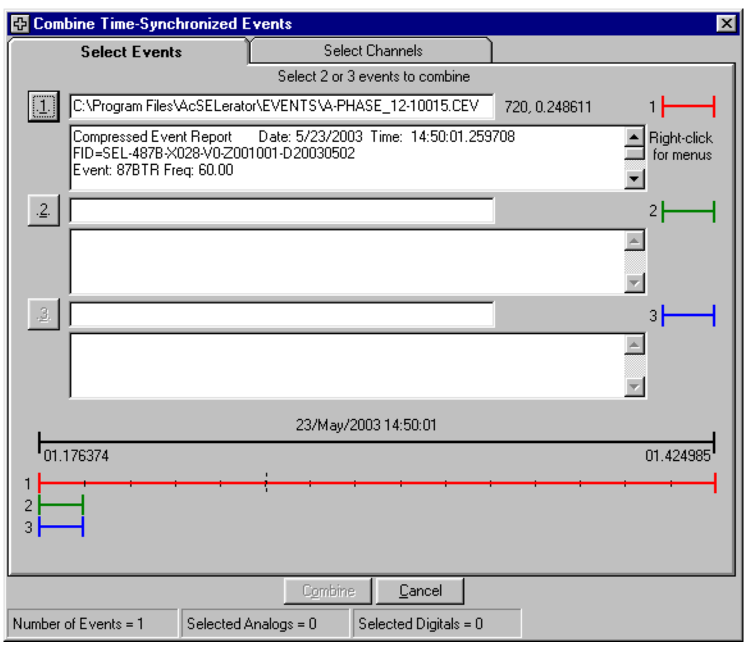


Figure 3.24 First Event of the Analysis

Notice that the actual event control line of the first events now appears at the bottom of the screen and becomes the reference time position. All other events must overlap the reference time position by at least one data point. The software positions the subsequent events relative to the position of the first event.

If the subsequent event does not overlap the first event by at least one data point, the software does not allow the events to be combined.

Step 24. Click on the button for Event 2 and repeat the steps described for selecting Event 1.

Step 25. Repeat the steps for Event 3. *Figure 3.25* shows the screen after reading all three events.

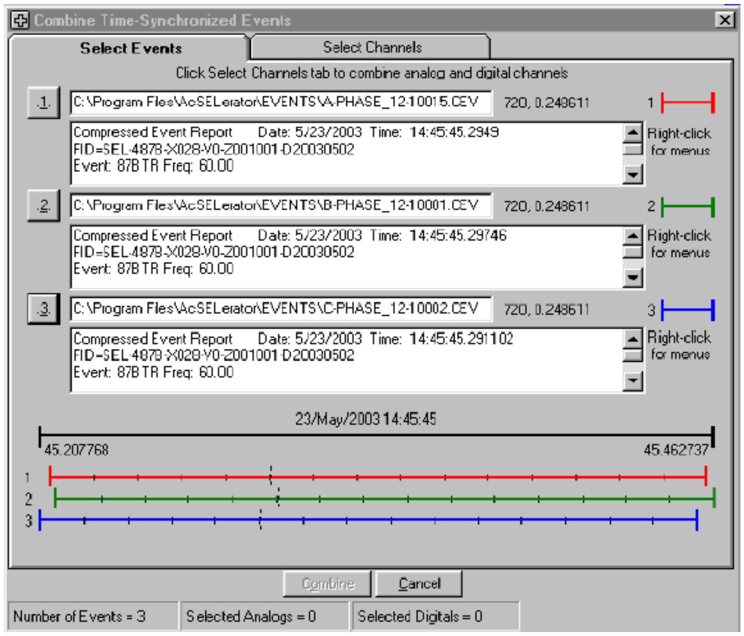


Figure 3.25 Screen After Reading All Three Events

The information displayed at the bottom of the screen shows that we have opened three events but have not as yet selected any analog channels or digital Relay Word bits from these events.

Step 26. Click on the **Select Channels** tab to select analog channels and digital Relay Word bits. *Figure 3.26* shows the screen for selecting the channels.

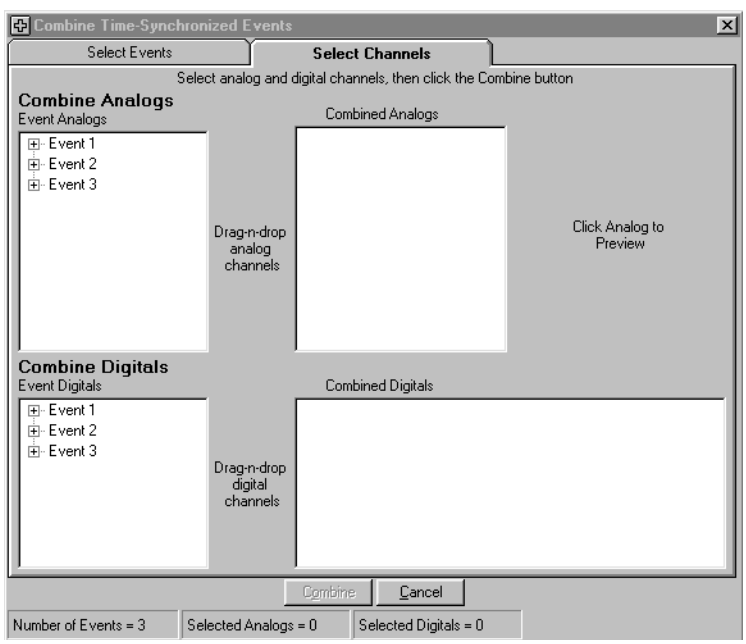


Figure 3.26 Screen for Selecting Analog Channels and Digital Relay Word Bits

The three events appear in the window labeled Event Analogs.

Step 27. Click on the **+** of Event 1 to see a list of the analog channels in the event report.

Step 28. Click on **1_FDR_1(A)**, the first analog channel in the list.

Step 29. A trace of channel **1_ FDR _1** appears on the right hand window next to the **Combined Analogs** list.

Step 30. Right click on channel **1_ FDR _1**.

Step 31. Hold the mouse button down.

Step 32. Drag the cursor to the **Combined Analogs** window.

Alternatively, press the **A** key to add the selected channel to the list.

Step 33. Release the mouse button to complete the transfer of channel 1_ FDR _1 from the **Event Analogs** window to the **Combine Analogs** window.

Alternatively, select the channels to be removed and press the **<Delete>** key.

Drag and drop is similarly supported for digital channels.

Step 34. Select a channel.

Step 35. Drop the selection into the **Event Analogs** or **Event Digitals** window to remove channels from the **Combined Analogs** or **Combined Digitals** windows.

Figure 3.27 shows the screen with Analog Channel **1_ FDR _1** from Event Report 1, **2_ FDR _1** from Event Report 2, and **3_ FDR _1** from Event Report 3 selected for analysis and appearing in the **Combined Analogs** window.

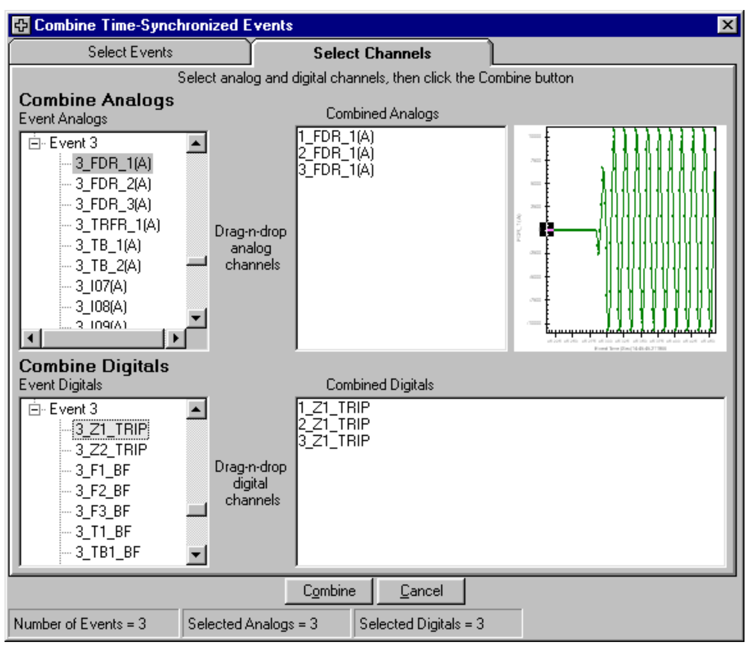


Figure 3.27 Selection of Analog Channels and Digital Relay Word Bits

Figure 3.27 also shows the differential element from each event report: **Relay Word bit 1_Z1_TRIP** from Event Report 1, **Relay Word bit, 2_ Z1_TRIP** from Event Report 2, and **Relay Word bit, 3_ Z1_TRIP** from Event Report 3.

Step 36. Click on the **Combine** button to create a single, combined report comprising the selected analog and digital selections from three individual event reports.

Step 37. On the graph preference form, select the values of interest from the **Analogs** window.

Step 38. Drop these selections in any one of the six available **Axis** windows.

You can select up to 12 analog channels.

Figure 3.28 shows an example after selecting all three analog channels on Axis 1 for analysis.

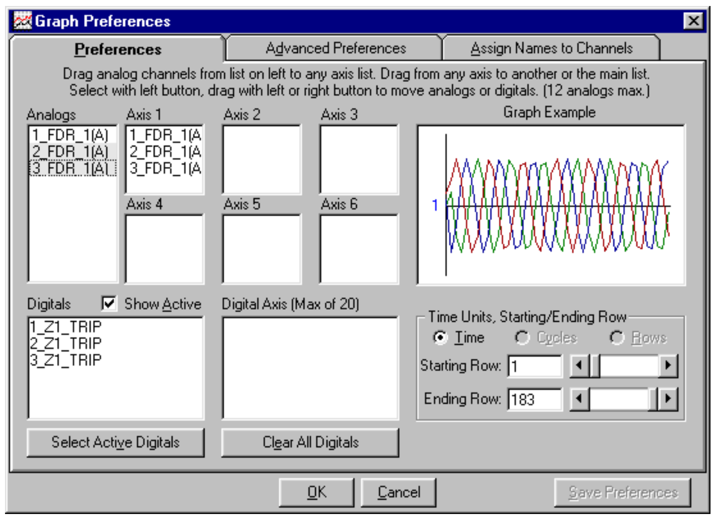


Figure 3.28 Data From Three Separate Event Reports Combined in a Single Report

Step 39. Click **OK** to view the report.

The software displays the three traces on the same screen, as shown in *Figure 3.29*.

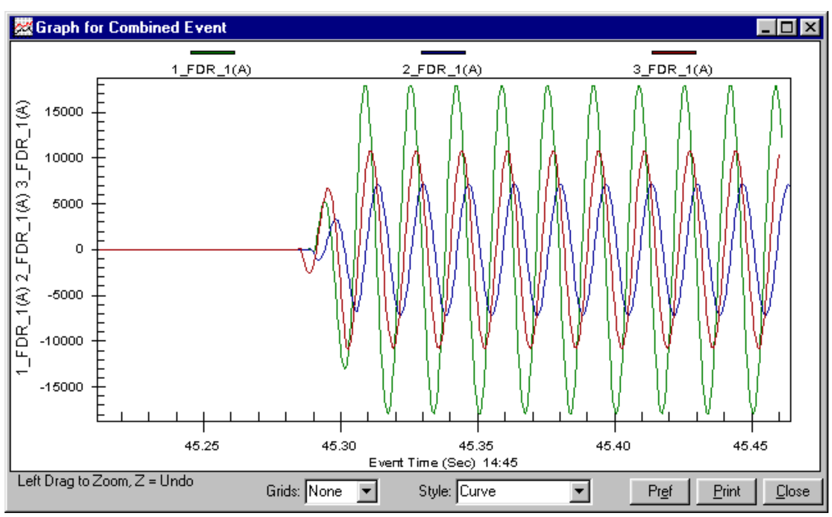


Figure 3.29 Traces of the Three Analog Channels

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Section 4
Basic Relay Operations

Overview

The SEL-487B Relay is a powerful tool for power system protection and control. Understanding basic relay operation principles will help you use the relay effectively using the front panel and a computer terminal emulation program. See *Section 3: PC Software* for information about the ACSELERATOR QuickSet® SEL-5030 software.

This section presents the fundamental knowledge you need to operate the SEL-487B organized by task. These tasks help you become familiar with the relay and include the following:

- ➤ Inspecting a new relay
- ➤ Connecting and applying power
- ➤ Establishing communication
- ➤ Changing the default passwords
- ➤ Checking relay status
- ➤ Making simple settings changes
- ➤ Examining metering quantities
- ➤ Reading event reports and SER (Sequential Events Recorder)
- ➤ Operating the relay inputs and outputs
- ➤ Configuring timekeeping
- ➤ Readying the relay for field application

Perform these tasks to gain a good understanding of relay operation, be able to confirm that the relay is properly connected, and be more effective when using the relay.

Inspecting a New Relay

⚠CAUTION
Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Otherwise, equipment damage can result.

The following items are included in your shipment from SEL:

- ➤ SEL-487B Relay
- ➤ Printed volume of the SEL-487B Relay *User's Guide* (on request)
- ➤ CD-ROM containing the electronic version of the SEL-487B Relay Instruction Manual and the Customer Label Templates

- ➤ CD-ROM containing ACSELERATOR
- ➤ Configurable Front-Panel Label Kit

If any item is missing or damaged, please contact your distributor or SEL immediately.

Initial Inspection

Remove the protective wrapping from the SEL-487B. Observe the outside of the front cover and the rear panel. Check that no significant scratches or dents are evident on any outer surface. Confirm that all terminal strips on the rear panel are secure.

Cleaning

Use care when cleaning the SEL-487B. Use a mild soap or detergent solution and a damp cloth to clean the relay chassis. Allow the relay to air dry, or wipe dry with a soft dry cloth. Do not use abrasive materials or polishing compounds on any relay surface. Be careful when cleaning the front and rear panels because a permanent plastic sheet covers each panel; do not use harsh chemical solvents such as xylene or acetone on these surfaces.

Verify Relay Configuration

When you first inspect the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. Examine the serial number label on the relay rear panel; *Figure 4.1* shows a sample rear-panel serial number label.

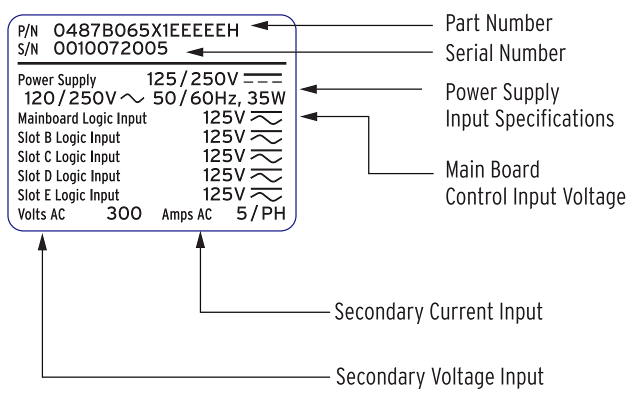

Figure 4.1 SEL-487B Serial Number Label

This example serial number label is for a 5 A secondary current input relay. For information on CT and PT inputs, see *Secondary Circuits on page U.2.7*.

The power supply specification in *Figure 4.1* indicates that this relay is equipped with a power supply that accepts a nominal 125/250 Vdc input. This power supply also accepts a 120/230 Vac input. Refer to the serial number label affixed to the back of your relay to determine the power supply voltage you should apply to the relay power supply input terminals. As this label indicates, the voltage source should be capable of providing at least 35 W for dc inputs and 170 VA for ac inputs. See *Power Supply on page U.1.11* for more information on power supply specifications.

The part number lists the relay composition and ordering options (see the SEL website at www.selinc.com for more Model Option Table detail).

Connecting and Applying Power

Connect external power to the SEL-487B to perform the initial checkout and familiarization procedures in this section. For complete information on power connections, see *Power Connections on page U.2.30*. *Figure 4.2* shows the portion of the relay rear panel where you connect the power input.

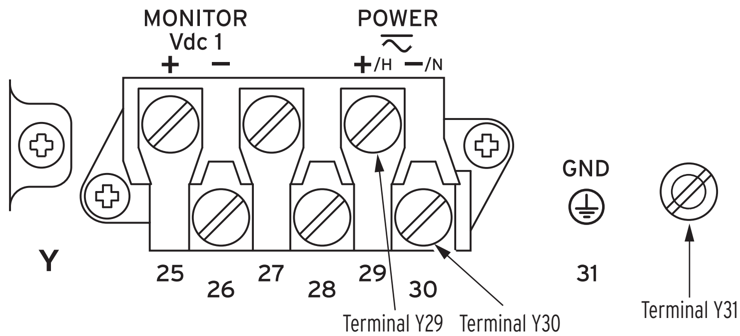

Figure 4.2 Power Connection Areas of the Rear Panel

Always attach a safety ground as the first connection you make to the SEL-487B. You must connect the grounding terminal (#Y31) next to the symbol labeled GND on the rear panel to the rack grounding bar for proper safety and performance.

You can order the SEL-487B with one of three power supplies with nominal operating voltages: 24/48 Vdc, 48/125 Vdc, and 125/250 Vdc. The two higher voltage supplies, 48/125 Vdc and 125/250 Vdc, use ac input or dc input. The relay serial number label on the back of the relay lists voltage ranges that encompass the nominal voltages. *Table 4.1* shows the nominal voltage inputs and power supply voltage ranges for dc input and ac inputs, if applicable.

Table 4.1 Power Supply Voltage Inputs

Nominal DC Voltage Input	DC Input Range	AC Input Range (30–120 Hz)
24/48 Vdc	18–60 Vdc <35 W	N/A
48/125 Vdc	38–140 Vdc <35 W	85–140 Vac <170 VA
125/250 Vdc	85–300 Vdc <35 W	85–264 Vac <180 VA

Use 16 AWG (1.5 mm^2) wire (or thicker) to connect to the POWER terminals. When you use a dc power source, you must connect the source with the proper polarity, as indicated by the + (Terminal #Y29) and – (Terminal #Y30) symbols on the power terminals. You can use ac input for the 48/125 Vdc power supply and the 125/250 Vdc power supply. The relay power supply operates from 30 to 120 Hz when alternating current supplies the POWER input.

Upon connecting power, you will see information on the front-panel LCD (liquid crystal display) and the ENABLED LED (light-emitting diode) will light. For complete information on the SEL-487B front panel, see *Section 5: Front-Panel Operations*.

Establishing Communication

Once you have applied the correct power input successfully, you are ready to operate the relay. Use the relay front panel and the communications ports to communicate with the relay.

Front-panel control of relay functions involves use of a menu system that you access through the LCD and the six navigational pushbuttons shown in *Figure 4.3*. For complete instructions on using the front-panel menu system, see *Navigating the Menus on page U.5.4*.

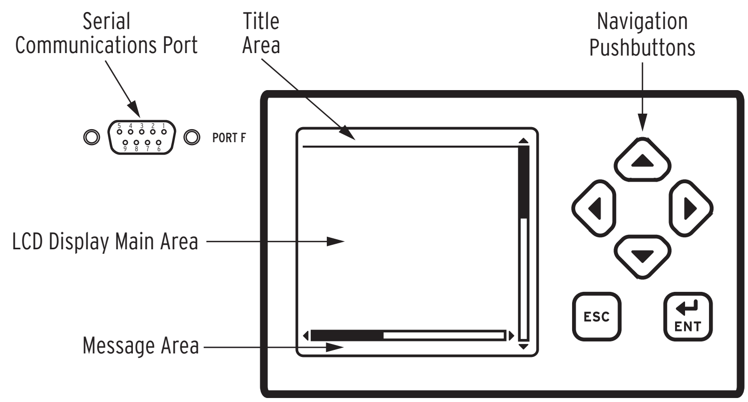

Figure 4.3 PORT F, LCD Display, and Navigation Pushbuttons

Fast and efficient communication with the relay is available through communications ports such as PORT F, also shown in *Figure 4.3*. A design philosophy for all SEL relays is that an ASCII or open terminal is all that you need to communicate with the relay. Many "off-the-shelf" computer programs provide computer terminal emulation. These programs are inexpensive and widely available. Use the cable connections appropriate for your terminal configuration. See *Section 3: Communications Interfaces in the Reference Manual* for more information on communications ports.

All ASCII commands you send to the relay must terminate with a carriage return or carriage return/line feed; the terminal emulation program appends the necessary carriage return when you press **<Enter>** on the computer keyboard. You can truncate commands to the first three characters: **EVENT 1 <Enter>** becomes **EVE 1 <Enter>**. Use upper- and lowercase characters without distinction, except in passwords, which are case sensitive. For a list of ASCII commands see *Section 7: ASCII Command Reference in the Reference Manual*.

Help

When you are using a computer terminal, you can access built-in relay help for each ASCII command. Relay help is access-level sensitive; you see only the ASCII commands for the present access level when you type **HELP <Enter>**. For in-depth information on a particular ASCII command, enter the command name after typing **HELP**. For example, for help on the **EVENT** ASCII command, type **HELP EVE <Enter>**.

When you are using the ACSELERATOR software, press the **<F1>** key to get help, or select the **Help** menu from the ACSELERATOR toolbars. The help information in the ACSELERATOR software gives detailed information and sample screens in a GUI format.

Making an EIA-232 Serial Port Connection

The following steps use any popular computer terminal emulation software and an SEL serial cable to connect to the SEL-487B. Use SEL Cable C234A to connect a 9-pin computer serial port to the SEL-487B. Use SEL Cable C227A to connect a 25-pin computer serial port to the relay. See *Section 3: Communications Interfaces in the Reference Manual* for further information on serial communications connections. These and other cables are available from SEL. Contact the factory or your local distributor for more information.

Step 1. Connect the computer and the SEL-487B using the serial communications cable.

Use the 9-pin serial port labeled PORT F on the relay front panel.

Step 2. Apply power to both the computer and to the relay.

Step 3. Start the computer terminal emulation program.

Step 4. Set your computer terminal emulation program serial communications parameters.

The default SEL-487B communications port settings are listed in *Table 4.2*.

a. Set your computer terminal emulation program to the parameters in the Default column.

b. Set the computer terminal program to emulate either VT100 or VT52 terminals (these terminal emulations work best with SEL relays).

Table 4.2 General Serial Port Settings

Name	Description	Default
PROTO	Protocol (SEL, DNP[a], MBA, MBB)	SEL
SPEED	Data speed (300 to 57600)	9600
DATABIT	Data bits (7, 8 bits)	8
PARITY	Parity (Odd, Even, None)	N
STOPBIT	Stop bits (1, 2, bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

[a] DNP protocol is an ordering option.

Step 5. Check the communications link.

a. Press the **<Enter>** key on the computer keyboard to confirm that you can communicate with the relay.

You will see the = prompt at the left side of your computer screen (column 1).

b. If you do not see the prompt, check the cable connections and confirm the settings for the default communications parameters of *Table 4.2* in your computer terminal emulation program.

Step 6. View the relay report header.

a. Type **QUIT <Enter>**.

You will see a computer screen display similar to *Figure 4.4*.

b. If you see jumbled characters, change the terminal emulation type in the computer terminal program.

```
=QUIT <Enter>

Relay 1                                     Date: 03/15/2001  Time: 00:01:05.209
Station A                                   Serial Number: 2003001234

=
```

Figure 4.4 Report Header

When you communicate with the relay at the = prompt, you are in Access Level 0. You cannot control relay functions at this level. Higher access levels are password protected and allow increased control over relay operation. For more information on access levels and password protection, see *Changing the Default Passwords on page U.4.6*.

Changing the Default Passwords

NOTE: Perform the password-change steps described in Changing the Default Passwords: Terminal on page U.4.9.

It is extremely important that you change the factory default passwords programmed in the SEL-487B. Setting unique passwords for the relay access levels increases the security of your substation and the power system. This subsection begins with information on the access level/password system in the SEL-487B and includes an example for changing the default passwords.

Access Levels

Access levels control whether you can perform different operations within the SEL-487B. These security levels are labeled 0, 1, B, P, A, O, 2, and C. *Figure 4.5* presents an overview of the general access level structure in the relay.

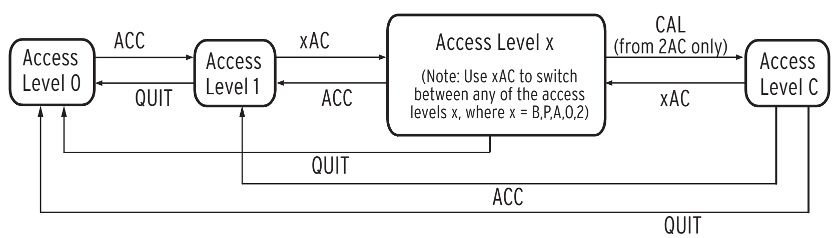

Figure 4.5 Access Level Structure

Access Level 0 is the least secure and most limited access level, and Access Level 2 is the most secure level where you have total relay functionality. (Access Level C is reserved for SEL factory operations. Only go to Access Level C to change the Level C password or under the direction of an SEL employee.) For example, from Access Level 1 you can view settings; you cannot change settings unless you are at a higher access level. *Table 4.3* lists access levels and operator functions for the SEL-487B.

Table 4.3 SEL-487B Access Levels (Sheet 1 of 2)

Access Level	Prompt	Allowed Operations
0	=	Log in to Access Level 1; some test diagnostics.
1	=>	View data and status information.
B	==>	Access Level 1 functions plus breaker control.
P	P=>	Access Level B functions plus protection settings.
A	A=>	Access Level B functions plus automation settings.

Table 4.3 SEL-487B Access Levels (Sheet 2 of 2)

Access Level	Prompt	Allowed Operations
O	0=>	Access Level B functions plus output settings.
2	=>>	Perform all relay access level functions.
C	==>>	SEL calibration-specific functions. For a list of commands available, contact SEL.

The SEL-487B performs command interpretation and execution according to your validated access level. Each access level has a password that the relay must verify before you can control the relay at that level. *Table 4.4* lists the access level commands with corresponding passwords.

Table 4.4 Access Level Commands and Passwords

Access Level	Command	Factory Default Password
0	**QUIT**	(None)
1	**ACCESS**	OTTER
B	**BACCESS**	EDITH
P	**PACCESS**	AMPERE
A	**AACCESS**	VOLTA
O	**OACCESS**	WATT
2	**2ACCESS**	TAIL
C	**CAL**	Sel-1

Communications Ports Access Levels

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Entrance to the higher security levels is sequential. First enter a correct password to move from Access Level 0 to Access Level 1. To enter Access Levels B, P, A, O, and 2, enter a correct password from Access Level 1. For example, to go to the O (Output) Access Level from Access Level 1, type **OAC <Enter>**; at the `Password: ?` prompt, type your Access Level O password.

To enter Access Level C, you must enter a correct password from Access Level 2.

Use the relay **QUIT** command from any access level to return the relay to Access Level 0. To reestablish control at a previous access level from Access Level 1, use the access level commands and passwords to log in to that previous access level.

When a connection with the SEL-487B times out, the relay reduces the access level to Access Level 0 for that communications port connection.

The MAXACC port setting can be used to limit the maximum access level permitted on a port. This can be useful to restrict what remote users can do.

Front-Panel Access Levels

The lowest access level for the front panel is Access Level 1. To enter Access Levels B, P, A, O, and 2, enter a correct password from Access Level 1. The front-panel LCD displays a password prompt when you attempt to control the relay at any access level higher than Access Level 1. (For more information on entering passwords from the front panel, see *Password on page U.5.13*.) The front-panel MAIN MENU item RESET ACCESS LEVEL returns the relay to Access Level 1. In addition, when the front-panel inactivity timer times out (indicated by the ROTATING DISPLAY on the front-panel LCD), the relay returns the front-panel access level to Access Level 1.

ACCESS Command

NOTE: You can shorten relay commands to the first three letters of the full command. See Section 6: ASCII Command Reference in the Reference Manual for more information.

Use the **ACCESS** command to change to Access Level 1. Passwords are case sensitive; enter a password exactly as set. If you enter the password correctly, the SEL-487B moves you to Access Level 1 from Access Level 0. The Access Level 1 prompt (=>) appears. If you are at a higher access level (B, P, A, O, and 2), you can reduce the access level to Access Level 1 by entering the **ACC** command; the relay performs no password validation to reduce the present access level.

Higher Access Level Commands

Use the commands in *Table 4.4* to enter access levels above Access Level 1. For example, use the **2ACCESS** command to change to Access Level 2. If you are presently at Access Level 1, B, P, A, or O, type **2AC <Enter>**. The SEL-487B prompts you to type the Access Level 2 password. If the present level is Access Level 0, the SEL-487B responds with the following:

```
Invalid Access Level
```

The relay asserts alarm Relay Word bit SALARM when entering Access Level B, P, A, O, and 2 from a lower access level.

If you are unable to enter the correct password after the third failed attempt, the SEL-487B asserts the SALARM and BADPASS Relay Word bits and displays this error message on a communications terminal screen:

```
WARNING: ACCESS BY UNAUTHORIZED PERSONS STRICTLY PROHIBITED
```

In addition, you cannot make further access level entry attempts for 30 seconds.

The relay will also terminate the communications connection after the third failed password entry attempt when you use any of the following communications modes: Ethernet via an Ethernet card, DNP3 (Distributed Network Protocol Version 3.0), and MIRRORED BITS® communications virtual terminal mode. For more information on these protocols, see *Section 4: SEL Communications Protocols in the Reference Manual* and *Section 5: DNP3 Communications in the Reference Manual.*

If your connection to the SEL-487B has a valid inactivity time-out setting other than OFF (in the **SET P** port settings), the SEL-487B automatically closes the communications connection and changes to Access Level 0 when the timeout occurs.

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Valid passwords are character sequences of as many as 12 characters. Valid password characters are any printable ASCII character. HMI password entry is limited to upper- and lower-case letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel. Passwords are case sensitive.

It is important that you change all of the passwords from their default values. This will protect you from unauthorized access.

Use strong passwords. These contain a mix of valid password characters in a combination that does not spell common words in any portion of the password.

Changing the Default Passwords: Terminal

Step 1. Confirm that the relay is operating.

See *Connecting and Applying Power on page U.4.3*.

Step 2. Establish communication with the SEL-487B (see *Making an EIA-232 Serial Port Connection on page U.4.5* to learn how to use a computer terminal to communicate with the relay).

Step 3. Prepare to control the relay at Access Level C (Access Level 2 is sufficient except when changing Access Level C password).

a. Type **ACC <Enter>** at a communications terminal.

b. Type **OTTER <Enter>** (Access Level 1).

You will see the => prompt.

c. Type **2AC <Enter>**.

d. At the password prompt, type **TAIL <Enter>**.

e. Type **CAL <Enter>**.

f. At the password prompt, type **Sel-1 <Enter>**.

You will see the Access Level C ==>> prompt.

NOTE: Passwords are case sensitive; you must enter passwords exactly as set.

Step 4. Set a new password for Access Level 2.

a. Type **PAS 2 nE2Pw- <Enter>**.

nE2Pw- is the new strong password. The relay will display the following:

```
Set
=>>
```

Step 5. Set new passwords for each access level.

a. In a similar manner as the previous step, create new strong passwords for each access level.

b. Commit these passwords to memory, permanently record your new passwords, and store this permanent record in a secure location.

Eliminate password verification for an access level by entering DISABLE in place of the new password. This action will disable the password of that level; therefore, the relay does not check for a password upon entering that access level. Using DISABLE is not recommended. Always set a unique, strong password in the relay for each access level. Failure to do this can severely jeopardize the security of your substation and the power system.

After you enter a new password, the relay pulses the Relay Word bit SALARM for one second and responds with the following:

```
Set

=>>
```

If you used the DISABLE parameter, the relay responds with the following message:

```
Password Disabled

=>>
```

If you forget a password, or encounter difficulty changing the default passwords in *Changing the Default Passwords: Terminal on page U.4.9*, you can temporarily disable password verification. See *Jumpers on page U.2.16* for information on the password disable jumper J18B.

Checking Relay Status

With continual self-testing the SEL-487B monitors the internal operation of all circuits to verify optimal performance of relay functions. If an internal circuit, protection algorithm, or automation algorithm enters an out-of-tolerance operating range, the relay reports a status warning. In the unlikely event that an internal failure occurs, the relay reports a status failure. For more information on relay status, see *Relay Self-Tests on page U.6.34*.

You can check relay status through a communications port by using a computer terminal, computer terminal emulation computer program, or the ACSELERATOR software. In addition, you can use the relay front panel to view status information.

Computer Terminal

The procedure in the following steps assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

Step 2. Type **STA <Enter>**. The relay returns a status terminal screen similar to that in *Figure 4.6*.

```
=>>STA <Enter>

Busbar Protection                          Date: 07/24/2003  Time: 15:32:45.492
Atlantis                                   Serial Number: 0000000001

FID=SEL-487B-R102-V0-Z001001-D20030724 CID=0xd930
Failures
  No Failures

Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors
Relay Enabled

=>>
```

Figure 4.6 Relay Status

To view all relay status entries, use the **STA A** command. For more information on relay status report items, see *STATUS on page R.7.40*.

Front Panel

Use the front-panel display and navigation pushbuttons to check SEL-487B status. See *Section 5: Front-Panel Operations* for information on using the relay front panel.

Step 1. Apply power to the relay.

Note that the LCD shows a sequence of screens called the ROTATING DISPLAY. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **{ENT}** pushbutton to display the MAIN MENU shown in *Figure 4.7*.

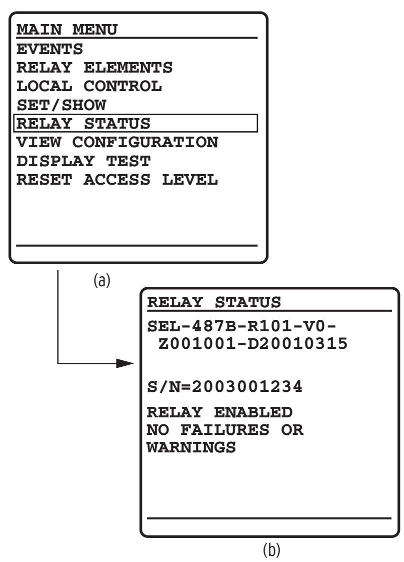

Figure 4.7 Checking Relay Status: Front-Panel LCD

Step 3. View relay status.

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the RELAY STATUS action item (see *Figure 4.7*).

b. Press the **{ENT}** pushbutton. You will see the RELAY STATUS screen (the second screen of *Figure 4.7*).

Step 4. Normalize the front-panel display.

a. To return to the MAIN MENU, press the **{ESC}** key.

b. To return to the ROTATING DISPLAY, press **{ESC}** again.

For more information on the front-panel screen presentations and the items in the STATUS screens, see *RELAY STATUS on page U.5.29*.

Making Simple Settings Changes

The SEL-487B settings structure makes setting the relay easy and efficient. Settings are grouped logically, and you do not see relay elements that are not used in your selected protection scheme.

The ACSELERATOR software uses a similar method to focus your attention on the active settings. Unused relay elements and inactive settings are dimmed (grayed) in the ACSELERATOR software menus. See *Section 3: PC Software* for more information on the ACSELERATOR software.

Settings Structure

The SEL-487B settings structure assigns each relay setting to a specific location based on the setting type. A top-down organization allocates relay settings into these layers:

- Class
- Instance
- Category
- Setting

Examine *Figure 4.8* to understand the settings structure in the SEL-487B. The top layer of the settings structure contains classes and instances. Class is the primary sort level; all classes have at least one instance, and some classes have multiple instances. Settings classes and related instances for the SEL-487B are listed in *Table 4.5*.

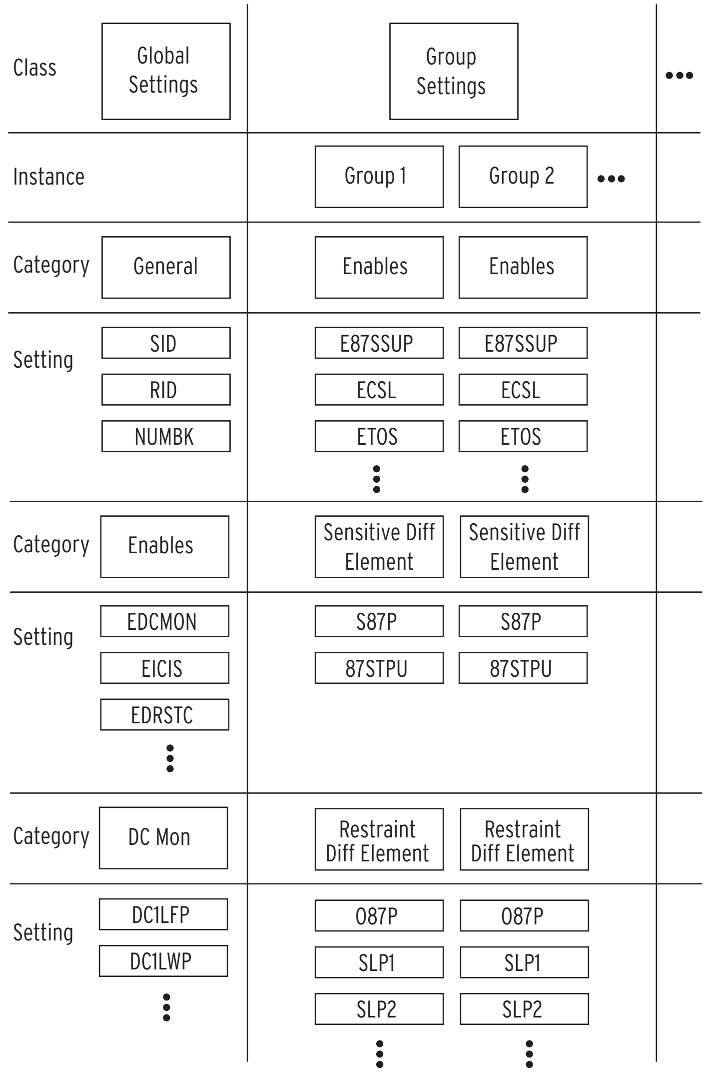

Figure 4.8 Relay Settings Structure Overview

Table 4.5 Settings Classes and Instances (Sheet 1 of 3)

Class	Description	Instance	Description	ASCII Command
Global	Relay-wide applications settings	Global		**SET G**
Group	Individual scheme settings	Group 1 • • • Group 6	Group 1 settings • • • Group 6 settings	**SET 1, SET S 1** • • • **SET 6, SET S 6**

Table 4.5 Settings Classes and Instances (Sheet 2 of 3)

Class	Description	Instance	Description	ASCII Command
Port	Communications port settings	Port F	Front-panel port	**SET P F**
		Port 1	Port 1 settings	**SET P 1**
		• • •	• • •	• • •
		Port 3	Port 3 settings	**SET P 3**
		Port 5	Communications card settings	**SET P 5**
Report	Event report and SER[a] settings	Report		**SET R**
Front Panel	Front-panel HMI settings	Front Panel		**SET F**
Protection SELOGIC control equations	Protection-related SELOGIC control equations	Group 1	Group 1 protection SELOGIC control equations	**SET L 1**
		• • •	• • •	• • •
		Group 6	Group 6 protection SELOGIC control equations	**SET L 6**
Automation SELOGIC control equations	Automation-related SELOGIC control equations	Block 1	Block 1 automation SELOGIC control equations	**SET A 1**
		• • •	• • •	• • •
		Block 10	Block 10 automation SELOGIC control equations	**SET A 10**
DNP	Distributed Network Protocol data remapping	DNP		**SET D**

Table 4.5 Settings Classes and Instances (Sheet 3 of 3)

Class	Description	Instance	Description	ASCII Command
Alias	Set aliases	Analog or digital quantities		**SET T**
Zone configuration	Terminal and Bus-zone to Bus-zone connections	Group 1 • • • Group 6	Group 1 zone configuration settings • • • Group 6 zone configuration settings	**SET Z 1** • • • **SET Z 6**
Output SELOGIC control equations	Relay control output settings and MIRRORED BITS communication transmit equations	Output		**SET O**

[a] SER is the Sequential Events Recorder; see SER (Sequential Events Recorder) on page A.3.31.

Note that some settings classes have only one instance and you do not specify the instance designator when accessing these classes. An example is the Global settings class. You can view or modify Global settings with a communications terminal by entering **SET G** as shown in the ASCII Command column of *Table 4.5*. The relay presents the Global settings categories at the **SET G** command; no instance numbers follow **SET G**. Conversely, the Port settings command has five instances (Port F, Port 1, Port 2, Port 3, and Port 5). To access the Port 1 settings, you must type **SET P 1 <Enter>**. If you do not specify which port to set, the relay defaults to the active port (the port you are presently using).

The Group settings can have the optional one-letter acronym S attached to the command; you can enter **SET 1** or **SET S 1** for Group 1 settings, **SET 2** or **SET S 2** for Group 2 settings, etc. If you do not specify which group to set, the relay defaults to the present active group. If Group 6 is the active group, and you type **SET <Enter>**, for example, you will see the settings prompts for the Group 6 settings.

Settings: Computer Terminal

When you change settings (with any **SET** command) from a terminal, the relay shows the setting category, prompt, present value, and prompt. *Figure 4.9* shows two settings examples: multiple-line settings (SID and RID) and an in-line setting (NUMBK) for relay Global settings from Access Level P (protection). The relay prompts you for input by presenting a prompt. You have many options for navigating the settings at the ? prompt. *Table 4.6* lists the operations possible from a settings prompt.

```
P=>SET G <Enter>
Global

General Global Settings  ---------------------------  Category

Station Identifier (40 characters) -----------------  Prompt
SID := "Station A" ---------------------------------  Present Value
?<Enter> -------------------------------------------  Prompt
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>                   ┌------------------------  Settings Prompt
Number of Breakers (N, 1-18)     NUMBK   := 5 ? ----  Prompt
                                          └---------  Present Value
=>
```

Figure 4.9 Components of SET Commands

Table 4.6 Actions at Settings Prompts

Action	Relay Response
<Enter>	Accept setting and move to the next setting; if at the last setting, exit settings.
[value] <Enter>	Enter the given value and move to the next setting if valid; if at the last setting, exit settings.
^ <Enter>	Move to the previous setting; if at the top of settings, stay at the present setting.
< <Enter>	Move to the top of the previous settings category; if at the top of settings, stay at the present setting.
> <Enter>	Move to the top of the next settings category; if in the last category, exit settings.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the "Save settings (Y, N) ?" prompt.
<Ctrl+X>	Abort editing session without saving changes.

When you exit settings entry from the **SET** commands, the relay responds:

```
Save settings (Y,N) ?
```

If you answer **Y <Enter>** (Yes), the relay writes the new settings to nonvolatile storage. If you answer **N <Enter>** (No), the relay discards any settings changes you have made.

Making Settings Changes: Initial Global Settings

The procedure in the following steps assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords. See *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords.

This example jumps to a Global setting that is not at the beginning of the Global settings list. Enter **SET G**, the setting name, and **<Enter>**. To start at the beginning of the Global settings, simply type **SET G <Enter>** without a settings name.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** using a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Type **SET G NFREQ <Enter>** to set the nominal system frequency.

The NFREQ setting has options of 50 Hz and 60 Hz.

The relay responds with a terminal screen display similar to the beginning of *Figure 4.10*.

```
=>>SET G NFREQ <Enter>

Global

General Global Settings

Nominal System Frequency (50,60 Hz)                NFREQ   := 60     ?<Enter>
Date Format (MDY,YMD,DMY)                          DATE_F  := MDY    ?YMD <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                   EDCMON  := N      ?END <Enter>
Global

General Global Settings

SID     := "Station A"
RID     := "Relay 1"
NUMBK   := 5        NUMDS   := N        NFREQ   := 60       DATE_F  := YMD

Global Enables

EDCMON  := N        EICIS   := N        EDRSTC  := N

Control Inputs (Global)

GINPU   := 0.17     GINDO   := 0.17

Settings Group Selection

SS1     := NA
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 4.10 Initial Global Settings

Vertical dots represent the relay information during readback.

Step 3. For a 60 Hz system, press **<Enter>** to accept the NFREQ existing value of 60 (Hz).

The relay presents the next setting, DATE_F (date).

Step 4. Set the date format.

The SEL-487B reports dates in three formats: MDY, YMD, and DMY (where M = month, D = date, and Y = year).

a. Type **YMD <Enter>**.

At each setting in turn, the relay presents the settings prompt, name, present value, and prompt.

b. Type **^ <Enter>** if you make a mistake or want to go backward through the settings.

Refer to *Table 4.6* for this and other navigational aids.

Step 5. End the settings session.

a. Type **END <Enter>** at the `EDCMON` prompt.

The EDCMON remains unchanged. The relay next scrolls a readback of all the Global settings, eventually displaying:

```
Save settings (Y, N) ?
```

b. Examine the settings readback to verify your new settings.

c. Type **Y <Enter>** to save your new settings.

Text-Edit Mode Line Editing

Some SEL-487B settings present multiple input lines to your terminal; you use basic line text editing commands to construct the setting. For display, the relay references each line of the setting by line number, not by the setting name. See *Making Text-Edit Mode Settings Changes* for an example of a text-edit mode setting.

While in the text-edit mode, you see a prompt consisting of the line number and the present setting for that line. You can keep the setting, enter a new setting, or delete the setting. *Table 4.7* lists the commands for text-edit mode.

Table 4.7 Actions at Text-Edit Mode Prompts

Action	Relay Response
<Enter>	Accept the setting and move to the next line; if at the last line or at a blank line, exit settings.
>*n* <Enter>	Move to line *n*. If this is beyond the end of the list, move to a blank line following the last line.
^ <Enter>	Move to the previous line; if at the first line, stay at the present line.
< <Enter>	Move to the first line.
> <Enter>	Move to a blank line following the last line.
LIST <Enter>	List all settings and return to the present prompt.
DELETE *n* <Enter>	Delete the present line and subsequent lines for a total of *n* lines; *n* = 1 if not provided. Lines after deletion shift upward by the number of lines deleted.
INSERT <Enter>	Insert a blank line at the present location; the present line and subsequent lines shift down.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the save settings prompt.
<Ctrl+X>	Abort editing session without saving changes.

Use commas to separate the items in a text-edit mode setting when you are entering multiple items per line. After you enter each line, the relay checks the validity of the setting. If the entered setting is invalid, the relay responds with an error message and prompts you again for the setting.

Making Text-Edit Mode Settings Changes

The procedure in the following steps familiarizes you with basic text-edit mode line editing. For this example, we use inputs IN106 and Remote Bit RB01. You can use other inputs for your particular application. See *Control Inputs on page U.2.8* for more information on control inputs.

This procedure assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords; see *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the `=>` prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the `=>>` prompt.

Step 2. Access the display point settings.

a. Type **SET F <Enter>** to modify the front-panel settings.

b. Type **> <Enter>** repeatedly to advance through the front-panel settings until you reach the Display Points category.

Figure 4.11 shows a representative terminal screen. The relay displays the first line that you can edit.

Step 3. Set Display Point 1.

a. Type **IN106,"Terminal 1",Closed,Open <Enter>** at the Line 1 `?` settings prompt to create Display Point 1.

The relay verifies that this is a valid entry, then responds with the next line prompt `2:` followed by the `?` settings prompt (see *Figure 4.11*).

Step 4. Set Display Point 2.

a. Type **RB01,"Message",Received <Enter>** at the Line 2 `?` settings prompt, to create Display Point 2.

The relay verifies that this is a valid entry, then responds with the next line prompt `3:` followed by the `?` settings prompt (see *Figure 4.11*.)

Step 5. List active display points.

At the Display Points, use the text-edit mode line editing commands to list the active display points.

a. Type **LIST <Enter>**.

After showing the active display points, the relay returns you to line `3:` followed by the `?` settings prompt.

Step 6. End the settings session.

a. Type **END <Enter>**.

The relay scrolls a readback of all the Front-Panel settings, eventually displaying the `Save settings (Y, N) ?` prompt. At the end of the readback information, just before the `Save settings (Y, N) ?` prompt, you can verify the new display point information.

b. Type **Y <Enter>** to save the new settings.

```
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)       FP_TO   := 15     ?<Enter>

Selectable Screens for the Front Panel

Station Battery Screen (Y,N)                        STA_BAT := N      ?<Enter>

Display Points
(Boolean): RWB Name,"Label","Set String","Clear String","Text Size"
(Analog): Analog Quantity Name,"User Text and Formatting","Text Size"

1:
?  IN106,"Terminal 1",Closed,Open <Enter>
2:
?  RB01,"Message",Received <Enter>
3:
?  LIST <Enter>

1: IN106,"Terminal 1","Closed","Open",S
2: RB01,"Message","Received",S
3:
?  END <Enter>
Front Panel

Front Panel Settings
.
.
.

Display Points
(Boolean): RWB Name,"Label","Set String","Clear String","Text Size"
(Analog): Analog Quantity Name,"User Text and Formatting","Text Size"

1: IN106,"Terminal 1","Closed","Open",S
2: RB01,"Message","Received",S

Local Control
(Local Bit, Local Name, Local Set State, Local Clear State, Pulse Enable)

1: LB01,"F1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
2: LB02,"F2 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
3: LB03,"F3 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
4: LB04,"T1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
5: LB05,"TB OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.11 Using Text-Edit Mode Line Editing to Set Display Points

The three dotted lines below the Front Panel Settings represent the readback.

This procedure proposes connecting circuit breaker auxiliary contacts from Terminal 1 to input contact IN106 of the main board. In the **SET G** (GLOBAL) command, verify that the debounce time (setting IN106PU and IN106DO) are correct for the circuit breaker auxiliary contact. To enter separate input debounce values, first enable the independent control input settings with setting EICIS. To change the input debounce time, enter these settings:

EICIS := **Y** Independent Control Input Settings (Y, N)

Press the **<Enter>** key repeatedly until you get to the IN106PU setting:

IN106PU := **0.2** Input IN106 De-bounce Pickup Time (0.00–1.00 cycles)

IN106DO := **0.2** Input IN106 De-bounce Dropout Time (0.00–1.00 cycles)

Use the appropriate interface hardware to connect the circuit breaker auxiliary contact to IN106 of the main board. See *Control Inputs on page U.2.8* for more information on SEL-487B control inputs.

Deleting a Display Point

This example shows how you can delete a previously used display point. In the **SET F** command, at the Display Points prompt, use the text-edit mode line editing commands to set and delete the display points. This procedure shows two previously programmed display points that indicate on the front-panel LCD the status of Terminal 1 and Remote Bit 1. Relay control input IN106 is the Relay Word bit for Terminal 1 display point (see *Making Text-Edit Mode Settings Changes on page U.4.19*). You can use other inputs for your particular application. See *Control Inputs on page U.2.8* for more information on control inputs.

The procedure in the following steps assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords. See *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Access the Display Points prompt.

a. Type **SET F <Enter>**.

b. Type **> <Enter>** repeatedly to advance through the front-panel settings until you reach the Display Points category.

Figure 4.12 shows a representative terminal screen. The relay displays the first line that you can edit.

```
=>>SET F <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)       FP_TO   := 15     ?> <Enter>

Selectable Screens for the Front Panel

Station Battery Screen (Y,N)                        STA_BAT := N      ?> <Enter>

Display Points
(Boolean): RWB Name,"Label","Set String","Clear String","Text Size"
(Analog): Analog Quantity Name,"User Text and Formatting","Text Size"

1: IN106,"Terminal 1","Closed","Open",S
?  LIST <Enter>

1: IN106,"Terminal 1","Closed","Open",S
2: RB01,"Message","Received",S

1: IN106,"Terminal 1","Closed","Open",S
?  <Enter>
2: RB01,"Message","Received",S
?  DELETE <Enter>
2:
?  LIST <Enter>

1: IN106,"Terminal 1","Closed","Open",S
2:

?  END <Enter>

Front Panel

Front Panel Settings

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 4.12 Using Text-Edit Mode Line Editing to Delete a Display Point
A vertical ellipsis represents this scrolling readback.

Step 3. Type **LIST <Enter>** at the ? prompt to list the present display points.

After showing the active display points, the relay returns you to line 1: followed by the ? settings prompt.

Step 4. Type **<Enter>** once to proceed to the line 2 present value and ? settings prompt.

Step 5. Type **DELETE <Enter>** to Delete Display Point 2.

Step 6. Type **LIST <Enter>** to examine the remaining display points.

Former Display Point 2 is eliminated. The relay returns you to line 2: followed by the ? settings prompt.

Step 7. Type **END <Enter>** to end the settings process.

The relay next scrolls a readback of all the front-panel settings, eventually displaying the Save settings (Y, N) ? prompt.

At the end of the readback information, just before the Save settings (Y, N) ? prompt, you can verify the new display point information.

Step 8. Type **Y <Enter>** to save your new settings.

Alias Settings

Rename, or assign up to 200 alias names to any Relay Word bit or analog quantity in the relay. This is very useful when programming using SELOGIC® control equations or analyzing SER and event report data. Assigning alias names is also a text-edit type entry, with the same syntax as the display point entries.

Use the **SHO T** command to view the default settings, as shown in *Figure 4.13*.

```
=>>SHO T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])


1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
9: FBF01,"F1_BF"
10: FBF02,"F2_BF"
11: FBF03,"F3_BF"
12: FBF04,"T1_BF"
13: FBF05,"TB1_BF"
14: FBF06,"TB2_BF"
15: 87Z1,"Z1_TRIP"
16: 87Z2,"Z2_TRIP"
17: IN101,"F1_BFI"
18: IN102,"F2_BFI"
19: IN103,"F3_BFI"
20: IN104,"T1_BFI"
21: IN105,"TB_BFI"
22: PLT01,"DIFF_EN"
23: PLT02,"BF_EN"
24: PLT03,"TNS_SW"
25: 87ST1,"CTZ1_AN"
26: 87ST2,"CTZ2_AN"
27: SBFTR01,"F1_BFT"
28: SBFTR02,"F2_BFT"
29: SBFTR03,"F3_BFT"
30: SBFTR04,"T1_BFT"
31: SBFTR05,"TB1_BFT"
32: SBFTR06,"TB2_BFT"
33: 87BTR01,"F1_DPT"
34: 87BTR02,"F2_DPT"
35: 87BTR03,"F3_DPT"
36: 87BTR04,"T1_DPT"
37: 87BTR05,"TB1_DPT"
38: 87BTR06,"TB2_DPT"
39: OUT101,"F1_TRIP"
40: OUT102,"F2_TRIP"
41: OUT103,"F3_TRIP"
42: OUT104,"T1_TRIP"
43: OUT105,"TB_TRIP"
44: OUT107,"TEST"
45: OUT108,"ALARM"
46: TLED_1,"87_DIFF"
47: TLED_2,"BK_FAIL"
48: TLED_3,"ZONE_1"
49: TLED_4,"ZONE_2"
50: TLED_5,"ZONE_3"
51: TLED_6,"ZONE_4"
52: TLED_7,"ZONE_5"
53: TLED_8,"ZONE_6"
54: TLED_9,"50_TRIP"
55: TLED_10,"51_TRIP"
56: TLED_11,"CT_ALRM"
57: TLED_12,"87_BLK"
58: TLED_13,"TOS"
59: TLED_14,"89_OIP"
60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"
62: TLED_17,"27_LED"
63: TLED_18,"59_LED"
64: TLED_19,"V01_ON"
```

```
65: TLED_20,"V02_ON"
66: TLED_21,"V03_ON"
67: TLED_22,"FLT_LED"
68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"

=>>
```

Figure 4.13 Default Alias Settings

Making Text-Edit Mode Alias Changes

Assign the alias name THETA to math variable PMV01 and the alias TAN to math variable PMV02. These variables are then used in calculating the tangent of theta, using their alias names in the equation.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Type **SET T <Enter>** to access the alias settings.

Figure 4.14 shows a representative computer terminal screen.

Step 3. Type **> <Enter>** for the relay to display the first line that you can edit.

Step 4. Type **PMV01,THETA <Enter>** at the Line 60 ? settings prompt to set the alias for PMV01.

The relay verifies that this is a valid entry, then responds with the next line prompt 61: followed by the ? settings prompt.

Step 5. Type **PMV02,TAN <Enter>** at the Line 61 ? settings prompt to set the alias for PMV02.

The relay verifies that this is a valid entry, then responds with the next line prompt 62: followed by the ? settings prompt.

Step 6. Type **END <Enter>** to end the settings session.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y, N) ?` prompt. At the end of the readback information, just before the `Save settings (Y, N) ?` prompt, you can verify the new display point information.

Step 7. Type **Y <Enter>** to save the new settings.

```
=>>SET T <Enter>

Alias

Relay Aliases
(RW Bit, Analog Qty., Terminal, Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: IO1,"FDR_1"
?  > <Enter>
62:
?  PMV01,THETA <Enter>
63:
?  PMV02,TAN <Enter>

64:

?  END <Enter>

Alias

Relay Aliases
(RW Bit, Analog Qty., Terminal, Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: IO1,"FDR_1"
.
.
.

62: PMV01,"THETA"
63: PMV02,"TAN"

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.14 Using Text-Edit Mode Line Editing to Set Aliases
Three dotted lines below IO1 represent the readback.

Use the alias names, instead of the Relay Word bits, in SELOGIC control equation programming. *Figure 4.15* shows an example of an alias used in protection logic programming.

```
=>>SET L <Enter>

Protection 1

1: PLT01S := PCT02Q AND NOT DIFF_EN # DIFFERENTIAL ENABLED
?  > <Enter>
15:
?  THETA:=IO1FA <Enter>
16:
?  TAN:=SIN(THETA)/COS(THETA) <Enter>
17:
?  END <Enter>
Protection 1
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.15 Using Text-Edit Mode Line Editing to Set Protection Logic

Settings: Front Panel

You can use the relay front panel to enter some of the relay settings. The SEL-487B presents the settings in order from class to instance (if applicable) to category to the particular setting, in a manner similar to setting the relay using a terminal. Use the LCD and the adjacent navigation pushbuttons to enter each character of the setting in sequence.

Entering DATE and TIME From the Front Panel

The purpose of the procedure in the following steps is to familiarize you with entering data from the SEL-487B front panel. Refer to *Connecting and Applying Power on page U.4.3* before performing this example.

Step 1. Apply power to the relay.

Note that the relay front-panel display shows a sequence of LCD screens called the ROTATING DISPLAY. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **{ENT}** pushbutton to display the MAIN MENU as shown in *Figure 4.16*.

Step 3. View settings screens.

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the SET/SHOW action item (see *Figure 4.16*).

b. Press the **{ENT}** pushbutton.

You will see the SET/SHOW submenu.

Step 4. View the date/time screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the DATE/TIME action item.

b. Press the **{ENT}** pushbutton.

The relay next displays the DATE/TIME submenu.

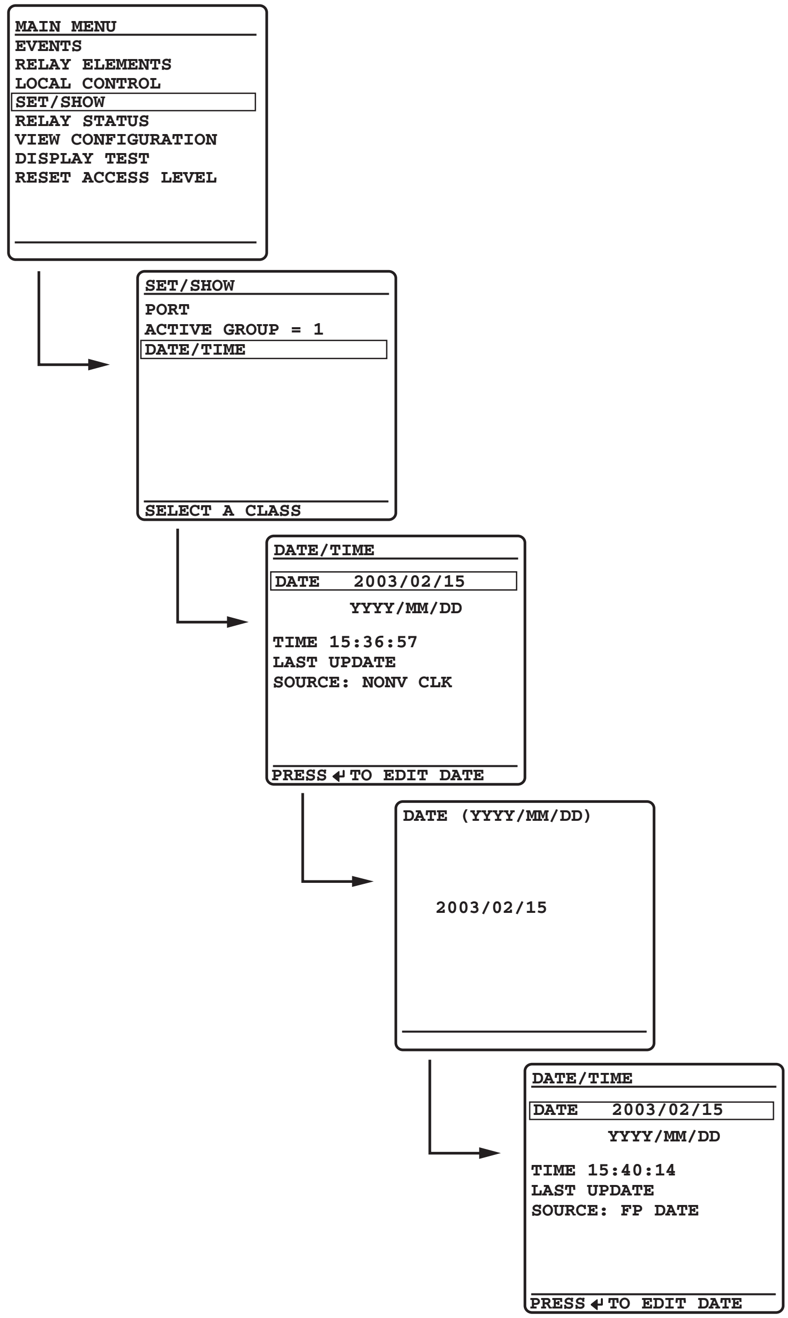

Figure 4.16 DATE and TIME Settings: Front-Panel LCD

Step 5. Set the date.

a. Press the **{ENT}** pushbutton.

The relay shows the second last screen of *Figure 4.16*, the `DATE` edit screen.

b. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to increase and decrease the date position numbers.

c. Move to the next or previous position by using the **{Left Arrow}** and **{Right Arrow}** pushbuttons.

d. When finished adjusting the new date, press **{ENT}**.

The relay returns the display to the DATE/TIME submenu. Note that the relay reports the TIME SOURCE as FP DATE (front-panel date).

Step 6. Press **{ESC}** repeatedly to normalize the front-panel display.

Changing a Relay Setting From the Front Panel

The purpose of the procedure in the following steps is to provide additional practice at entering relay settings from the front panel. In this example, you change the **PORT F** front-panel communications port settings.

Step 1. View the MAIN MENU.

➤ If you have been using the front panel (as in the previous example), press the **{ESC}** key repeatedly until you see the MAIN MENU.

➤ If the relay is displaying the ROTATING DISPLAY, press the **{ENT}** pushbutton to display the MAIN MENU.

The first screen of *Figure 4.17* shows the MAIN MENU.

Step 2. View the settings screens.

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the SET/SHOW action item (see *Figure 4.17*).

b. Press the **{ENT}** pushbutton.

You will see the SET/SHOW submenu (the second screen in *Figure 4.17*).

c. Press the **{ENT}** pushbutton.

Step 3. Select Port F.

a. Highlight Port and press the **{ENT}** pushbutton.

Next, the relay displays the Port instances (the third screen of *Figure 4.17*).

b. Move the screen arrow **{Up Arrow}** and **{Down Arrow}** pushbuttons to choose the port you want to configure.

For this example, select Port F and press **{ENT}**.

Step 4. View the Communications Settings category screen.

The relay shows the Port F category screen (the fourth screen of *Figure 4.17*).

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the Communications Settings settings category.

b. Press **{ENT}**.

The relay displays the Communications Settings screen (the fifth screen of *Figure 4.17*).

NOTE: Once you have changed communications parameters, you must change the corresponding parameters in your terminal emulation program to communicate with the relay via a communications port.

Step 5. Change settings.

a. Highlight the SPEED setting.

b. Press **{ENT}**.

(The relay possibly requires a password here; see *Passwords on page U.4.8* and *Section 5: Front-Panel Operations*.)

The LCD displays the SPEED selection submenu that has all the possible choices for serial data speeds.

The highlight in the sixth screen of *Figure 4.17* indicates the default setting of 9600 (bps).

c. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to select a different speed.

d. Press the **{ENT}** pushbutton once you have selected a data speed.

Step 6. End the settings session.

The relay returns to the previous category settings list screen.

a. Press **{ESC}** to return to the categories screen where you see the Save Settings ? prompt.

b. Press **{ENT}** to save the settings.

The relay validates the setting and returns you to the Port screen (the third screen of *Figure 4.17*).

Step 7. Press **{ESC}** repeatedly to return to the MAIN MENU.

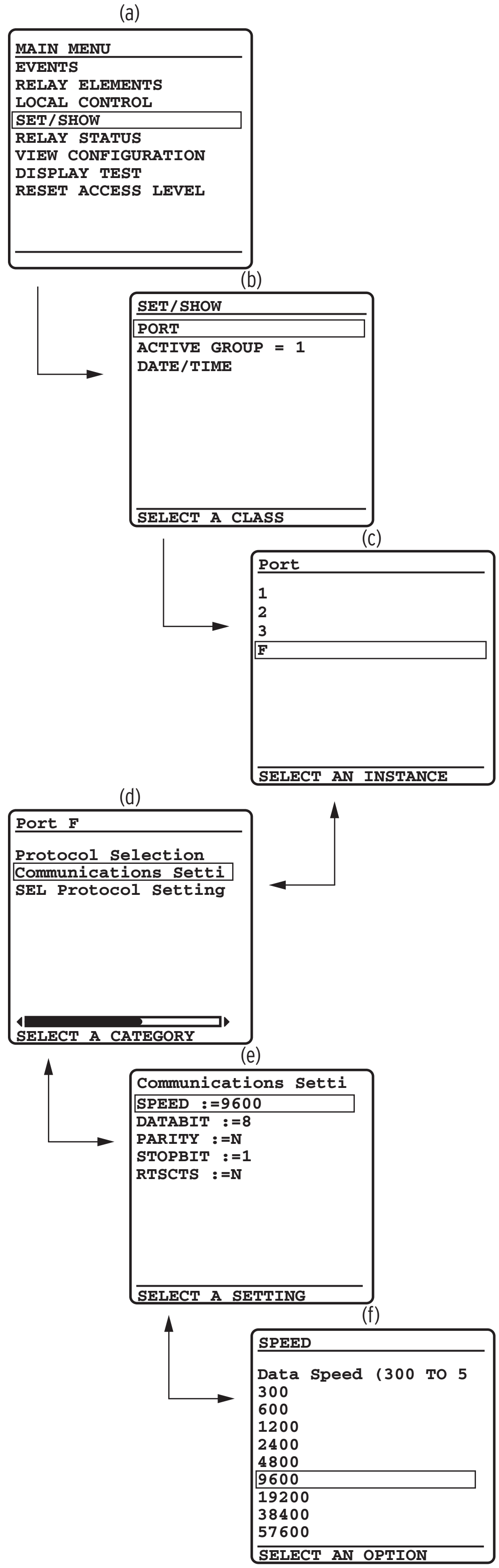

Figure 4.17 Changing a Setting From the Front Panel

Examining Metering Quantities

You can view the SEL-487B metering quantities by using a communications terminal, the ACSELERATOR software, or the front panel. For more information on SEL-487B metering, see *Metering on page A.2.7*.

View Metering: Terminal

The procedure in the following steps shows how to use a computer terminal or computer terminal emulation computer program to view power system metering. In this example, you connect specific voltages and currents for a 5 A, 60 Hz relay. Scale these quantities appropriately for your particular relay. For more information on testing the relay and making test connections, see *Section 6: Testing and Troubleshooting*.

This example assumes that you have successfully established communication with the relay, and that three voltage sources and three current sources are available. In addition, you must be familiar with relay access levels and passwords. See *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Confirm the default CT and PT ratios.

a. Type **SHO Z <Enter>** at the terminal to confirm the Group 1 PTR and CTR settings.

Figure 4.18 shows an extract of the result.

```
=>>SHO Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

PTR1    := 2000     PTR2    := 2000     PTR3    := 2000

Current Transformer Ratio

CTR01   := 600      CTR02   := 600      CTR03   := 600      CTR04   := 600
CTR05   := 600      CTR06   := 600      CTR07   := 600      CTR08   := 600
CTR09   := 600      CTR10   := 600      CTR11   := 600      CTR12   := 600
CTR13   := 600      CTR14   := 600      CTR15   := 600      CTR16   := 600
CTR17   := 600      CTR18   := 600

Zone Configuration: Terminal to Bus-Zone Connections
.
.
.

Current Normalization Factor

TAP01   := 5.00     TAP02   := 5.00     TAP03   := 5.00     TAP04   := 5.00
TAP05   := 5.00     TAP06   := 5.00

=>>
```

Figure 4.18 Confirm Settings With the SHO Z Command

Step 3. Turn relay power off.

Step 4. Connect analog inputs as shown in *Figure 4.19*.

a. Apply 67 V per phase (line-to-neutral) in ABC phase rotation.

b. Insert quantities as shown in *Table 4.8*.

Table 4.8 Quantities for Secondary Injection

Phase	Quantity
IA	2∠0°
IB	2∠–120°
IC	2∠120°
VA	67∠0°
VB	67∠–120°
VC	67∠120°

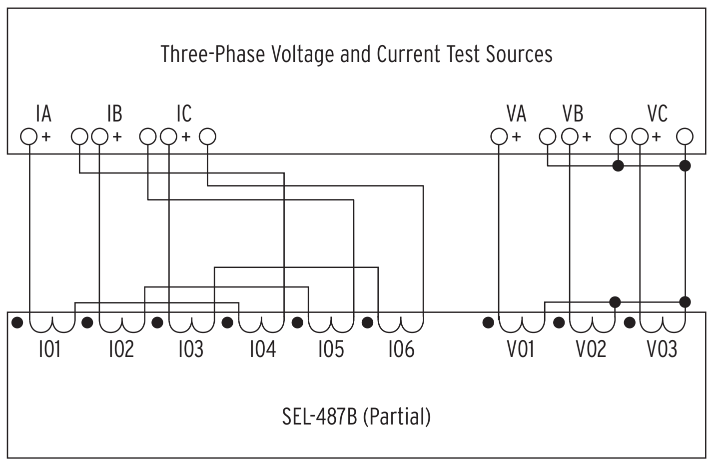

Figure 4.19 Test Connections Using Three Voltage Sources/Three Current Sources

Step 5. Turn relay power on.

Step 6. View metering.

a. Type **ACC <Enter>** to log in to relay Access Level 1.

b. Type your password and press **<Enter>**.

c. Type **MET <Enter>**.

The relay displays the fundamental frequency primary metering information in a manner similar to that shown in *Figure 4.20*.

```
==>>MET <Enter>
Relay 1                                     Date: 05/08/2003  Time: 14:45:57.186
Station A                                   Serial Number: 2003000208

       Primary Currents
Terminal    MAG(A)   ANG(DEG)          Terminal    MAG(A)   ANG(DEG)
 FDR_1     1197.502     0.00            I10         0.000   -69.88
 FDR_2     1197.502  -120.00            I11         0.000   -66.94
 FDR_3     1197.502   120.00            I12         0.000   -69.24
 TRFR_1    1197.502     0.00            I13         0.000   -65.57
 TB_1      1197.502  -120.00            I14         0.000   -66.29
 TB_2      1197.502   120.00            I15         0.000   104.11
 I07          0.000   114.52            I16         0.000   -68.26
 I08          0.000   113.08            I17         0.000   -65.91
 I09          0.000   115.07            I18         0.000   111.67

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        133.991     0.00
 V02        133.991  -120.00
 V03        133.991   120.00

==>>
```

Figure 4.20 Terminal Screen MET Metering Quantities

The metering quantities of *Figure 4.20* are the fundamental primary quantities. Other variants of the **MET** command give different relay metering quantities. See *Metering on page A.2.7* and *METER on page R.7.22* for more information on the **MET** command.

View Metering: Front Panel

View the metering quantities of the SEL-487B on the ROTATING DISPLAY screen of the front-panel display. Metering information available in the relay consists of the following screen(s):

- Station Battery Screen
- Fundamental Voltage and Current Screen
- Differential Metering Screen
- Terminals Associated with Zones Screen

By default, the Fundamental Voltage and Current Screen, Differential Metering Screen, and Terminals Associated with Zones Screen are enabled. To enable the Station Battery Screen, proceed with the following steps.

Step 1. Type **SET F <Enter>**.

Step 2. Type **> <Enter>**.

Step 3. Type **Y** at the prompt, as shown in *Figure 4.21*.

Step 4. Save the settings.

```
=>>SET F <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)        FP_TO   := 15      ?> <Enter>

Selectable Screens for the Front Panel

Station Battery Screen (Y,N)                         STA_BAT := N       ?Y <Enter>
Fundamental Voltage and Current Screen (Y,N)         FUND_VI := Y       ?END <Enter>
Front Panel
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.21 Steps to Enable the Station Battery Front-Panel Display Screen

After applying power to the relay, note that the LCD shows a sequence of screens called the ROTATING DISPLAY. The display shows the display points (if any) and the metering screen. To freeze any one of these screens, press either the {Up Arrow} or {Down Arrow} pushbutton. Further use of the {Up Arrow} and {Down Arrow} pushbuttons allows the viewing of the remaining screens on a per-screen basis.

Metering information is not available on the MAIN MENU screen, only on the ROTATING DISPLAY screen. If you are in the MAIN MENU or other submenus, press the {ESC} pushbutton repeatedly until you reach the ROTATING DISPLAY screen as shown in *Figure 4.22*.

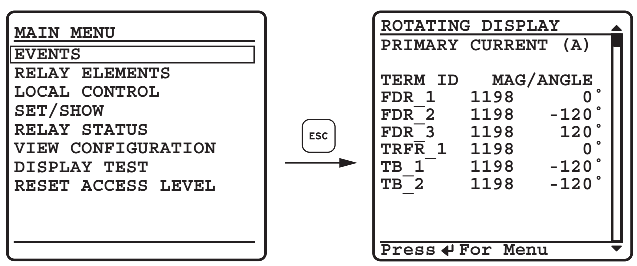

Figure 4.22 Press {ESC} to Go to the Rotating Display When in the Main Menu Display

Reading Event Reports and SER

The SEL-487B has great capabilities for storing and reporting power system events. These include oscillography with a sampling rate of 24 samples per power system cycle, event reports that encompass important variables in the power system, and the SER that reports changing power system conditions and relay operating states.

You can view event reports taken from instantaneous raw data or from filtered event report data. Each type of presentation gives you a unique view of the power system. Raw or unfiltered event reports are useful for viewing system transients and dc transients. Filtered event reports give you a picture of the quantities that the relay used in the protection algorithms.

The examples listed in this subsection give step-by-step procedures to acquaint you with these features. *Section 3: Analyzing Data in the Applications Handbook* gives a complete discussion of these relay features.

Generating an Event

To view raw data event reports, generate a relay event. All event reports use the same event triggering methods. The relay uses five event type sources to initiate a data capture, as shown in *Table 4.9*.

NOTE: 87BTR asserts when any one of Relay Word bits 87BTR01 through 87BTR18 asserts, SBFTR asserts when any one of Relay Word bits SBFTR01 through SBFTR18 asserts, and TRIP asserts when any one of Relay Word bits TRIP01 through TRIP18 asserts.

Table 4.9 The Five Event Type Sources That Initiate a Data Capture in the Relay

Event	Description
87BTR	Rising edge of Relay Word bit 87BTR on or after trigger
SBFTR	Rising edge of Relay Word bit SBFTR on or after trigger
TRIP	Rising edge of Relay Word bit TRIP on or after trigger
ER	Rising edge of ER, the event report trigger
TRI	Execution of the ASCII **TRIGGER** command

Triggering an Event

You can use an event trigger to initiate capturing power system data. The procedure in the following steps shows how to trigger an event capture with the **TRI** command. In this example, the relay uses default parameters to record the event. These parameters are at a pretrigger or prefault recording length (PRE) of 5 cycles and an event report length (LER) of 15 cycles.

This example assumes that you have successfully established communication with the relay. In addition, you should connect secondary test voltages and currents, and set the relay to meter these quantities correctly.

Step 1. Connect voltage and current sources to the relay secondary voltage and secondary current inputs using the connections shown in *View Metering: Terminal on page U.4.31* and *Figure 4.19* and the quantities in *Table 4.8*.

Step 2. Type **TRI <Enter>**.

The relay triggers and captures the power system data.

Reading the Event History

The SEL-487B has two convenient methods for checking whether you successfully captured power system data. You can view the event history data with the ACSELERATOR software, or you can examine internal relay file folders for the recorded data.

Reading the Event History: Terminal Emulation Software

The procedure in the following steps shows how to use the SEL-487B file structure to confirm that you captured power system data with an event trigger. This example assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

Step 2. Type **HIS <Enter>** to display the event history.

You will see a screen display similar to *Figure 4.23*.

```
=>>HIS <Enter>

Relay 1                                     Date: 02/19/2003  Time: 12:03:49.988
Station A                                   Serial Number: 0000000001

#       DATE        TIME      EVENT  GRP  TARGETS
10000 02/19/2003 11:45:17.256  TRIG    1

=>>
```

Figure 4.23 Sample HIS Command Output: Terminal Emulation Software

For more information on event history, see *Event History on page A.3.27*.

Viewing Event Report Data

The relay stores filtered and unfiltered event reports. Examine either filtered or unfiltered relay event reports to inspect the quantities used when the SEL-487B triggered an event. For more information on event reports, see *Event Report on page A.3.6*. *Table 4.10* shows the types of event report files available in the relay.

Table 4.10 Types of Event Report Files Available in the Relay

Event File Types	Description
E4_10000.TXT	4-sample/cycle filtered ASCII event report
E1210000.TXT	12-sample/cycle filtered ASCII event report
E2410000.TXT	24-sample/cycle raw ASCII event report
D1210000.TXT	12-sample/cycle ASCII differential element report
C1210000.TXT	12-sample/cycle filtered Compressed ASCII event report
C2410000.TXT	24-sample/cycle raw Compressed ASCII event report
Z2410000.TXT	Combination of C2410000.TXT and D1210000.TXT event reports

Retrieving Event Report Data Files: Terminal Emulation Software

NOTE: See FTP Session on page A.5.11 for more information on file retrieval using the Ethernet card.

The relay records the event triggered in *Triggering an Event on page U.4.35* in the EVENTS directory. Follow the procedure in the following steps to retrieve the event report data files for this event. Perform the steps listed in *Triggering an Event* before executing the instructions in this example. For this procedure, use a terminal program capable of Ymodem protocol file transfer.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

Step 2. Type **FILE DIR EVENTS <Enter>** to view the events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 4.24*.

```
=>>FILE DIR EVENTS <Enter>
C1210000.TXT                R   03/05/2003 10:37:23
C2410000.TXT                R   03/05/2003 10:37:23
CHISTORY.TXT                R
D1210000.TXT                R   03/05/2003 10:37:23
E1210000.TXT                R   03/05/2003 10:37:23
E2410000.TXT                R   03/05/2003 10:37:23
E4_10000.TXT                R   03/05/2003 10:37:23
HISTORY.TXT                 R
Z2410000.TXT                R   03/05/2003 10:37:23

=>>
```

Figure 4.24 Sample FILE DIR EVENTS Display

Step 3. Type **FILE READ EVENTS C1210000.TXT <Enter>** to transfer the Compressed ASCII event report file to your computer.

Step 4. Download the file.

Perform the steps necessary for your terminal emulation program to receive a file. The steps below are typical file transfer steps:

a. Specify the destination file location in your computer file storage system and file name.

b. Select the transfer type as Ymodem (if not already enabled).

c. Click on Receive. You will usually see a confirmation message when the file transfer is complete.

When this file has transferred successfully, use the SEL-5030 Analytic Assistant to play back the event report oscillograms of the 12-samples/cycle event report file you just transferred.

Viewing SER Records

The relay SER records relay operating changes and relay element states. In response to an element change of state, the SER logs the element, the element state, and a time stamp. Program the relay elements that the relay stores in the SER records, thus capturing significant system events such as an input/output change of state, element pick up/drop out, etc. The SEL-487B stores the latest 1000 entries to a nonvolatile record. Use the relay communications ports or the ACSELERATOR software to view the SER records. For more information on the SER, see *Section 3: Analyzing Data in the Applications Handbook*. The latest 200 SER events are viewable from the front panel. For more information, see *Section 5: Front-Panel Operations in the User's Guide*.

Setting and Examining the SER Record: Terminal Emulation Software

The procedure in the following steps shows how to use a terminal connected to an SEL-487B communications port to set an element in the SER. Use text-edit mode line editing to enter the SER settings; see *Text-Edit Mode Line Editing on page U.4.18*. Also included is a procedure for viewing the SER report with a terminal. For more information on the SER, see *SER (Sequential Events Recorder) on page A.3.31*.

This example assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Enter SER trigger data.

a. Type **SET R <Enter>** to access the Report settings (see *Figure 4.25*).

b. Type **<Enter>** to move past the SER Chatter Criteria setting.

c. At the SER Points prompt line, type **TRGTR,"TARGET RESET PB",TEST,OFF <Enter>**.

d. At the next line, type **END <Enter>**.

e. Type **Y <Enter>** when the relay prompts you to save the new setting.

Figure 4.25 shows the steps to set an SER monitoring point.

```
=>>SET R <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N      ?<Enter>

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)
1:
?   TRGTR,"TARGET RESET PB",TEST,OFF <Enter>
2:
?   END <Enter>
Report
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
```

Figure 4.25 Setting an SER Element: Terminal Emulation Software

Step 3. Press and release the front-panel {TARGET RESET} pushbutton to generate an SER record.

Step 4. Type **SER <Enter>** (at the Access Level 1 prompt or higher) to view the SER report.

The relay presents a screen similar to the SER display of *Figure 4.26*.

```
=>>SER <Enter>

Relay 1                                    Date: 07/24/2003  Time: 10:52:10.104
Station A                                  Serial Number: 2003000040

FID=SEL-487B-R102-V0-Z001001-D20030724

#      DATE        TIME          ELEMENT             STATE
5    03/05/2003  08:09:50.300   Power-up            Group 1
4    03/05/2003  08:09:50.300   Relay               Enabled
3    03/05/2003  08:20:54.006   Settings changed    Class R 1
2    03/05/2003  08:21:12.674   TARGET RESET PB     TEST
1    03/05/2003  08:21:13.695   TARGET RESET PB     OFF

=>>
```

Figure 4.26 Sample SER Report

Downloading an SER Report File

The procedure in the following steps shows you how to retrieve the SER report stored in the relay as a file. For this procedure you must use a computer terminal emulation program with file transfer capability. For more information on the SER, see *SER (Sequential Events Recorder) on page A.3.31*.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

Step 2. Type **FILE DIR REPORTS <Enter>** to view the events file directory.

The terminal lists the file names for standard reports as shown in *Figure 4.27*.

Step 3. Prepare the relay to download an SER report.

a. Type **FILE READ REPORTS SER.TXT <Enter>**.

b. If you want the Compressed ASCII file, type **FILE READ REPORTS CSER.TXT <Enter>**.

```
=>FILE DIR REPORTS <Enter>
CHISTORY.TXT                    R
CSER.TXT                        R
HISTORY.TXT                     R
SER.TXT                         R

=>
```

Figure 4.27 Reports File Structure

Step 4. Download the SER report.

Perform the steps necessary for your terminal emulation program to receive a file. Typically, these are the file transfer steps:

a. Specify the destination file location in your computer file storage system and file name.

b. Select the transfer type as Ymodem (if not already enabled).

c. Click on Receive.

You will usually see a confirmation message when the file transfer is complete.

NOTE: Transferring SER files (or CSER files) with the **FILE READ REPORTS SER.TXT** command, performs an **SER CV** command as part of the transfer. **SER CV** clears the SER information from the present port. With the SER information cleared, there is no data available for subsequent SER or CSER transfers from the same port.

Step 5. Use a word-processing program to view the contents of the file to confirm a successful download.

The CSER.TXT file viewed with a word-processing program is similar to the example in *CSER on page A.3.33*.

Operating the Relay Inputs and Outputs

The SEL-487B gives you great ability to perform control actions at terminal and substation locations via the relay control outputs. The control outputs open circuit breakers, switch disconnects, and operate auxiliary station equipment such as fans and lights. The relay reads data from the power system and interfaces with external signals (contact closures and data) through the control inputs. This subsection is an introduction to operating the SEL-487B control outputs and control inputs. For more information on connecting and applying the control outputs and control inputs, see *Section 2: Installation*.

Control Output

The SEL-487B features Standard and Hybrid (High-Speed, High-Current Interrupting) control outputs that you can use to control circuit breakers and other devices in an equipment bay or substation control house. See *Control Outputs on page U.2.9* for more information on control outputs.

Pulsing a Control Output: Terminal Emulation Software

NOTE: To **PULSE** an output, the circuit breaker control enable jumper, J18C, must be installed on the main board.

The procedure in the following steps shows how to use a communications terminal to pulse the control output contacts. Perform the steps in this example to become familiar with relay control and serial communication. For more information on the **PULSE** command, see *PULSE on page R.7.29*.

This example assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Prepare to control the relay at Access Level B.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **BAC <Enter>**.

d. Type the correct password to go to Access Level B.

You will see the ==> prompt.

Step 2. Attach an indicating device (ohmmeter with a beep sounder or a test set) to the terminals for control output OUT104 on the main board.

This output is a Standard control output and is not polarity sensitive. For more information on connecting control outputs, see *Control Outputs on page U.2.9*.

Step 3. Type **PULSE OUT104 <Enter>** to perform the pulse operation.

The relay confirms your request to pulse an output with a prompt such as that shown in *Figure 4.28*. Output OUT104 has been renamed with the alias name T1_TRIP, and the alias name appears in the prompt.

Step 4. Type **Y <Enter>** at the prompt.

You will see or hear the indicating device turn on for one second and then turn off.

You can also pulse an output for longer than the default one-second period.

If you enter a number after the **PULSE** command, that number specifies the duration in seconds for the pulse. For example, if you enter **PULSE OUT104 3 <Enter>**, the relay pulses OUT104 for three seconds.

```
==>PULSE OUT104 <Enter>
Pulse contact T1_TRP for 1 seconds (Y/N)? Y <Enter>

==>
```

Figure 4.28 Terminal Display for PULSE Command

Pulsing a Control Output: Front Panel

The procedure in the following steps shows you how to use the front-panel display and navigation pushbuttons to check for proper operation of the SEL-487B control outputs. See *Section 5: Front-Panel Operations* for information on using the relay front panel.

Step 1. Attach an indicating device (an ohmmeter with a beep sounder or a test set) to the terminals for control output OUT104 on the main board.

This output is a Standard control output and is not polarity sensitive. For more information on connecting control outputs, see *Control Outputs on page U.2.9*.

Step 2. Apply power to the relay.

Note that the LCD shows a sequence of screens called the ROTATING DISPLAY. (Also, if you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 3. Press the **{ENT}** pushbutton to view the MAIN MENU similar to the top screen in *Figure 4.29*.

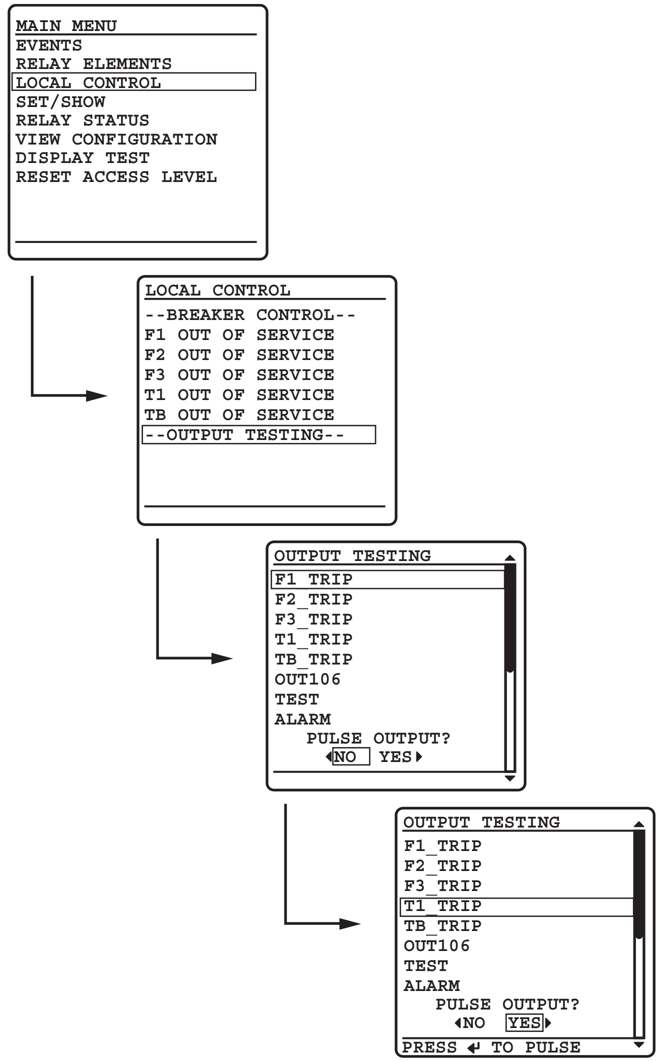

Figure 4.29 Front-Panel Menus for Pulsing T1_TRP

Step 4. View the local control screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the LOCAL CONTROL action item (see *Figure 4.29*).

b. Press the **{ENT}** pushbutton.

You will see the LOCAL CONTROL submenu.

Step 5. View the output testing screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the --OUTPUT TESTING-- action item.

b. Press the **{ENT}** pushbutton.

The relay next displays the OUTPUT TESTING submenu.

Step 6. Command the relay to pulse the control output.

a. Press the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight T1_TRIP (OUT104).

b. Press the **{Right Arrow}** pushbutton to highlight YES under PULSE OUTPUT?

c. Press the **{ENT}** pushbutton.

The relay detects your request for a function at an access level for which you do not yet have authorization. Whenever this condition occurs, the relay displays the password access screen of *Figure 4.30*.

```
Password Required
█
A B C D E F G H
I J K L M N O P
Q R S T U V W X
Y Z a b c d e f
g h i j k l m n
o p q r s t u v
w x y z 0 1 2 3
4 5 6 7 8 9 _ .
ACCEPT  BACKSPACE
```

Figure 4.30 Password Entry Screen

Step 7. Input a password and pulse the output.

a. Enter a valid Access Level B, P, A, O, or 2 password by using the navigation pushbuttons to select the alphanumeric characters that correspond to your password.

(The front panel is always at Access Level 1, so you do not enter the Access Level 1 password.)

b. Press the **{ENT}** pushbutton at each password character.

(If you make a mistake, highlight the BACKSPACE option and press **{ENT}** to reenter a character or characters.)

c. After entering all password characters, press the **{Up Arrow}** or **{Down Arrow}** pushbuttons to highlight ACCEPT.

d. Press **{ENT}**.

The relay pulses the output, and you will see the indicating device turn on for a second and then turn off.

Controlling a Relay Control Output With a Local Bit: Terminal

In this example, you set Local Bit 6 to start the transformer cooling fans of the transformer at the station. You can use the LCD screen and navigation pushbuttons to toggle relay Local Bit 6 to control the state of the cooling fans. Relay Word bit LB_SP06 provides supervision for Local Bit 6. Relay Word bit LB_SP06 must be asserted for successful Local Bit 6 operations. For more information on local bits, see *Local Control Bits on page U.5.22*.

The procedure in the following steps proposes connecting the transformer bank fan control to relay output OUT106 on the main board. You can choose any relay output that conforms to your requirements. See *Control Outputs on page U.2.9* for more information on SEL-487B control outputs.

This example assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>.**

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Access the local control settings.

a. Type **SET F <Enter>**.

b. Repeatedly type **> <Enter>** to advance through the front-panel settings until you reach the Display Points category.

c. Press **<Enter>** to access the Local Control Points Category.

Figure 4.31 shows a representative terminal screen.

```
=>>SET F <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)       FP_TO   := 15     ?> <Enter>

Selectable Screens for the Front Panel

Station Battery Screen (Y,N)                        STA_BAT := N      ?> <Enter>

Display Points
(Relay Word Bit, Display Name, Display Set State, Display Clear State)

1: <Enter>
?

Local Control
(Local Bit, Local Name, Local Set State, Local Clear State, Pulse Enable)

1: LB01,"TB1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  LIST <Enter>

1: LB01,"F1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
2: LB02,"F2 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
3: LB03,"F3 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
4: LB04,"T1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
5: LB05,"TB OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N

1: LB01,"TB1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N

?  > <Enter>
6:
?  LB06,"5 MVA XFMR FANS",ON,OFF <Enter>
7:
?  END <Enter>
Front Panel

Front Panel Settings

.
.
.
6: LB06,"5 MVA XFMR FANS","ON","OFF",N

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.31 Using Text-Edit Mode Line Editing to Set Local Bit 6

Step 3. Type **LIST <Enter>** at the Local Control prompt ? to list the active control points.

The relay displays the default settings.

Step 4. Type **> <Enter>** to move to the end of the list.

Step 5. Type **LB06,"5 MVA XFMR FANS",ON,OFF <Enter>** at the line 6 prompt to assign Local Bit 6.

The relay checks that this is a valid entry and responds with the next line prompt `7:` followed by the `?` settings prompt.

Step 6. Type **END <Enter>** to end the settings session.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y, N) ?` prompt.

Step 7. Type **Y <Enter>** to save your new settings.

Step 8. Set OUT106 to respond to Local Bit 6.

a. Type **SET O OUT106 <Enter>** (see *Figure 4.32*).

b. Type **LB06 <Enter>** at the `?` prompt.

c. Type **END <Enter>** at the next `?` prompt.

d. Type **Y <Enter>** when prompted to save settings.

```
=>>SET O OUT106 <Enter>
Output
Main Board
OUT106 := NA
? LB06 <Enter>
OUT107 := TNS_SW #RELAY TEST MODE
? END <Enter>
Output
Main Board
.
.
.
Save settings (Y,N) ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.32 Setting Control Output OUT106: Terminal Emulation Software

Step 9. Test the connection and programming.

a. Use the appropriate interface hardware to connect the fan control start circuit to terminal OUT106 of the main board.

b. Select `LOCAL CONTROL` at the relay front-panel `MAIN MENU`.

c. Press the **{ENT}** pushbutton (see *Figure 4.33*).

d. Select `5 MVA XFMR FANS` on the `LOCAL CONTROL` screen as shown in *Figure 4.33*.

e. Press **{ENT}** and highlight `1 ON` and press **{ENT}** again.

The graphical local control handle moves to the 1 position. At this time, the transformer fans will begin running.

f. Press **{ESC}** repeatedly to return to the `MAIN MENU`.

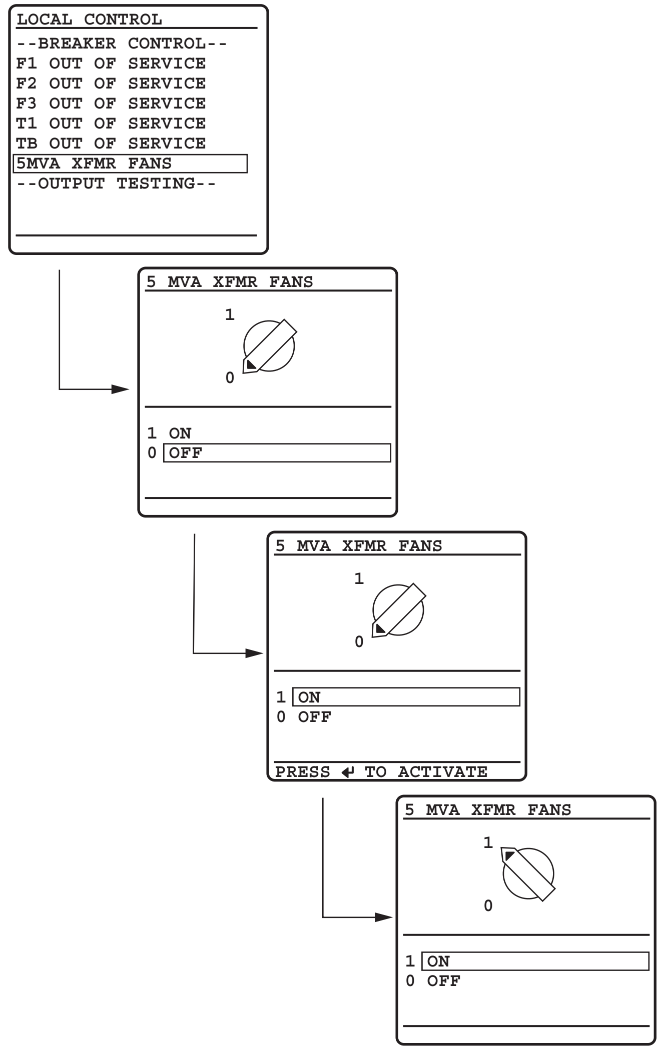

Figure 4.33 Front-Panel LOCAL CONTROL Screens

Setting Outputs for Tripping

To actuate power system circuit breakers, you must configure the SEL-487B control outputs to operate the trip bus. The relay uses internal logic and SELOGIC control equations to activate the control outputs.

Trip Output Signals

Although the SEL-487B is capable of single-pole and three-pole tripping, the traditional application for busbar protection is for three-pole tripping only. There are many Relay Word bits available that you can use to program control outputs to trip circuit breakers. See *Section 1: Protection Functions in the Reference Manual* for complete information on tripping equations and settings. For target illumination at tripping, see *Section 5: Front-Panel Operations*.

Assigning a Control Output for Tripping

The procedure in the following steps shows a method for setting the relay to operate the trip bus at a typical substation. Relay factory defaults assign main board control outputs OUT101 through OUT105 on the main board to trip the circuit breakers, as well as relay test mode to OUT107 and the alarms SALARM and HALARM to OUT108. The following procedure assigns an additional trip output at OUT106 on the main board.

This example assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

From Access Level 2, type **SHO O <Enter>** to view the present output settings, as shown in *Figure 4.34*.

```
=>>SHO O <Enter>
Output

Main Board

OUT101  := TRIP01 AND NOT TNS_SW
OUT102  := TRIP02 AND NOT TNS_SW
OUT103  := TRIP03 AND NOT TNS_SW
OUT104  := TRIP04 AND NOT TNS_SW
OUT105  := TRIP05 AND NOT TNS_SW
OUT106  := NA
OUT107  := TNS_SW #RELAY TEST MODE
OUT108  := NOT (SALARM OR HALARM)

.
.
.

=>>
```

Figure 4.34 Result of the SHO O Command, Showing the Output Contacts from the Main Board

As *Figure 4.34* shows, OUT106 is not used. Follow the steps in *Figure 4.35* to assign Relay Word bit TRIP06 to output OUT106 of the main board.

```
=>>SET O OUT106 <Enter>
Output

Main Board

OUT106 := NA
?   TRIP06 <Enter>

OUT107 := TNS_SW #RELAY TEST MODE
?   END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.35 Assign Relay Word Bit TRIP06 to Output OUT106 of the Main Board

Control Input Assignment

The SEL-487B features high-isolation direct connection control inputs that the relay uses to detect contact closures and signal level changes in an equipment bay or substation control house. See *Control Inputs on page U.2.8* for more information on control inputs.

If all of the control inputs share common signal properties of assertion level, debounce time, and dropout or deassertion level, you can enter these settings for all inputs. These settings are GINPU and GINDO for global input pickup time and global input dropout time settings respectively. See *Global Settings on page R.8.6* for more information. When you enable setting EICIS (Enable

Independent Control Input Settings), you can set separate input pickup and dropout time settings for control inputs that are exceptions to these global control input settings.

Setting a Control Input: Circuit Breaker Auxiliary Contacts (52A01): Computer Terminal Emulation Software

Following is a step-by-step procedure to configure a control input that reflects the state of the circuit breaker auxiliary (52A01) NO (normally open) contact. Commonly, a circuit breaker auxiliary contact is wired to the relay input to detect the closed/open status of the circuit breaker. Perform the following steps to configure a circuit breaker auxiliary contact in the SEL-487B.

This example assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the `=>` prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the `=>>` prompt.

Step 2. Configure the relay to read the circuit breaker auxiliary contact.

Relay Word bits 52A01 through 52A05 are enabled in the relay default settings.

a. Type **SET G <Enter>** (see *Figure 4.36*) to enter the Global settings.

b. Type **> <Enter>** successively until you reach the 52A01 prompt.

c. Type **IN101 <Enter>** at the `?` prompt to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

d. Type **IN102 <Enter>** and **IN103 <Enter>** at the next two `?` prompts to specify input IN102 and IN103 as the control inputs that represent the close/open state of Circuit Breaker 2 and Circuit Breaker 3 respectively.

e. Type **END <Enter>** at the next prompt.

Step 3. Confirm the new control information in the readback of all the Global settings, just before the `Save settings (Y, N) ?` prompt.

Step 4. Type **Y <Enter>** to save your new settings.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?  >

Global Enables

Station DC Battery Monitor (Y,N)                    EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                     GINPU   := 0.17   ?> <Enter

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  >

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  IN101 <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
?  IN102 <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  IN103 <Enter>
N/O Contact Input -BK04 (SELogic Equation)
52A04 := NA
?  END <Enter>
Global

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.36 Setting 52A01, 52A02, and 52A03: Terminal Emulation Software

Configuring Timekeeping

IRIG-B

You can connect time signals from many sources that produce the IRIG-B (Inter-Range Instrumentation Group-B) time code format (SEL-20xx family of communications processors, GPS receiver, etc.). The IRIG-B serial data format consists of a one-second frame containing 100 pulses divided into fields. The relay decodes the second, minute, hour, and day fields and sets the internal time clock upon detecting valid time data. The IRIG-B signal includes code for time-of-day and day-of-year time stamping, but does not include a code to identify the year. To verify that the SEL-487B calendar is set to the proper year, use the **DATE** command to view or change the date (see *DATE on page R.7.13*). The relay stores the year in nonvolatile memory and will maintain the proper year even if relay power cycles off and on. The relay also maintains the time, month, and day in nonvolatile memory while relay power is off.

Each SEL-487B provides two IRIG-B BNC connectors, labeled IN and OUT.

Step 1. Referring to the external source connections in *Figure 4.37*, connect the IRIG-B signals to the IN connection of Relay A to update the clock of Relay A.

Step 2. Connect the OUT connection of Relay A to the IN connector of Relay B to update the clock in Relay B.

A similar connection between Relay B and Relay C updates the time in Relay C.

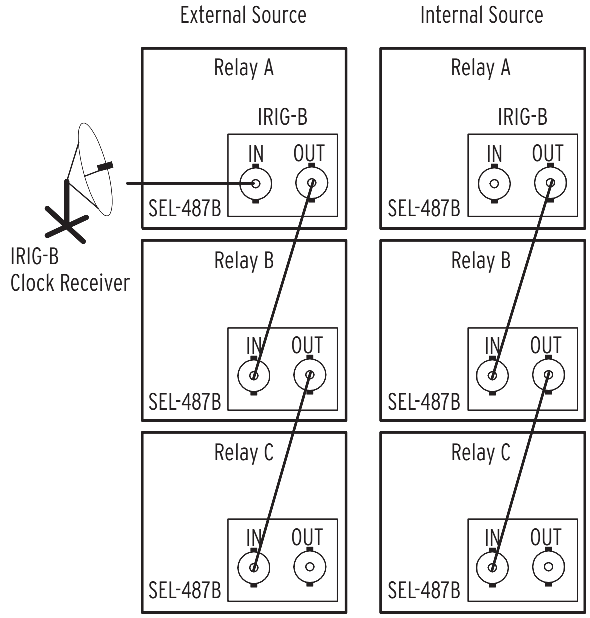

Figure 4.37 Time Synchronization Connections Between Three Relays

In the absence of an external IRIG-B signal, connect the relays as shown by the internal source connections in *Figure 4.37*. Connected this way, Relay B uses the clock of Relay A as time reference, and Relay C uses the clock of Relay B as time reference.

Automatic Time Source Selection

The SEL-487B automatically detects time source inputs. If the IRIG-B time source is unavailable or is unreliable, then the relay switches to a lower-priority source (DNP3, MIRRORED BITS®, and ASCII, for example). The relay automatically switches up to a higher priority time source when the relay measures an acceptable time source in terms of stability and reliability.

Connecting High-Accuracy Timekeeping

The procedure in the following steps assumes that you have a modern high-accuracy GPS receiver with BNC connector outputs for an IRIG-B. Use a communications terminal to send commands and receive data from the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*).

This example assumes that you have successfully established communication with the relay and are familiar with relay access levels and passwords. See *Making an EIA-232 Serial Port Connection on page U.4.5* and *Changing the Default Passwords: Terminal on page U.4.9*.

Step 1. Confirm that the relay is operating. See *Connecting and Applying Power on page U.4.3*.

Step 2. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the `=>>` prompt.

Step 3. Connect cables.

a. Attach the IRIG-B signal with a BNC-to-BNC coaxial jumper cable from the GPS receiver IRIG-B output to the SEL-487B **TIME IRIG-B BNC** connector.

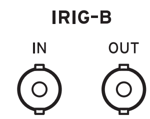

Figure 4.38 IRIG-B IN and IRIG-B OUT Connections at the Back of the Relay (BNC Connectors)

TIME Q Descriptions

The **TIME Q** command provides details about relay timekeeping (see *Figure 4.39*). The header line internal clock setting is initially calibrated at the SEL factory. The `Time Source` provides the present timing input source; entries for this line are `IRIG` and `OTHER`.

```
=>>TIME Q <Enter>

Relay 1                                    Date: 01/14/2003  Time: 17:25:10.920
Station A                                  Serial Number: 0000000001

Time Source: OTHER
Last Update Source: NONV CLK

IRIG Time Mark Period:    0.000 ms

Internal Clock Period:  25.000000 ns


=>>
```

Figure 4.39 Results of the TIME Q Command

The `Last Update Source` reports the source from which the relay referenced the last time value measurement. Entries for this line can be high-accuracy or low-accuracy sources. *Table 4.11* lists the possible `Last Update Source` values for the SEL-487B.

Table 4.11 Date/Time Last Update Sources (Sheet 1 of 2)

Time Input Source Mode (QQQQQ)	Accuracy	Time Source	Front Panel Editing?
`IRIG`	High	Time/date from the IRIG-B format time base signal	No
`COMM CARD`	Low	Time/date signal from the communications card	Date and Time
`DNP`	Low	Time/date from the DNP3 communications port	Date and Time
`MIRRORED BITS`	Low	Time/date from the MIRRORED BITS port	Date and Time
`ASCII TIME`	Low	Time from the relay serial ports	Date only
`ASCII DATE`	Low	Date from the relay serial ports	Time only
`NONV CLK`	Low	Time/date from the nonvolatile random access memory clock	Date and Time

Table 4.11 Date/Time Last Update Sources (Sheet 2 of 2)

Time Input Source Mode (QQQQQ)	Accuracy	Time Source	Front Panel Editing?
FRONT PANEL TIME	Low	Time from the front-panel TIME entry screen	Date and Time
FRONT PANEL DATE	Low	Time from the front-panel DATE entry screen	Date and Time

Readying the Relay for Field Application

Before applying the SEL-487B in your power system, set the relay for your particular field application. Be sure to modify the relay factory default settings for your power system conditions to enable relay features to help you protect and control your system.

This procedure is a guide to help you ready the relay for field application. If you are unfamiliar with the steps in this procedure, see the many relay usage examples presented in this section. This is a suggested procedure; modify the procedure as necessary to conform to your standard company practices.

Step 1. Open the appropriate low-voltage breaker(s).

a. Remove fuses to verify removal of control power and ac signals from the SEL-487B.

b. Isolate the relay TRIP control output.

Step 2. Perform point-to-point continuity checks on the circuits associated with the SEL-487B to verify the accuracy and correctness of the ac and dc connections.

Step 3. Apply power to the relay. See *Connecting and Applying Power on page U.4.3*. The green enable LED on the front panel will illuminate.

Step 4. Use an SEL Cable C234A to connect a serial terminal to the relay.

a. Start the terminal (usually a PC with terminal emulation software).

b. Establish communication with the relay at Access Level 0.

c. Proceed to Access Level 2.

Step 5. Change the default passwords.

See *Changing the Default Passwords: Terminal on page U.4.9*.

Step 6. Use test sources to verify relay ac connections.

See *Examining Metering Quantities on page U.4.31*.

Step 7. Verify control input connections.

See *Operating the Relay Inputs and Outputs on page U.4.40* and *Control Inputs on page U.2.8*.

Step 8. Verify control output connections.

See *Operating the Relay Inputs and Outputs on page U.4.40* and *Control Outputs on page U.2.9*.

Step 9. Perform protection element tests.

See *Checking Relay Operation on page U.6.18*.

Step 10. Set the relay.

See *Making Simple Settings Changes on page U.4.12*, *Section 1: System Configuration Guideline and Application Examples in the Applications Handbook*, and *Section 1: Protection Functions in the Reference Manual*.

Step 11. Connect the relay for tripping duty.

See *AC/DC Connection Diagrams on page U.2.38*.

Step 12. Clear the relay data buffers.

a. From Access Level 2, use a communications terminal to issue the commands listed in *Table 4.12*.

Table 4.12 Communications Port Commands That Clear Relay Buffers

Communications Port Command	Task Performed
HIS CA	Reset event report and history buffers
SER CA	Reset Sequential Events Recorder data

Step 13. Connect the secondary voltage (if required) and current inputs.

See *Section 2: Installation*.

Step 14. Confirm secondary connections.

Use the **MET** command to view relay metering. See *Examining Metering Quantities on page U.4.31*.

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Section 5
Front-Panel Operations

Overview

The SEL-487B Relay front panel makes power system data collection and system control quick and efficient. Using the front panel, you can examine power system operating information, view and change port settings, and perform relay control functions. The relay features a straightforward menu-driven control structure presented on the front-panel liquid crystal display (LCD). Front-panel targets and other LED (light-emitting diodes) indicators give a quick look at SEL-487B operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include the following:

- ➤ Reading metering
- ➤ Inspecting targets
- ➤ Accessing port, date and time settings
- ➤ Controlling relay operations

Front-Panel Layout

Figure 5.1 shows the front panel of the SEL-487B.

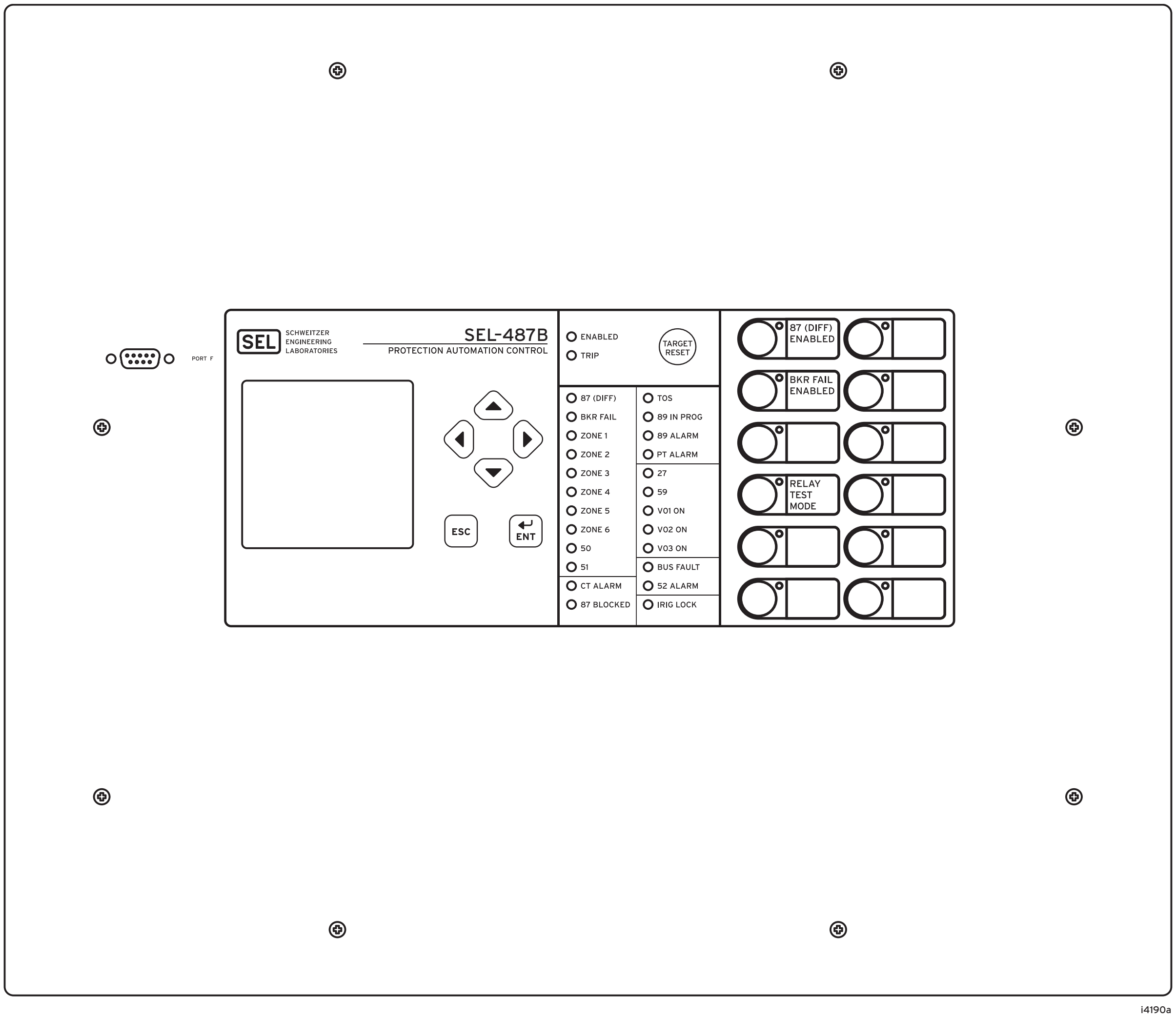

Figure 5.1 Front Panel, 12 Pushbutton (9U Version)

A 128 x 128 pixel LCD shows relay operating data including event summaries, metering, settings, and relay self-test information. Six navigation pushbuttons adjacent to the LCD window control the relay menus and information screens. Sequentially rotating display screens relate terminal and Bus-Zone metering and configuration parameters; you can easily change this ROTATING DISPLAY to suit your particular on-site monitoring needs. Use the simple and efficient menu structure to operate the relay from the front panel. With these menus you can quickly access SEL-487B metering, control, and settings.

Front-panel LEDs indicate the relay operating status. You can confirm that the SEL-487B is operational by viewing the **ENABLED** LED. The relay illuminates the **TRIP** LED target to indicate a tripping incident. The relay is factory programmed for particular relay elements to illuminate the other target LEDs. You can program these target LEDs to show the results of the most recent relay trip event. Change the pushbutton and pushbutton LED labels with the slide-in label carriers adjacent to the pushbuttons. The asserted and deasserted colors for the LEDs are programmable (12-pushbutton version).

The SEL-487B front panel features operator control pushbutton switches with annunciator LEDs that facilitate local control. Factory-default settings associate specific relay functions with these direct-action pushbuttons and LEDs. Using SELOGIC® control equations or front-panel settings PB*n*_HMI, you can change the default direct-action pushbutton functions and LED indications to fit your specific control and operational needs. Change the pushbutton and pushbutton LED labels with the slide-in labels adjacent to the pushbuttons. The asserted and deasserted colors for the LEDs are programmable (12-pushbutton version).

The SEL-487B front panel includes an EIA-232 serial port (labeled **PORT F**) for connecting a communications terminal or using the ACSELERATOR QuickSet® SEL-5030 Software program. Use the common EIA-232 open ASCII communications protocol to communicate with the relay via front-panel **PORT F**. Other communications protocols available with the front-panel port are MIRRORED BITS® communications, and optional DNP3. For more information on communications protocols and Port F, see *Establishing Communication on page U.4.4*.

Front-Panel LCD

The LCD is the prominent feature of the SEL-487B front panel. *Figure 5.2* shows the areas contained in the LCD:

- ➤ Title area
- ➤ Main area
- ➤ Message area
- ➤ Scroll bars

The scroll bars are present only when a display has multiple screens.

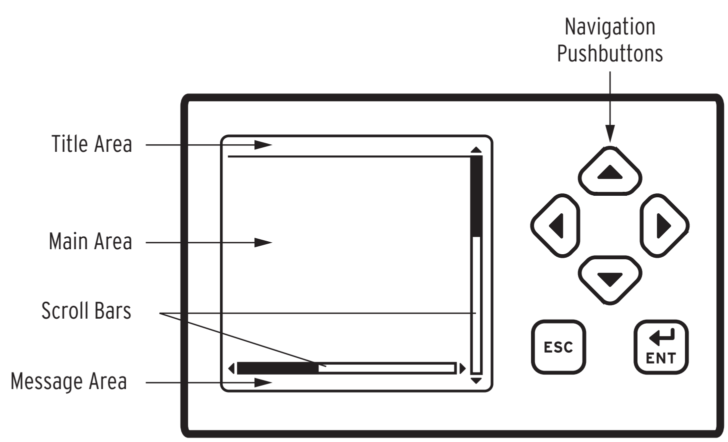

Figure 5.2 LCD Display and Navigation Pushbuttons

Front-Panel Inactivity Time Out

The LCD has a backlight that illuminates the screen when you press any front-panel pushbutton. This backlight extinguishes after a front-panel inactivity time out. You can control the duration of the time out with relay setting FP_TO, listed in *Table 5.1*. To set FP_TO, use the **SET F** (set front panel) settings from any communications port or use the **Front Panel** branch of the ACSELERATOR software settings tree view. The maximum backlight time is one hour. Obtain this 60-minute maximum backlight time by setting FP_TO to 60 or to OFF. When the front panel times out, the relay displays an automatic ROTATING DISPLAY, described in *Screen Scrolling on page U.5.4*.

Table 5.1 Front-Panel Inactivity Time-Out Setting

Name	Description	Range	Default
FP_TO	Front-panel display time-out	OFF, 1–60 minutes	15 minutes

Navigating the Menus

The SEL-487B front panel presents a menu system for accessing port settings and control functions. Use the LCD and the six pushbuttons adjacent to the display (see *Figure 5.2*) to navigate these front-panel menus.

The navigation pushbutton names and functions are the following:

- **{ESC}**—Escape pushbutton
- **{ENT}**—Enter pushbutton
- **{Left Arrow}**, **{Right Arrow}**, **{Up Arrow}**, and **{Down Arrow}**—Navigation pushbuttons

Relay menus show lists of items that display information or control the relay. A rectangular box around an action or choice indicates the menu item you have selected. This rectangular box is the menu item highlight. *Figure 5.3* shows an example of the highlighted item RELAY ELEMENTS in the MAIN MENU. When you highlight a menu item, pressing the **{ENT}** pushbutton selects the highlighted item.

```
MAIN MENU
EVENTS
RELAY ELEMENTS
LOCAL CONTROL
SET/SHOW
RELAY STATUS
VIEW CONFIGURATION
DISPLAY TEST
RESET ACCESS LEVEL
```

Figure 5.3 RELAY ELEMENTS Highlighted in MAIN MENU

The **{Up Arrow}** pushbutton and **{Down Arrow}** pushbutton scroll the highlight box to the previous or next menu selection, respectively.

Pressing the **{ESC}** pushbutton reverts the LCD display to the previous screen. Pressing **{ESC}** repeatedly returns you to the ROTATING DISPLAY. If a status warning, alarm condition, or event condition is active (not acknowledged or reset), the relay displays the full-screen status warning, alarm screen, or event screen in place of the ROTATING DISPLAY.

Screen Scrolling

The SEL-487B has two screen scrolling modes: autoscrolling and manual scrolling. After the initial relay power up, or after front-panel time out, the LCD presents each of the display screens in this sequence:

- Any active (filled) alarm points screens
- Any active (filled) display points screens
- Enabled metering screens
- Zone configuration screens

If enabled, the relay displays the metering and zone configuration screens in the order listed in *Table 5.2* (see *Figure 5.18* for samples of the metering screens). This sequence comprises the ROTATING DISPLAY.

Table 5.2 Metering Screens Enable Settings

Name	Description	Range	Default
STA_BAT	Station Battery Screen	Y, N	N
FUND_VI	Fundamental Voltage and Current Screens	Y, N	Y
DIFF	Differential Metering	Y, N	Y
ZONECFG	Terminals Associated With Zones	Y, N	Y

Use the front-panel settings (the **SET F** command from a communications port or the **Front Panel** settings in the ACSELERATOR software) to access the metering screen enable settings. Entering a **Y** (Yes) for a metering screen enable setting results in the corresponding metering screen appearing in the ROTATING DISPLAY. Entering an **N** (No) hides the metering screen from presentation in the ROTATING DISPLAY. If all metering screen enable settings are set to **N** (No) and there are no configured display points screens, the DIFF screen appears by default in the ROTATING DISPLAY. *Figure 5.4* shows a ROTATING DISPLAY example consisting of an example alarm points screen, a display points screen, and one of the factory-default metering screens (the screen values in *Figure 5.4* are representative values).

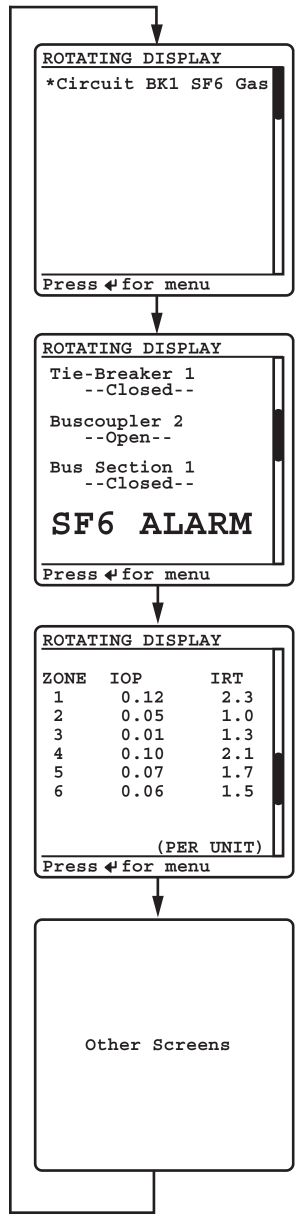

Figure 5.4 ROTATING DISPLAY

The active alarm points are the first screens in the ROTATING DISPLAY (see *Alarm Points on page U.5.7*). Each alarm points screen shows as many as 11 alarm conditions. The SEL-487B Relay can present a maximum of six alarm points screens. The active display points are the next screens in the ROTATING DISPLAY (see *Display Points on page U.5.9*). Each display points screen shows as many as 11 enabled display points. If a display point does not have text to display, the screen space for that display point is maintained.

Autoscrolling Mode

Autoscrolling mode shows each screen for a user-settable period of time. Front-panel setting SCROLD defines the period of time each screen is shown. When you first apply power to the relay, the LCD shows the autoscrolling ROTATING DISPLAY. With SCROLD := OFF, the screen remains on the first screen in the rotating display order, and automatic rotation of additional screens is disabled.

The autoscrolling ROTATING DISPLAY also appears after a front-panel inactivity time out (see *Front-Panel Inactivity Time Out on page U.5.3*). The relay retrieves data prior to displaying each new screen. The relay does not update screen information during the five-second display interval. At any time during autoscrolling mode, pressing **{ENT}** takes you to the MAIN MENU. Pressing any of the four navigation pushbuttons switches the display to manual-scrolling mode.

Manual-Scrolling Mode

In the manual-scrolling mode you can use the directional navigation arrow pushbuttons to select the next or previous screen. Pressing the **{Down Arrow}** or **{Right Arrow}** pushbuttons switches the display to the next screen; pressing the **{Up Arrow}** or **{Left Arrow}** pushbuttons switches the display to the previous screen. In manual-scrolling mode, the display shows arrows at the top and bottom of the vertical scroll bar. The screen arrows indicate that you can navigate between the different screens at will. The relay retrieves data prior to displaying each new screen. Unlike the autoscrolling mode, the relay continues to update screen information while you view it in the manual-scrolling mode. To return to autoscrolling mode, press **{ESC}** or wait for a front-panel time out.

Alarm Points

You can display messages on the SEL-487B front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 5.5 shows a sample alarm points screen. The relay is capable of displaying as many as 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. While you navigate the HMI menu structure, the relay does not automatically display the alarm points. Instead, ALARM EVENT displays in the footer. When you escape the HMI menu structure, the relay will display the alarm points screen.

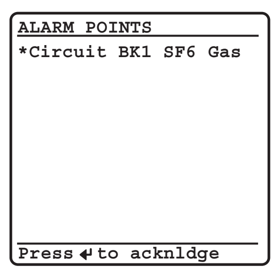

Figure 5.5 Sample Alarm Points Screen

The alarm point setting is an element of the SER settings. To enable an alarm point, enable the HMI alarm parameter of the SER Point Settings listed in *Table 5.3*. The format for entering the SER point data is the following comma-delimited string:

> Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Names can contain any valid ASCII character. Enclose the name in double quotation marks. See *Example 5.1* for particular information on the format for entering SER point data.

Table 5.3 SER Point Settings

Description	Range
Relay Word Bit	Any valid relay element
Reporting Name	20-character maximum ASCII string
SET State Name (logical 1)	20-character maximum ASCII string
CLR State Name (logical 0)	20-character maximum ASCII string
HMI Alarm	Y, N

If you enter a Relay Word bit that does not match a valid relay element, the relay displays `Unknown relay word reference`. If you enter an alias or name that is too long, the relay displays `Alias label too long`.

The relay displays alarm points in a similar fashion as the SER. As many as 19 characters of the given alias are displayed, with a character reserved for the asterisk (*). The asterisk denotes if the element is asserted. Initially, an alarm point must be asserted in order to be displayed; after the corresponding element deasserts, the asterisk is removed, but the alias is not. The relay displays alarm points in reverse chronological order, just as in the SER, with the most recently asserted alarm displayed on the top. Deasserted alarms may be removed from the display with user acknowledgement, as shown in *Example 5.1*.

EXAMPLE 5.1 Creating an Alarm Point

Alarm points screens provide operator feedback about the status of system conditions. An alarm points screen contains 11 alarm points; this example demonstrates a method to set the alarm point message that is shown in Figure 5.5. This example is based on the Relay Word bit IN101 asserting when Circuit Breaker 1 is in an alarm condition. In the Report settings (**SET R**), enter the following after the SER Points Line 1 prompt:

1: **IN101,"Circuit BK1 SF6 Gas","Alarm","Normal","Y"**

The circuit breaker alarm condition is indicated by the set state, "Alarm" and the circuit breaker normal condition is indicated by the clear state "Normal." The HMI Alarm parameter is set to "Y" in order to enable alarm points screen display of this element.

While in the scrolling mode, the assertion of IN101 will cause Figure 5.5 to be automatically displayed. Upon the deassertion of IN101, the asterisk will disappear, as in Figure 5.6.

While in the scrolling mode, the assertion of IN101 will cause Figure 5.5 to be automatically displayed. Upon the deassertion of IN101, the asterisk will disappear, as in Figure 5.6.

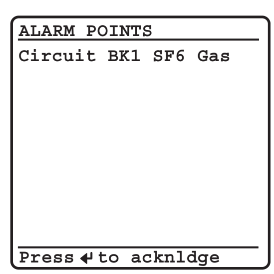

Figure 5.6 Deasserted Alarm Point

Pressing the **{ENT}** pushbutton will allow the user to acknowledge and clear deasserted alarms. Before clearing, the user will be prompted to confirm that this is the intended action, as in Figure 5.7.

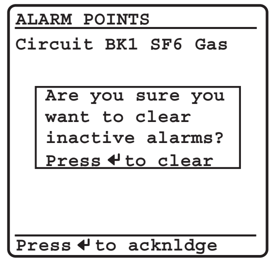

Figure 5.7 Clear Alarm Points Confirmation Screen

In the case that all alarms are deasserted, pressing the **{ENT}** pushbutton will allow the user to acknowledge and clear all alarms. After clearing, a screen showing the results of the action will be shown, as in Figure 5.8.

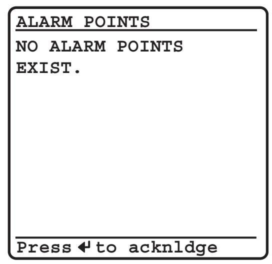

Figure 5.8 No Alarm Points Screen

Alarm Points are not updated for a particular element if it has been deleted from the SER because of chatter criteria (see Automatic Deletion and Reinsertion on page A.3.34). Upon reinsertion, the element state will be updated on the alarm points display. If the relay enters a period of SER data loss because of a rapidly toggling element, the status of alarm points cannot be determined. The screen shown in Figure 5.9 will be shown until the data loss condition has been exited, at which point the alarm point elements will be polled and displayed if asserted and the data loss message will be deasserted. Subsequent alarm point assertions will be displayed above the data loss message.

Figure 5.9 Alarm Points Data Loss Screen

Display Points

You can display messages on the SEL-487B front-panel LCD that indicate conditions in the power system. The relay uses display points to place these messages on the LCD. *Figure 5.10* shows a display points screen example. Display points can show the status of Relay Word bits or display the value of analog quantities. The relay has 96 possible display points; *Table 5.4* and *Table 5.5* list the display points settings. The relay updates the display points data once per second if you are viewing the display points in manual-scrolling mode; in autoscrolling mode, the relay updates the display points information each time the screen appears in the ROTATING DISPLAY sequence.

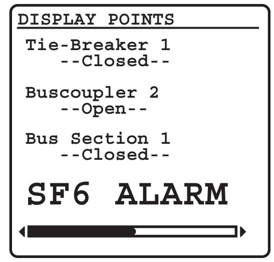

Figure 5.10 Display Points Screen

To enable a display point, enter the display point settings listed in *Table 5.4* or *Table 5.5*. All display points occupy one, and only one, line on the display at all times. The height of the line is determined by the "Text Size" setting parameter. Display points of single-line height span one screen in total width. Display points of double-line height span two screens in total width. You can use multiple display points to simulate multiple lines.

Use the following syntax to display the given Relay Word bit exactly as seen in the navigational menu (name and value).

DPxx := **Name**

Use the following syntax to display the given Relay Word bit as seen in the navigational menu, replacing the name of the value with the given alias string. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Text Size"**

Use the following syntax to display the given Relay Word bit with the given alias. If the Relay Word bit is asserted (logical 1), the LCD displays the set string in the place of the value. If the Relay Word bit is deasserted (logical 0), the LCD displays the clear string in the place of the value. One or all of Alias, Set String, or Clear String can be empty. If Alias is empty, then the LCD displays only the Set or Clear Strings. If either Set String or Clear String is empty, then an empty line is displayed when the bit matches that state. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Set String", "Clear String", "Text Size"**

Use the following syntax to display the given analog quantity with the given text and formatting. Formatting must be in the form {Width.Decimal,Scale} with the value of Name, scaled by "Scale," formatted with total width "Width" and ""Decimal" decimal places. The width value includes the decimal point and sign character, if applicable. The "scale" value is optional; if omitted, the scale factor is processed as 1. If the numeric value is smaller than the field size requested, the field is padded with spaces to the left of the number. If the numeric value will not fit within the field width given, "$" characters are displayed. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Text1 {Width.Decimal,Scale} Text2", "Text Size"**

Table 5.4 Display Point Settings—Boolean

Description	Range
Relay Word Bit Name	*Appendix A: Relay Word Bits in the Reference Manual*
Alias	ASCII string
Set String	ASCII string
Clear String	ASCII string
Text Size	S, D

Table 5.5 Display Point Settings—Analog

Description	Range
Analog Quantity Name	*Appendix B: Analog Quantities in the Reference Manual*
"User Text and Formatting"	ASCII string
Text Size	S, D

Table 5.6 Display Point Settings—Boolean and Analog Examples

Example Display Point Setting Value	Example Display 12345678901234567890
IN101	IN101=1 IN101=0
I01FIM,"{7.2}"	1234.56
50P01,Overcurrent,,	Overcurrent=1 Overcurrent=0
PSV01,Control,On,Off	Control=On Control=Off
PSV02,Breaker,Tripped,	Breaker=Tripped ***Empty Line***
50P01,,,Overcurrent	***Empty Line*** Overcurrent
I01FIM,"Terminal 01={7.2}"	Terminal 01=1234.56
I01FIM,"Terminal 01={7.3}"	Terminal 01=$$$.$$$
I01FIM,"Terminal 01 {4} A"	Terminal 01 1234 A
IOP1,"{7.2}"	1234.56
IOP1,"Zone1 Operate={4.1}"	Zone1 Operate=1234.5
IRT1,"Restraint1={5}"	Restraint1=1230
IRT1,"Restraint1={4.2,0.001} PU"	Restraint1=1.23 PU
V01FIM,"Term 01 Volt={3, 1000}"	Term 01 Volt=1234
V01FIM,"Term 01 Volt={3, 1000} kV"	Term 01 Volt=$$$ kV
1,"Fixed Text"	Fixed Text
0,"Fixed Text"	Fixed Text
1,	***Empty Line***
0,	***Empty Line*** ***Display Point is hidden***

EXAMPLE 5.2 Creating a Display Point

Display points screens provide operator feedback about the readiness of equipment connected to the SEL-487B. A display points screen contains 11 display points; this example demonstrates a method to set the top (first) display point message that is shown in Figure 5.10. The SEL-487B in this example has an additional I/O interface board.

Use appropriate interface hardware to connect the circuit breaker auxiliary contacts to IN201 to read the circuit breaker status.

In the Front Panel settings (**SET F**), enter the following after the Display Points and Aliases line 1 prompt:

1: **"Tie-Breaker 1"**

2: **IN201,," --Closed--"," --Open--"**

3: **0**

This example sets input IN201, represented by Relay Word bit IN201, as Tie-Breaker 1. Fixed text is set by assigning an alias to a "1" or "0." Blank lines are set by assigning a blank alias to a "1" or "0." The circuit breaker closed condition is indicated by the set state, "-- Closed--" where leading spaces are added to center the set state message. Add a clear state named " --Open--" to show that the circuit breaker is open.

EXAMPLE 5.3 Monitoring Test Modes With Display Points

This example uses the Relay Word bit TESTFM (Fast Meter test running) to activate a front-panel display point that alerts an on-site operator that the relay is in Fast Meter test mode.

In the Front Panel settings (**SET F**), enter the following after the line 4 prompt:

4: **TESTFM,,"FAST METER TEST!!!!"**

The LCD displays the screen shown in Figure 5.11 as a part of the ROTATING DISPLAY if the Fast Meter test is running. (Instruct the operator to view the relay front panel for messages or warnings as the last item on a "Leaving the Substation" checklist.)

This display point application example does not require a clear state, so the clear state is blank. If the Fast Meter test is not running and no other display points are active, the relay shows a blank screen in the ROTATING DISPLAY.

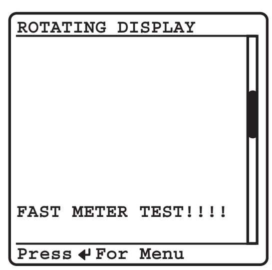

Figure 5.11 Fast Meter Display Points Screen

Front-Panel Menus and Screens

Operate the SEL-487B front panel through a sequence of menus that you view on the front-panel display. The `MAIN MENU` is the introductory menu for other front-panel menus (see *Figure 5.3*). These additional menus allow you on-site access to control and port settings. Use the following menus and screens to set the relay and perform local control actions:

- Support Screens
  - `Adjust Contrast`
  - `Password`
- `MAIN MENU`
  - `EVENTS`
  - `RELAY ELEMENTS`
  - `LOCAL CONTROL`
  - `SET/SHOW`
  - `RELAY STATUS`
  - `VIEW CONFIGURATION`
  - `DISPLAY TEST`
  - `RESET ACCESS LEVEL`

Support Screens

The relay displays special screens over the top of the menu or screen that you are using to control the relay or view data. These screens are the contrast adjustment screen and the `Password Required` screen.

Contrast

You can adjust the LCD screen contrast to suit your viewing angle and lighting conditions. To change screen contrast, press and hold the **{ESC}** pushbutton for one second. The relay displays a contrast adjustment box superimposed over the display. *Figure 5.12* shows the contrast adjustment box with the `MAIN MENU` screen in the background. Pressing the **{Right Arrow}** pushbutton increases the contrast. Pressing the **{Left Arrow}** pushbutton decreases the screen contrast. When you finish adjusting the screen contrast, press the **{ENT}** pushbutton.

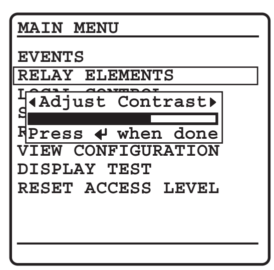

Figure 5.12 Contrast Adjustment

Password

The SEL-487B uses passwords to control access to settings and control menus. The relay has six access-level passwords. See *Changing the Default Passwords on page U.4.6* for more information on access levels and setting passwords. The SEL-487B front panel is at Access Level 1 upon initial power-up and after front-panel time out.

Password validation occurs only when you request a menu function that is at a higher access level than the presently authorized level. At this point, the relay displays a password entry screen, shown in *Figure 5.13*. This screen has a blank password field and an area containing alphabetic, numeric, and special password characters with a movable highlight box.

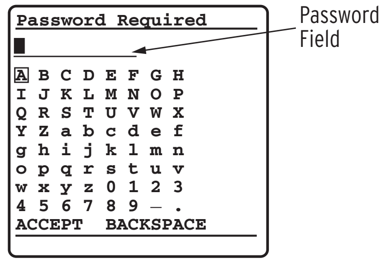

Figure 5.13 Enter Password Screen

Enter the password by pressing the navigation pushbuttons to move the highlight box through the alphanumeric field. When at the desired character, press **{ENT}**. The relay enters the selected character in the password field and moves the dark box cursor one space to the right. You can backspace at any time by highlighting the BACKSPACE option and then pressing **{ENT}**. When finished, enter the password by highlighting the ACCEPT option and then pressing **{ENT}**.

If you entered a valid password for an access level greater than or equal to the required access level, the relay authorizes front-panel access to the combination of access levels (new level and all lower levels) for which the password is valid. The relay replaces the password screen with the menu screen that was active before the password validation routine. When you enter Access Levels B, P, A, O, and 2, the Relay Word bit SALARM pulses for one second.

If you did not enter a valid password, the relay displays the error screen shown in *Figure 5.14*. Entering a valid password for an access level below the required access level also causes the relay to generate the error screen. In both password failure cases, the relay does not change the front-panel access level (it does not reset to Access Level 1 if at a higher access level). The relay displays the Password Invalid screen for five seconds. If you do not want to wait for the relay to remove the message, press any of the six navigational pushbuttons during the five-second error message to return to the previous screen in which you were working.

Figure 5.14 Invalid Password Screen

MAIN MENU

The MAIN MENU is the starting point for all other front-panel menus. The relay MAIN MENU is shown in *Figure 5.15*. When the front-panel LCD is in the ROTATING DISPLAY, press the **{ENT}** pushbutton to show the MAIN MENU.

Figure 5.15 MAIN MENU

METER

From the MAIN MENU shown in *Figure 5.15*, press the **{ESC}** key to return to the auto-scrolling rotating display. In the manual-scrolling mode, press the **{Up Arrow}** or **{Down Arrow}** keys repeatedly to get to and move between the metering screens. Factory-enabled metering screens scroll through the following metering screens:

- ➤ Differential quantities
- ➤ Zone configuration (when active)
- ➤ Fundamental Current
- ➤ Fundamental Voltage

Figure 5.16 shows the differential metering screen. The display shows the Bus-Zone number and the operating and restraint current for each active zone. An active zone is a zone with at least one terminal in the zone. Zones become inactive when there are no terminals connected to the zone or when the zone was merged with other zones. Inactive zones are not displayed. *Figure 5.16* shows an example with four zones active.

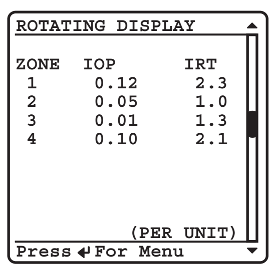

Figure 5.16 Differential Screen

Figure 5.17 shows the screen displaying the terminal(s) present in each active zone. For each active zone, the relay displays the terminals connected to that particular zone. When two zones merge, the new zone carries the zone number of the lower of the two zones. For example, when Zones 2 and 4 merge, the new combined zone becomes Zone 2.

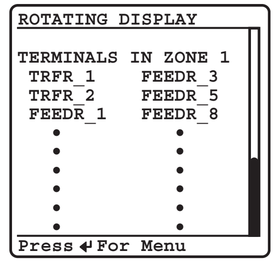

Figure 5.17 Terminals in Zone Screen

Figure 5.18 shows the fundamental current screens, displaying the primary current and phase angle for each terminal.

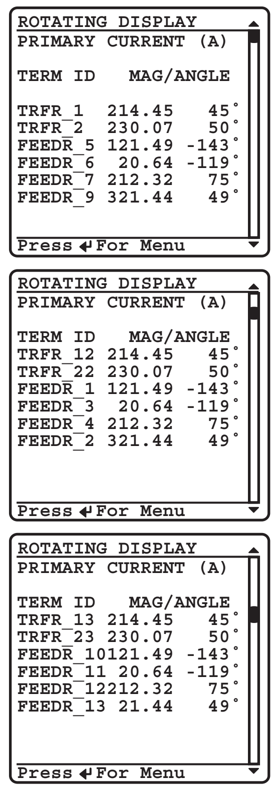

Figure 5.18 Fundamental Primary Current Screens

All angles are referenced to the voltage connected to voltage terminal V01. If voltage at terminal V01 is not available, the relay selects V02, and then V03. In the absence of voltage inputs, the relay references the current input of I01, provided the current is above 0.05 • I_{NOM}. If I01 is not above this current level, the relay references the current from I02, if available. If I02 is not available, the relay continues to I03, I04, and so on until it finds a current input above 0.05 • I_{NOM}.

Figure 5.19 shows the primary voltage magnitudes and angles from the three voltage inputs in kV.

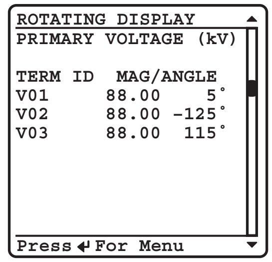

Figure 5.19 Fundamental Primary Voltage Screen

Use the **SET F** command and set STA_BAT = Y to enable the station battery screen, as displayed in *Figure 5.20*.

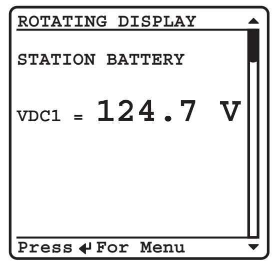

Figure 5.20 Station Battery Screen

EVENTS

The SEL-487B front panel features summary event reporting showing event number, group, time and date, and event trigger. See *Event Report on page A.3.6* for more information on event reports.

The front-panel event buffer size is at least 100 summaries. The relay numbers summary events in order from 10000 through 42767 and displays the most recent summaries on the LCD. You can view summary event reports from the relay front-panel display by selecting `EVENTS` from the `MAIN MENU`. The relay presents the `Events Menu` as shown in *Figure 5.21*. Select `Event Summary` from the `Events Menu` to view event summary data.

Figure 5.21 Events Menu Screen

Figure 5.22 shows a sample `EVENT SUMMARY` screen of a busbar fault. The vertical scroll bar indicates that there are more events available. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to move among the events in the summary buffer. Press **{ESC}** to return to the `MAIN MENU`. Event reports can also be viewed via a front-panel automatic message (see *Front-Panel Automatic Messages on page U.5.31*).

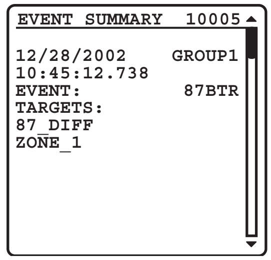

Figure 5.22 EVENT SUMMARY Screen

SER

The Sequential Events Recorder (SER) records state changes of user-programmable Relay Word bits. State changes are time-tagged for future analysis of relay operations during an event. See *Automatic Deletion and Reinsertion on page A.3.34* for more information on SER events. To view SER events from the front panel, select EVENTS from the MAIN MENU and SER Events from the Events Menu as shown in *Figure 5.21*. SER events are also viewable using programmable front-panel operator-control pushbuttons (see *Front-Panel Operator Control Pushbuttons on page U.5.36*).

Figure 5.23 illustrates the SER Events display screen. Data reported in this screen for each event are the SER number, SER Point Alias Name, Asserted or Deasserted state, and the Date and Time of the event. When in the SER Events screen, three SER records are displayed. Using the navigation pushbuttons, the most recent 200 SER events are viewable on the front-panel display. The topmost event is the most recent event and the bottommost event is the oldest. The upper right of the screen displays the number of the SER events currently being viewed. If a new event occurs while viewing the SER events, the display does not update with the new event automatically. To include the new SER event in the display, exit the SER screen by pressing **{ESC}** and re-enter the SER Events screen by pressing **{ENT}** with the SER Events selection highlighted. This rebuilds the SER Events display and contains the latest SER events triggered.

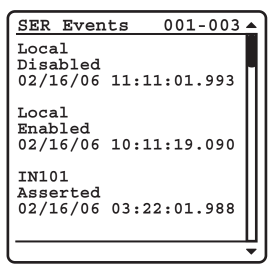

Figure 5.23 SER Events Screen

If no SER events are available, *Figure 5.24* is displayed.

Figure 5.24 No SER Events Screen

While viewing the SER events, front-panel pushbuttons provide navigation and control functions as indicated in *Table 5.7*.

Table 5.7 Front-Panel Pushbutton Functions While Viewing SER Events

Pushbutton	Description
{Up Arrow}, {Down Arrow}	Navigates one screen at a time up or down. Each screen contains three SER events. Accelerated scrolling is obtained when the pushbutton remains pressed (see accelerated scrolling behavior below).
{Left Arrow}, {Right Arrow}	Navigates between SER events to allow adjacent SER events to be displayed on one screen. For example, if events 1, 2, and 3 are displayed, press the {Right Arrow} once to display events 2, 3, and 4 in the same screen. No accelerated scrolling is provided with the {Left Arrow} and {Right Arrow} pushbuttons.
{ESC}	Returns to the Events Menu.
{ENT}	Does nothing.

Hold down either the {Up Arrow} or {Down Arrow} to achieve accelerated scrolling. Holding down the {Up Arrow} or {Down Arrow} navigates one screen at a time for the first five screens and then increases to five screens at a time if the button remains pressed. Accelerated scrolling stops at the newest or oldest SER event record available, depending on the direction of the scrolling. When the upper limit of the SER events is reached, press the {Down Arrow} one more time and the report will wrap around to display the screen containing the first SER event. Similarly, when the lower limit of the SER events is reached, press the {Up Arrow} one more time and the report will wrap around to display the screen containing the last SER event.

RELAY ELEMENTS (Relay Word Bits)

You can view the RELAY ELEMENTS screen to check the state of the Relay Word bits in the SEL-487B. The relay has two unique manual-scrolling features for viewing these elements:

- Accelerated navigation
- Search

These Relay Word bit scrolling features make selecting elements from among the many relay targets easy and efficient. *Figure 5.25* shows an example of the RELAY ELEMENTS screen. If an alias exists for an element, the alias name is displayed instead of the element name. Notice the labels 89BF1, 89CLF1, 89OIPF1, and 89ALF1, which are alias names for 89B44, 89CL44, 89OIP44 and 89AL44.

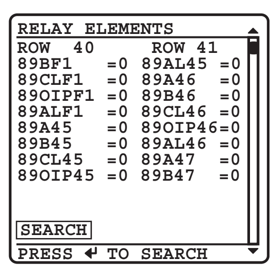

Figure 5.25 RELAY ELEMENTS Screen

When you move screen by screen through the Relay Word bit table, pressing the {Up Arrow} or {Down Arrow} pushbuttons shows each previous or next screen in turn. Accelerated navigation occurs when you press and hold the {Up Arrow} or {Down Arrow} pushbuttons.

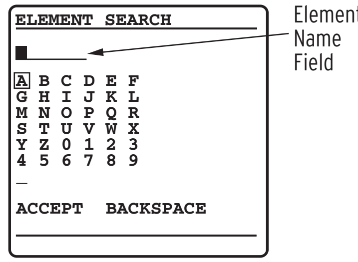

Figure 5.26 ELEMENT SEARCH Screen

Search mode allows you to find a specific relay target element quickly. *Figure 5.26* shows the menu screen that the relay displays when you select the SEARCH option of the RELAY ELEMENTS main screen. When you first enter this search menu, the block cursor is at the beginning of the element name field and the highlight box in the alphanumeric field is around the letter A. Use the navigation pushbuttons to move through the alphanumeric characters. If the highlight is on one of the characters, pressing **{ENT}** enters the character at the block cursor location in the element name field. Next, the block cursor moves automatically to the character placeholder to the right. To backspace the cursor in the element name field, move the highlight to BACKSPACE and press **{ENT}**. When you have finished entering an element name, move the highlight to ACCEPT and press **{ENT}**. At any time, pressing **{ESC}** returns the display to the RELAY ELEMENTS screen.

If the highlight is on ACCEPT, the relay finds the matching relay element when you press **{ENT}**. The relay first searches for alias names, seeking an exact match. If the relay does not find an exact alias name match, it searches for an exact primitive name match. If there is no exact primitive name match, the relay initiates a partial alias name string search, followed by a partial primitive name string search. If the relay finds no match, the screen displays an error message and stays in the ELEMENT SEARCH screen. If the relay finds a match, the screen displays the element row containing the matching element.

LOCAL CONTROL

The SEL-487B provides great flexibility in power system control through the LOCAL CONTROL menus. You can use the front-panel LOCAL CONTROL menus to perform these relay functions:

- ➤ Trip circuit breakers (password required)
- ➤ Switch terminals IN and OUT of service
- ➤ Test relay outputs (password required)

If the NUMBK setting (Global settings) is 1 or more, the relay displays the BREAKER CONTROL option, as shown in *Figure 5.27*. Other options are the local bit control and --OUTPUT TESTING--. You must install the circuit breaker control enable jumper to enable circuit breaker control and output testing capability. See *Operating the Relay Inputs and Outputs on page U.4.40* and *Password and Circuit Breaker Jumpers on page U.2.16*. The submenu does not display either the --OUTPUT TESTING-- or --BREAKER CONTROL-- options if the breaker jumper is not installed. (The relay checks the status of the breaker jumper at power up.) If the breaker jumper is not installed, and there are no local bits enabled, the relay displays an information message when you attempt to enter LOCAL CONTROL. Because there is no operation possible, the screen returns to the MAIN MENU following a short delay.

Local bit names appear in the local control bit names field, as shown in *Figure 5.27*. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the local control action you want to perform. Pressing **{ENT}** takes you to the specific LOCAL CONTROL screen.

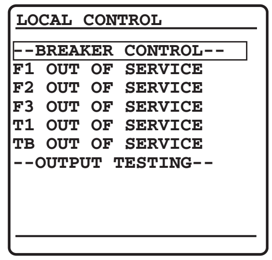

Figure 5.27 LOCAL CONTROL Initial Menu

BREAKER CONTROL

NOTE: If NUMBK = 1, selecting BREAKER CONTROL takes you directly to the BREAKER CONTROL screen.

NOTE: Default settings for the trip and output SELOGIC control equations do not include Relay Word bits OCnn. Include Relay Word bits OCnn in the TRnn SELOGIC control equations for those terminals you want to control from the front panel.

The BREAKER CONTROL option presents a circuit breaker selection submenu to open up to 18 breakers. Circuit breakers cannot be closed from this menu. NUMBK (Global settings) sets the number of breakers available. For example, if NUMBK is set to 5, then breakers one through five are presented for control. Operations from this submenu directly assert the OC*nn* Relay Word bits. For example, if BREAKER 5 is selected, the relay asserts the OC05 Relay Word bit for one processing interval. The relay uses the status of Relay Word bits 52CL*nn* (*nn* = 1 through 18) to display the breaker status. Relay Word bits 52CL*nn* are the outputs from the circuit breaker status logic (see *Section 1: Protection Functions in the Reference Manual* for more detail). Use the navigation pushbuttons and **{ENT}** to select the circuit breaker you want to control. *Figure 5.28* shows the BREAKER CONTROL submenu with NUMBK:=5, and circuit breaker control screens for BREAKER 1. Use the **{Right Arrow}** pushbutton to select the YES control action. When you highlight the YES option and press **{ENT}**, the relay displays the confirmation message OPEN COMMAND ISSUED and trips Circuit Breaker 1.

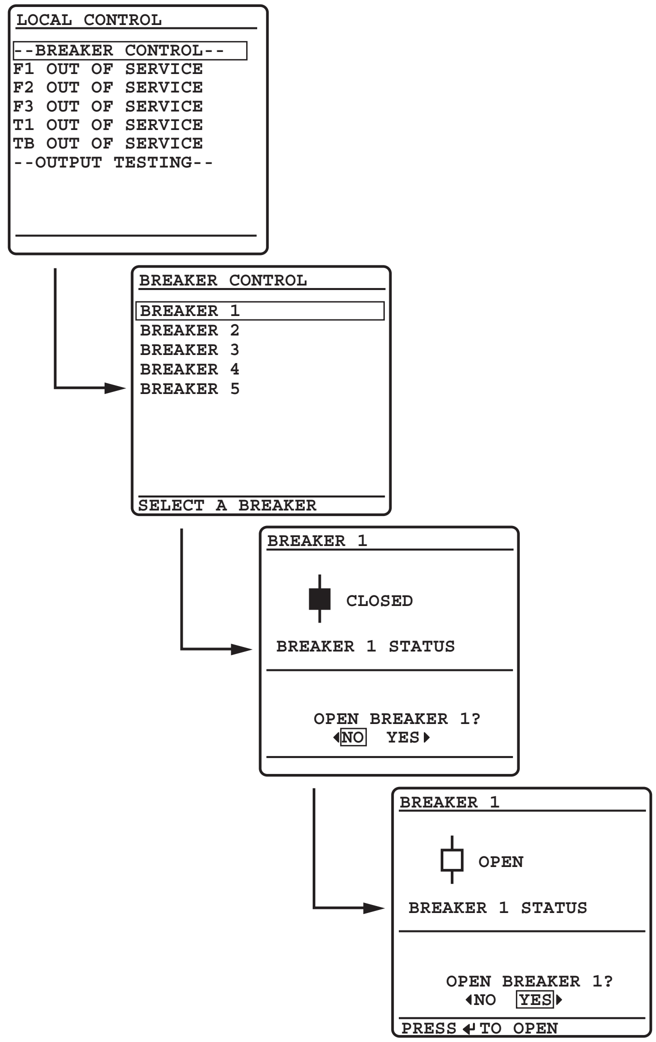

Figure 5.28 BREAKER CONTROL Screens

Local Control Bits

NOTE: The default setting for LB_SPnn is "1." The default settings satisfy the local bit supervision logic so that local bit operations can take place.

The relay provides 32 local control bits with SELOGIC control equation supervision. These local bits replace substation control handles to perform switching. The SEL-487B saves the states of the local bits in nonvolatile memory and restores the local bit states at relay power up.

Local control bit supervision is available through a SELOGIC control equation provided in the Front-Panel settings (LB_SP*nn*). For local bit operations to take place, the corresponding LB_SP*nn* must be asserted. *Table 5.9* defines the local bit SELOGIC settings available in the Front-Panel settings class. *Figure 5.40* illustrates the logic that supervises all local bit operations (Set, Clear, Pulse).

NOTE: The default settings for LB_DPnn are LBnn. The default settings cause the local bit switch to move to the corresponding state of the local bit (asserted = 1, deasserted = 0).

The SELOGIC control equation local bit status (LB_DP*nn*) is provided to return the status of a device that is being controlled by the local bit. The LB_DP*nn* Relay Word bit drives the state of the graphical switch on the display, i.e., with LB_DP*nn* deasserted, the switch points to 0.

Any unused local control bits default to the clear (logical 0) state. Also, any reconfigured local bit retains the existing bit state after you change the bit setting, unless set to momentary, in which case it goes to logical 0. Deleting a local bit sets that bit to the clear (logical 0) state.

Figure 5.29 shows a control example using the LOCAL CONTROL menus. The LCD shows a graphic representation of a substation control handle. The LB_DP*nn* SELOGIC control equation determines the state of the switch position on the LCD. If the LB_DP*nn* Relay Word bit is deasserted, the graphic control handle points to 0; if the LB_DP*nn* Relay Word bit is asserted, the switch points to 1. You can program names or aliases for the local bit clear and set states; these appear next to logical 0 and logical 1, respectively. Labels OUT OF SERVICE and IN SERVICE in *Figure 5.29* are examples of such labels. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the set (1) or clear (0) control actions. Highlighting the set option (shown in *Figure 5.29* as OUT OF SERVICE and pressing **{ENT}** changes the local control bit and performs the required control action. If the LB_DP*nn* Relay Word bit asserts, the graphical switch moves to 1 to indicate the asserted local bit status.

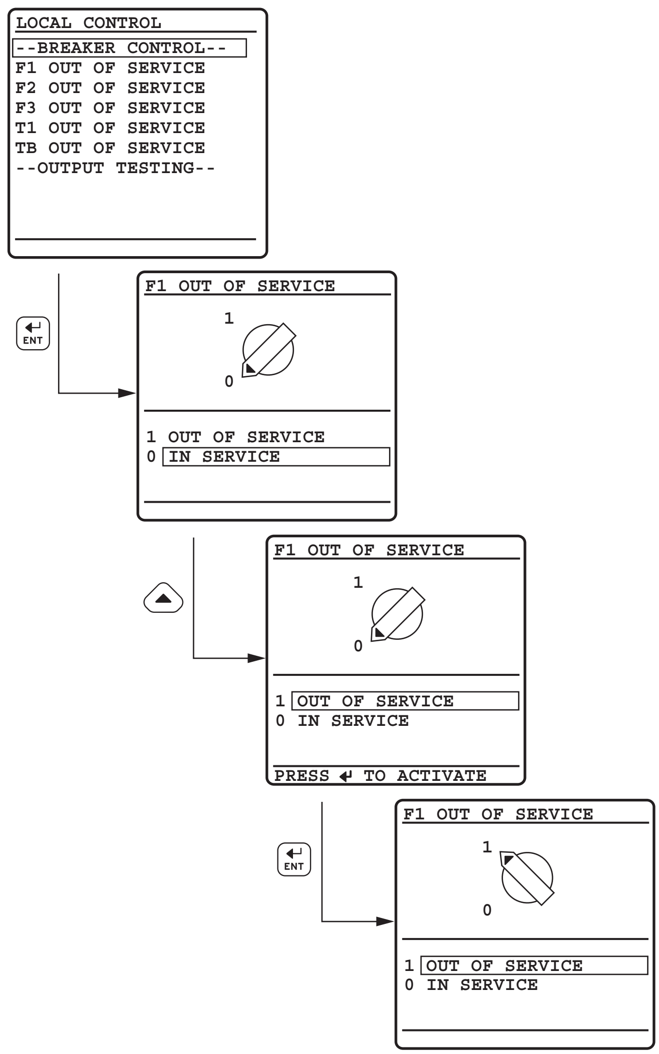

Figure 5.29 LOCAL CONTROL Example Menus

To enable a local bit, enter the local bit settings in *Table 5.8*. The format for entering the local bit data is the comma-delimited string listed below:

> local bit, control function name, alias for the set state, alias for the clear state, pulse enable

Names or aliases can contain any printable ASCII character except double quotation marks. Use double quotation marks to enclose the name or alias. See *Example 5.4* for particular information on enabling a local control bit.

Table 5.8 Local Bit Control Settings

Description	Range	Default
Local Bit *nn*[a]	1–32	1
Local Bit *nn* Name	20-character maximum ASCII string	(blank)
Local Bit *nn* Set Alias (1 state)	20-character maximum ASCII string	(blank)
Local Bit *nn* Clear Alias (0 state)	20-character maximum ASCII string	(blank)
Pulse Local Bit *nn*	Y, N	N

[a] nn = 01–32.

The pulse enable setting at the end of the setting string is optional. If your application requires a pulsed or momentary output, you can activate an output pulse by setting the option at the end of the local bit command string to **Y** (for Yes). The default for the pulse state is **N** (for No); if you do not specify **Y**, the local bit defaults at **N** and gives a continuous set or clear switch level.

If you enter an invalid setting, the relay displays an error message prompting you to correct your input. If you do not enter a valid local bit number, the relay displays `A local bit element must be entered`. If you enter a local bit number and that local bit is already in use, the relay displays `The local bit element is already in use`. Likewise, if you do not enter a valid local bit name, set alias, and clear alias, the relay returns an error message. If an alias is too long, the relay displays `Too many characters`.

Table 5.9 Local Bit SELogic[a]

Description	Range	Default
Local Bit Supervision *nn*	SELogic Equation, NA	1
Local Bit Status Display *nn*	SELogic Equation, NA	LB*nn*

[a] nn = 01–32, only available if the corresponding local bit is defined.

Local Bit Supervision SELogic control equation provides supervision of Local Bit Set, Clear, and Pulse operations.

Local Bit Status Display SELogic control equation returns the status of the local bit switch state.

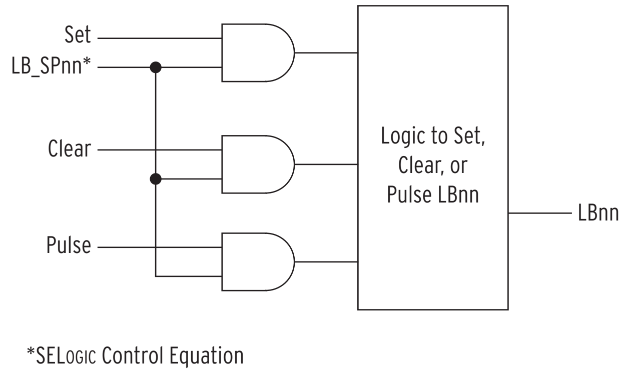

Figure 5.30 Local Bit Supervision Logic

EXAMPLE 5.4 Enabling Local Bit Control

This application example demonstrates a method to create one of the control points in the `LOCAL CONTROL` screens of Figure 5.30 to control the interlock on a power bus tie circuit breaker. Perform the following actions to create a local control bit:

- Eliminate previous usage of the local bit and condition the state of the local bit
- Set the local bit
- Assign the local bit to a relay output

If you are using a previously used local bit, delete all references to the local bit from the SELOGIC control equations already programmed in the relay. A good safety practice would be to disconnect any relay output that was programmed to that local bit.

To change the local bit state, select the bit and set it to the state you want. In addition, you can delete the local bit, which changes the state of this local bit to logical 0 when you save the settings. To delete, use the front-panel settings. When using a communications port and terminal, use the text-edit mode line setting editing commands at the Local Bits and Aliases prompt to go to the line that lists Local Bit 9 (see Text-Edit Mode Line Editing on page U.4.18 for information on text-edit mode line editing). To delete Local Bit 9, type **DELETE <Enter>** after the line that displays Local Bit 9 information. For example, if a previously programmed Local Bit 9 appears in the **SET F** line numbered listings on Line 1, then typing **DELETE <Enter>** at Line 1 deletes Local Bit 9.

Next, set the local bit. In the Front Panel settings (**SET F**), enter the following:

1: **LB09,"Bus Tie Interlock","Closed (OK to TIE)","Open (NoTIE)",N**

This sets Local Bit 9 to "Bus Tie Interlock" with the set state as "Closed (OK to TIE)" and the clear state as "Open (No TIE)."

Assign the local bit to a relay output. In the Output settings (**SET O**), set the SELOGIC control equation, OUT201, to respond to Local Bit 9.

OUT201 := **LB09**

Use the appropriate interface hardware to connect the circuit breaker interlock to OUT201.

OUTPUT TESTING

NOTE: The circuit breaker control enable jumper J18C must be installed to perform output testing. See Main Board Jumpers on page U.2.16.

You can check for proper operation of the SEL-487B control outputs by using the `OUTPUT TESTING` submenu of the `LOCAL CONTROL` menu. A menu screen similar to *Figure 5.31* displays a list of the control outputs available in your relay configuration. For more information on output testing, see *Control Output on page U.4.40*.

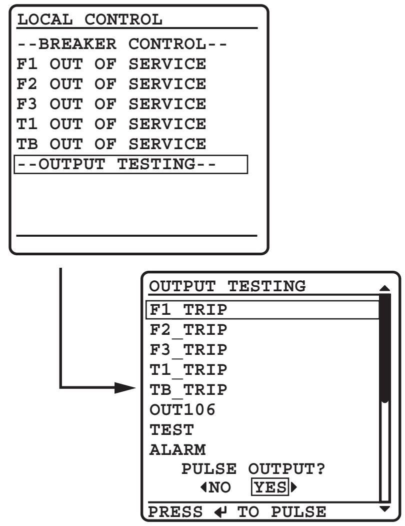

Figure 5.31 OUTPUT TESTING Screen

SET/SHOW

NOTE: You cannot use the front-panel SET/SHOW menus to change front-panel settings. To change front-panel settings, use a communications port interface and the **SET F** command or use the ACSELERATOR software **Front Panel** settings.

You can use the SET/SHOW menus to examine or modify SEL-487B port settings, active setting group, and date/time. From the front panel you can change only the settings class and settings listed in *Table 5.10*.

Table 5.10 Settings Available From the Front Panel

Class/Setting	Description
PORT	Relay communications port settings
ACTIVE GROUP	Active settings group number 1–6
DATE/TIME	Date and time settings

At the MAIN MENU, select the SET/SHOW item and press **{ENT}**. Use the navigation pushbuttons to select the relay PORT settings or to change the ACTIVE GROUP or the DATE/TIME.

Next, select the particular instance of the settings class. For the PORT settings class, the instances are Port 1, Port 2, Port 3, and Port F. The setting ACTIVE GROUP = *n* (where *n* is a number from 1 to 6) and the settings for DATE/TIME have no settings instance screens.

Figure 5.32 shows the major navigational steps to select MBA on Port 1. Select the PORT class.

If the data you entered are invalid, the relay displays an error message screen, then returns to the particular settings entry screen so you can attempt a valid settings entry.

When finished entering the new settings data, press **{ESC}**. The relay prompts you with a Save Settings screen. Using the navigation pushbuttons, answer YES to make the settings change(s) or NO to abort the settings change(s).

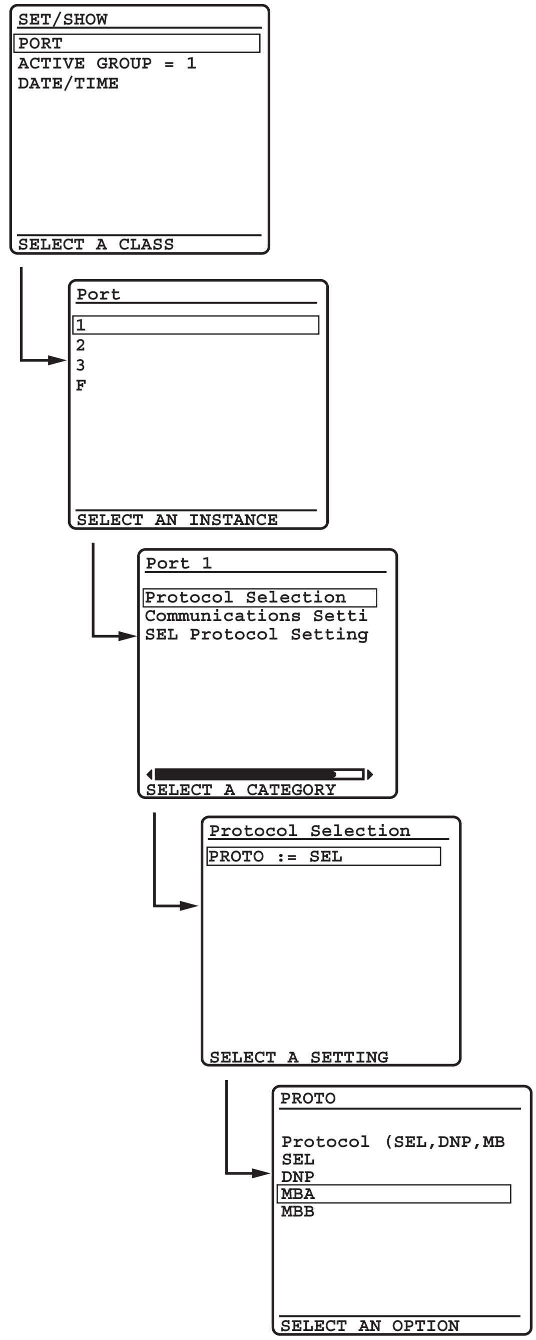

Figure 5.32 SET/SHOW Screens

ACTIVE GROUP

Select the ACTIVE GROUP option of the SET/SHOW submenu screen (shown in *Figure 5.33*) to change the settings group. The relay performs a password validation test at this point to confirm that you have Breaker Access Level authorization or above. If access is allowed, and all the results of SELOGIC control equations SS1–SS6 are not logical 1 (asserted), then the relay displays the EDIT ACTIVE GROUP screen in *Figure 5.33*. The relay shows the active group and underlines the group number after NEW GROUP =. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to increase or decrease the NEW GROUP number. Once you have selected the new active group, press **{ENT}** to change the relay settings to this new settings group.

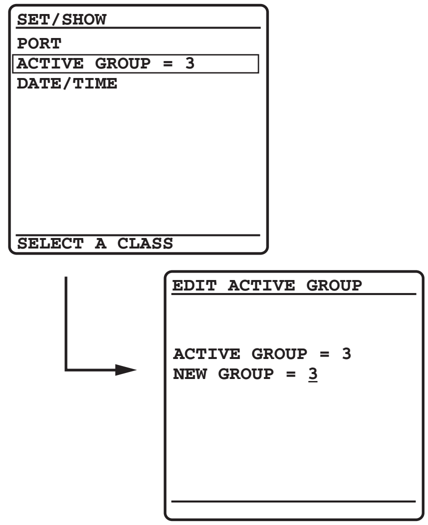

Figure 5.33 Changing the ACTIVE GROUP

DATE/TIME

Another submenu item of the SET/SHOW first screen (*Figure 5.32*) is the DATE/TIME screen shown in *Figure 5.34*. The SEL-487B generates date and time information internally, or you can use external high-accuracy time modes with time sources such as a GPS receiver.

Figure 5.34 is the relay date/time screen when a high accuracy source is in use. Possible time sources, qqqqq, are listed in *Table 4.9*. If you use a high-accuracy time source, edits are disabled, the DATE/TIME display does not show the highlight, and the screen does not show the help message on the bottom line.

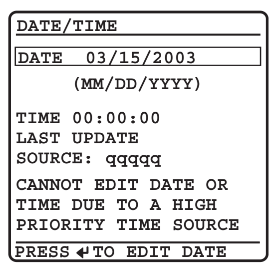

Figure 5.34 DATE/TIME Screen

When operating from a nonhigh-accuracy time source, you can use the front-panel DATE and TIME entry screens to set the date and time. *Figure 5.35* shows an example of these edit screens. Use the **{Left Arrow}** and **{Right Arrow}** navigation pushbuttons to move the underscore cursor; use the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to increment or decrement each date and time digit as appropriate to set the date and time. For a description of the LAST UPDATE SOURCE field, see *Configuring Timekeeping on page U.4.49*.

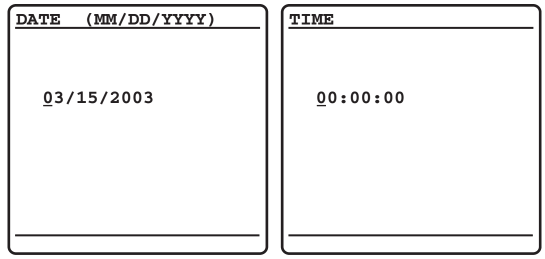

Figure 5.35 Edit DATE and Edit TIME Screens

To enable a high-accuracy external time source, connect a GPS receiver to the relay. For a discussion of the IRIG timing mode in the SEL-487B see *Configuring Timekeeping on page U.4.49*.

RELAY STATUS

The SEL-487B performs continuous hardware and software self-checking. If any vital system in the relay approaches a failure condition, the relay issues a status warning. If the relay detects a failure, the relay displays the RELAY STATUS screen immediately and freezes the front-panel display showing the failure report. For both warning and failure conditions, the relay shows the error message for the system or function that caused the warning or failure condition. You can access the RELAY STATUS screen via the MAIN MENU. The RELAY STATUS screen shows the firmware identification number (FID), serial number, whether the relay is enabled, and any status warnings. *Figure 5.36* shows examples of a normal RELAY STATUS screen, a status warning RELAY STATUS screen, and a status failure RELAY STATUS screen. For more information on status warning and status failure messages, see *Relay Self-Tests on page U.6.34*.

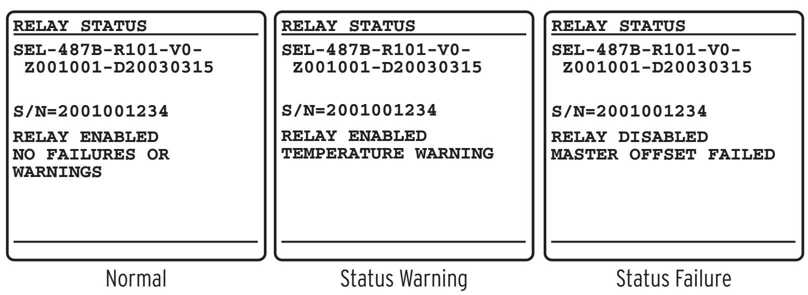

Figure 5.36 Relay STATUS Screens

VIEW CONFIGURATION

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the SEL-487B. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons. The relay presents five screens in the order shown in *Figure 5.37*. Use the navigation pushbuttons to scroll through these screens. When finished viewing these screens, press **{ESC}** to return to the MAIN MENU.

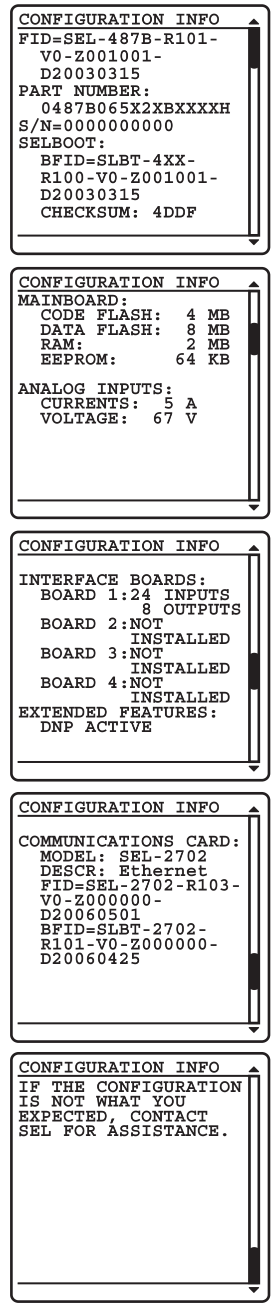

Figure 5.37 VIEW CONFIGURATION Sample Screens

DISPLAY TEST

You can use the DISPLAY TEST option of the MAIN MENU to confirm operation of all of the LCD pixels. The LCD screen alternates the on/off state of the display pixels once every time you press **{ENT}**. *Figure 5.38* shows the resulting two screens. The DISPLAY TEST option also illuminates all of the front-panel LEDs. To exit the test mode, press **{ESC}**.

NOTE: The LCD `DISPLAY TEST` does NOT reset the front-panel LED targets.

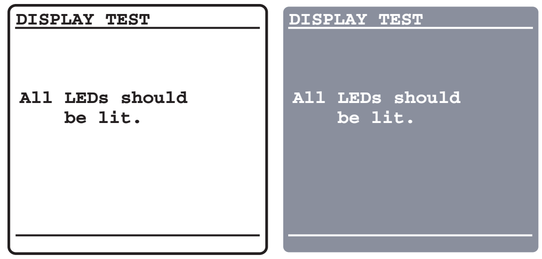

Figure 5.38 DISPLAY TEST Screens

RESET ACCESS LEVEL

The SEL-487B uses various passwords to control access to front-panel functions. As you progress through these menus, the relay detects the existing password level and prompts you for valid passwords before allowing you access to levels greater than Access Level 1. When you want to return the front panel to the lowest access level (Access Level 1), highlight `RESET ACCESS LEVEL` item on the `MAIN MENU`. Pressing **{ENT}** momentarily displays the screen of *Figure 5.39* and places the front panel at Access Level 1.

The relay automatically resets the access level to Access Level 1 upon front-panel time-out (setting FP_TO is not set to OFF). Use this feature to reduce the front-panel access level before the time-out occurs.

Figure 5.39 RESET ACCESS LEVEL Screen

Front-Panel Automatic Messages

The SEL-487B automatically displays alert messages. Any message generated due to an alert condition takes precedence over the normal `ROTATING DISPLAY` and the `MAIN MENU`. Alert conditions include these significant events:

- Alarm point asserts
- Event reports and trips
- Status warnings
- Status failures

In order to display event reports automatically from the `ROTATING DISPLAY`, you must set front-panel setting `DISP_ER` to `Y`. Front-panel setting `TYPE_ER` allows the user to define what types of event reports will be automatically displayed from the normal `ROTATING DISPLAY`; `ALL` will display all event types described in *Table 3.2 on page A.3.3* and `TRIP` will display only the event types that include the assertion of the TRIP Relay Word bit. For alarm point assertions, qualified event reports (including trip events) and status warnings, the relay displays the corresponding full-screen automatic message only if the front-panel display is in the time-out or standby condition (the relay is scrolling through the default display points/enabled metering screens of the ROTATING DISPLAY or is displaying the MAIN MENU).

If you are on site using the SEL-487B front panel in menus and screens other than the MAIN MENU and a status warning occurs, alarm point asserts, or an event report triggers, the relay shows automatic messages at the bottom of the active screen in the message area. For example, the message area shows RELAY STATUS WARNING for a status warning. *Figure 5.40* is an example of a status warning notification that appears in the message area of a LOCAL CONTROL (local bit) screen. If a trip event occurs while you are using a front-panel screen, the message area notification reads RELAY EVENT. When you repeatedly press **{ESC}** (as if returning to the MAIN MENU) during this warning or trip alert situation, the relay displays the full-screen automatic message concerning the warning or trip in place of the MAIN MENU. If the front-panel display is at the MAIN MENU and a status warning occurs, the full-screen warning replaces the MAIN MENU. After you view the warning or trip screen, pressing **{ESC}** returns the LCD to the MAIN MENU.

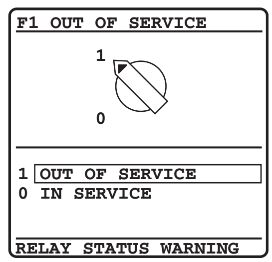

Figure 5.40 Sample Status Warning in the LCD Message Area

For a status failure, the relay immediately displays the full-screen status alert regardless of the present front-panel operating state. The relay displays no further LCD screens until the status failure clears. Should an unlikely status failure event occur, contact your local Technical Service Center or an SEL factory representative (see *Technical Support on page U.6.38*).

Operation and Target LEDs

The SEL-487B gives you at-a-glance confirmation of relay conditions via operation and target LEDs. These LEDs are located in the middle of the relay front panel. The SEL-487B provides either 16 or 24 LEDs depending on ordering options selected.

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect other operating conditions than the factory default programming described in this subsection. Settings T*n*_LED are SELOGIC control equations that, when asserted during a relay trip event, light the corresponding LED. Parameter *n* is a number from 1 through 24 that indicates each LED. LED positions are described in parenthesis next to each LED in *Figure 5.41*. Program settings T*n*LEDL := Y to latch the LEDs during trip events; when you set T*n*LEDL := N, the trip latch supervision has no effect and the LED follows the state of the T*n*_LED SELOGIC control equation. With T*n*LEDL := Y, the relay reports these targets in event report summaries. The asserted and deasserted colors for the LED are determined with settings T*n*LEDC (12-pushbutton version). Options include red, green, amber, or off. After setting the target LEDs, issue the **TAR R** command to reset the target LEDs. For a concise listing of the default programming on the front-panel LEDs, see *Front-Panel Settings on page R.8.23*.

Use the slide-in labels to mark the LEDs with custom names. Included on the SEL-487B Product Literature CD are Customer Label Templates to print labels for the slide-in label carrier. *Figure 5.41* shows the arrangement of the operation and target LEDs region into several areas described in *Table 5.11*.

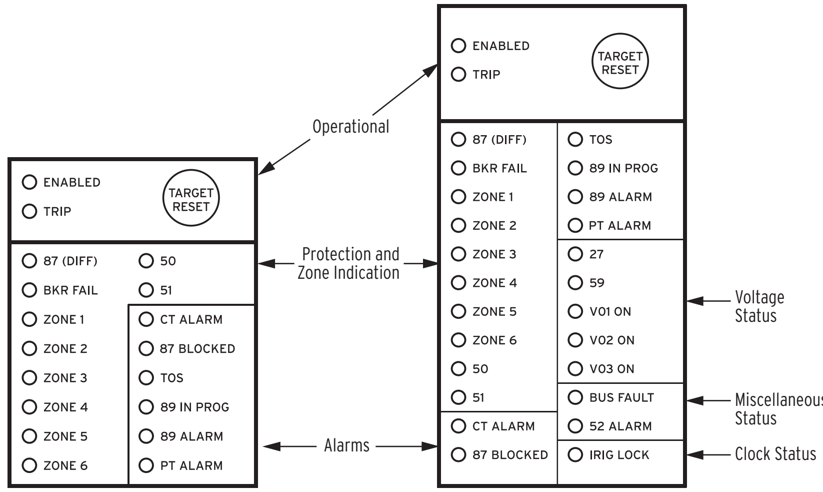

Figure 5.41 Factory Default Front-Panel Target Areas (16 or 24 LEDs)

Table 5.11 Front-Panel Target LEDs

Label	Function
ENABLED, TRIP	Operational
87 (DIFF), BKR FAIL, ZONE 1, ZONE 2, ZONE 3, ZONE 4, ZONE 5, ZONE 6, 50, 51	Protection and Zone Indication
CT ALARM, 87 BLOCKED, TOS, 89 IN PROG, 89 ALARM, PT ALARM	Alarms
27[a], 59[a], V01 ON[a], V02 ON[a], V03 ON[a]	Voltage Status
BUS FAULT[a], 52 ALARM[a]	Miscellaneous Status
IRIG LOCK[a]	Clock Status

[a] Only available in 24 LED models.

Operational

The ENABLED LED indicates that the relay is active. Trip events illuminate the TRIP LED. The prominent location of the TRIP LED in the top target area helps you recognize a trip event quickly. Program settings EN_LEDc and TR_LEDc to determine the color of the respective LED (12-pushbutton version). Options include red or green.

TARGET RESET and Lamp Test

For a trip event, the relay latches the trip-involved target. Press the {TARGET RESET} pushbutton to reset the latched target LEDs. When a new trip event occurs and you have not reset the previously latched trip targets, the relay clears the latched targets and displays the new trip targets.

Pressing the {TARGET RESET} pushbutton illuminates all the LEDs. Upon releasing the {TARGET RESET} pushbutton, one of two possible trip situations can exist:

- the conditions that caused the relay to trip have cleared
- the trip conditions remain present at the relay inputs

If the trip conditions have cleared, the latched target LEDs turn off. If the trip event conditions remain, the relay re-illuminates the corresponding target LEDs. The {TARGET RESET} pushbutton also removes the trip automatic message displayed on the LCD menu screens if the trip conditions have cleared.

Lamp Test Function With TARGET RESET

The {TARGET RESET} pushbutton also provides a front-panel lamp test. Pressing {TARGET RESET} illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as you press {TARGET RESET}. The target LEDs return to a normal operational state after you release the {TARGET RESET} pushbutton.

Lamp Test Function With LCD DISPLAY TEST Menu

The LCD menus provide a front-panel `DISPLAY TEST` mode. This menu-activated lamp test, from the `DISPLAY TEST` menu, does not reset the target LEDs (see *DISPLAY TEST on page U.5.30*).

Other Target Reset Options

You can reset the target LEDs with the **TAR R** ASCII command; see *TARGET on page R.7.42* for more information. Programming specific conditions in the SELOGIC control equation RSTTRGT is another method to reset the relay targets. Access RSTTRGT in the relay Global settings (Data Reset Control); to use RSTTRGT, you must enable data reset control with global setting EDRSTC := Y. You also need to assign the RSTTRGT Relay Word bit to the corresponding ULTR*nn* SELOGIC control equation.

Protection and Zone Indication

The SEL-487B indicates essential information about the most recent relay trip event with the LEDs of the Protection and Zone Indication area. These trip types are 87 (DIFF), BKR FAIL, ZONE 1–6, 50, 51.

The 87 (DIFF) target LED illuminates and latches the indication, indicating operation of any one of the six SEL-487B differential elements.

The BKR FAIL target LED illuminates and latches the indication, indicating operation of any one of the 18 SEL-487B breaker failure elements.

The ZONE 1–6 target LEDs illuminate and latches the indication, indicating the zone(s) in which the fault occurred.

The 50 target LED illuminates and latches the indication, indicating operation of any one of the 18 nondirectional, instantaneous elements.

The 51 target LED illuminates and latches the indication, indicating operation of any one of the 18 nondirectional, time-delayed overcurrent elements.

Alarms

The alarm area target indicators are the CT ALARM, 87 BLOCKED, TOS, 89 IN PROG, 89 ALARM, PT ALARM LEDs.

The CT ALARM (current transformer) target illuminates but does not latch the indication when any one of the six sensitive differential elements times out.

The 87 BLOCKED target illuminates and latches the indication when any one of the six Zone Supervision (Z*n*S) SELOGIC control equations becomes a logical 0.

The TOS (Terminal Out of Service) target illuminates but does not latch the indication when any one of the 18 terminals is out of service.

The 89 IN PROG target illuminates but does not latch the indication when a disconnect operation is in progress on any one of the 48 disconnects.

The 89 ALARM (Disconnect Alarm) target illuminates but does not latch the indication when the disconnect alarm 89AL asserts.

The PT ALARM (potential transformer) target illuminates and latches after a 240-cycle time delay, indicating the presence of a negative- or zero-sequence voltage. This function works on the assumption that all three phases from the PTs are available in the same relay. In a three-relay application, wire the three phases from the PTs to the same SEL-487B.

Voltage Status

The 27 target LED illuminates when any one of the terminal undervoltage elements operates.

The 59 target LED illuminates when any one of the terminal overvoltage elements operates.

The V01 ON, V02 ON, and V03 ON LEDs illuminate when the terminal filtered instantaneous voltages are greater than 55 V. See *Table 8.51 on page R.8.23* for setting default values. The default setting of 55 V is 82 percent of the line-to-neutral nominal voltage of 67 V to coincide with the nominal line-to-line voltage of 115 V.

Miscellaneous Status

The BUS FAULT target LED illuminates when a busbar fault is detected (Relay Word bit FAULT is asserted).

The 52 ALARM target LED illuminates when the relay detects any circuit breaker alarm (Relay Word bit 52AL is asserted).

Clock Status

The IRIG LOCK target LED illuminates in the SEL-487B when the relay detects synchronization to an external clock with less than 3 ms of jitter (Relay Word bit TIRIG is asserted). See *IRIG-B on page U.4.49* for complete details.

Front-Panel Operator Control Pushbuttons

The SEL-487B front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 5.42* shows this region of the relay front panel with factory default configurable front-panel label text. The SEL-487B provides either 8 or 12 pushbuttons depending on ordering options selected.

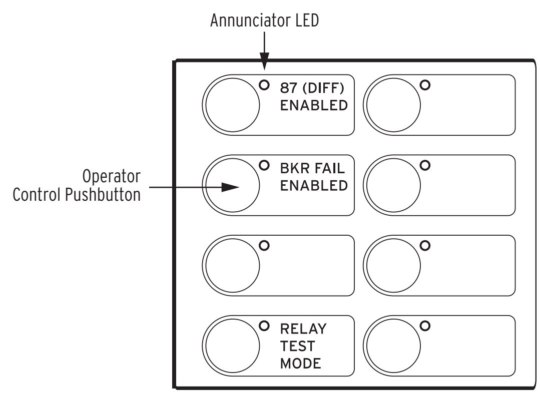

Figure 5.42 Operator Control Pushbuttons and LEDs (8 Pushbutton Version)

Factory default programming associates specific relay functions with the eight pushbuttons and LEDs. The SEL-487B default setting uses only three of the eight pushbuttons, as listed in *Table 5.12*. For a concise listing of the default programming for the front-panel pushbuttons and LEDs, see *Front-Panel Settings on page R.8.23*.

Table 5.12 Operator Control Pushbuttons and LEDs—Factory Defaults

LED	Function
{87 (DIFF) ENABLED}	Enable the differential protection
{BKR FAIL ENABLED}	Enable the breaker failure protection
{RELAY TEST MODE}	Enable the differential and breaker failure protection, but inhibit trip outputs

Press the operator control pushbuttons momentarily to toggle on and off the functions listed adjacent to each LED/pushbutton combination. The operator control pushbuttons and LEDs are programmable. *Figure 5.43* describes the factory defaults for the three operator controls.

There are two ways to program the operator control pushbuttons. The first is through front-panel settings PB*n*_HMI. These settings allow any of the operator control pushbuttons to be programmed to display a particular HMI screen category. The HMI screen categories available are Alarm Points, Display Points, Event Summaries, and SER. Front-panel setting NUM_ER allows the user to define the number of event summaries that are displayed via the operator control pushbutton; it has no effect on the event summaries automatically displayed or the event summaries available through the main menu. Each HMI screen category can be assigned to a single pushbutton. Attempting to program more than one pushbutton to a single HMI screen category will result in an error. After assigning a pushbutton to an HMI screen category, pressing the pushbutton will jump to the first available HMI screen in that particular category. If more than one screen is available, a navigation scroll bar will be displayed. Pressing the navigation arrows will scroll through the available screens. Subsequent pressing of the operator control pushbutton will advance through the available screens, behaving the same as the **{Right Arrow}** or the **{Down Arrow}** pushbutton. Pressing the **{ESC}** pushbutton will return the user to the ROTATING DISPLAY. The second way to program the operator control pushbutton is through SELOGIC control equations, using the pushbutton output as a programming element. Using SELOGIC control equations, you can change the default pushbutton and LED functions. Use the slide-in labels to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. The labels are keyed; you can insert each Operator Control Label in only one position on the front of the relay. Word processor templates for printing slide-in labels are included on the SEL-487B Product Literature CD. See *Relay Placement on page U.2.22* for more information on changing the slide-in labels.

The SEL-487B has two types of outputs for each of the front-panel pushbuttons. Relay Word bits represent the pushbutton presses. One set of Relay Word bits follows the pushbutton and another set pulses for one processing interval when the button is pressed. Relay Word bits PB1 through PB12 are the “follow” outputs of operator control pushbuttons. Relay Word bits PB1_PUL through PB12PUL are the “pulsed” outputs.

Annunciator LEDs for each operator control pushbutton are **PB1_LED** through **PB12LED**. The factory defaults programmed for three LEDs used are protection latches (PLT01, for example), settings groups, and Relay Word bits. The asserted and deasserted colors for the LED are determined with settings PB*n*COL (12-pushbutton version). Options include red, green, amber, or off. You can change the LED indications to fit your specific control and operational requirements. This programmability allows great flexibility and provides operator confidence and safety, especially in indicating the status of functions that are controlled both locally and remotely.

NOTE: The pushbutton outputs are delayed by approximately one-half of a second to prevent inadvertent operation.

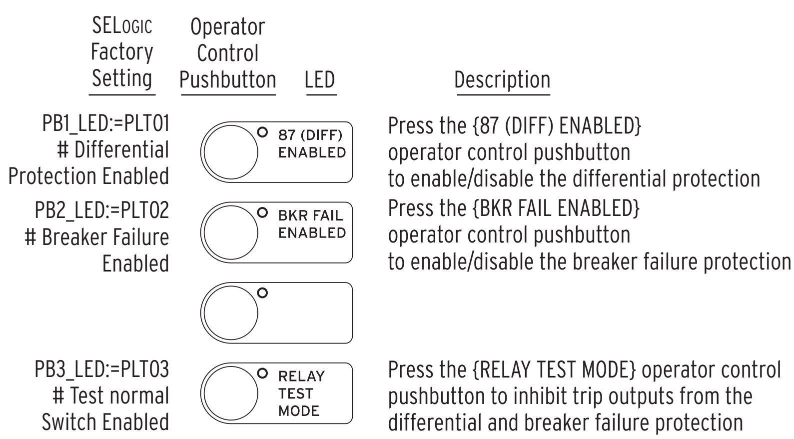

Figure 5.43 Factory Default Operator Control Pushbuttons

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Section 6
Testing and Troubleshooting

Overview

This section contains guidelines for determining and establishing test routines for the SEL-487B Relay. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. The SEL-487B incorporates self-tests to help you diagnose any potential difficulties. The subsection *Relay Troubleshooting on page U.6.36* contains a quick-reference table for common relay operation problems.

This section includes the following topics, tests, and troubleshooting procedures:

- ➤ Testing philosophy
- ➤ Testing features and tools
- ➤ Test methods
- ➤ Checking relay operation
- ➤ Relay self-tests
- ➤ Relay troubleshooting
- ➤ Factory assistance

The SEL-487B is factory calibrated; this section contains no calibration information. If you suspect that the relay is out of calibration, contact your Technical Service Center or the SEL factory.

Testing Philosophy

Protective relay testing generally consists of three categories: acceptance testing, commissioning testing, and maintenance testing. The categories differ in testing complexity and according to when the testing takes place in the life of the relay. Each testing category includes particular details as to when to perform the test, the testing goals, and the relay functions that you need to test. This information is a guide to testing the SEL-487B; be sure to follow the practices of your company for relay testing.

Acceptance Testing

SEL performs detailed acceptance testing on all new relay models and versions. Perform acceptance testing on a new relay model to become familiar with the relay operating theory and settings; this familiarity helps you apply the relay accurately and correctly. *Table 6.1* presents a summary of acceptance testing guidelines.

Table 6.1 Acceptance Testing

Details	Description
Time	Test when qualifying a relay model for use on the utility system.
Goals	a) Confirm that the relay meets published critical performance specifications such as operating speed and element accuracy.
	b) Confirm that the relay meets the requirements of the intended application.
	c) Gain familiarity with relay settings and capabilities.
Test	Test all protection elements and logic functions critical to your intended application.

Commissioning Testing

SEL performs a complete functional check and calibration of each SEL-487B before shipment so that your relay operates correctly and accurately. You should perform commissioning tests to verify proper connection of the relay to the power system and all auxiliary equipment.

Step 1. Check control signal inputs and outputs.

Step 2. Check disconnect auxiliary contact inputs, circuit breaker auxiliary contact inputs, breaker failure inputs, SCADA control inputs, trip outputs, and monitoring outputs.

Step 3. Use an ac test set to verify that the relay current and voltage inputs have the proper magnitude and angles.

Step 4. Conduct brief fault tests to confirm that the relay settings and protection scheme logic are correct.

You do not need to test every relay element, timer, and function in these tests.

Step 5. At commissioning, use the relay **METER** command to verify the ac current and voltage magnitudes and angles.

Step 6. Use the **PUL** command to pulse relay control output operation.

Step 7. Use the **TAR** command to view relay targets and verify that control inputs are operational.

Step 8. Use the **TEST DB, TEST FM**, and **TEST DNP** commands to check SCADA interfaces.

Table 6.2 lists guidelines for commissioning testing. For further discussion of these tests, see *Checking Relay Operation on page U.6.18*.

Table 6.2 Commissioning Testing

Details	Description
Time	Test when installing a new protection system.
Goals	a) Validate all system ac and dc connections.
	b) Confirm that the relay functions as intended using your settings.
	c) Check that all auxiliary equipment operates as intended.
	d) Check SCADA interface.
Tests	a) Test all connected inputs, outputs, and CT polarities. b) Make simple checks of protection elements. c) Test communications interfaces.

Maintenance Testing

The SEL-487B uses extensive self-testing routines and includes detailed metering and event reporting functions. These features reduce your dependence on routine maintenance testing. To perform maintenance testing, follow the recommendations in *Table 6.3*.

Table 6.3 Maintenance Testing

Details	Description
Time	Test at scheduled intervals or when there is an indication of a problem with the relay or power system.
Goals	a) Confirm that the relay is measuring ac quantities accurately.
	b) Check that scheme logic and protection elements function correctly.
	c) Verify that auxiliary equipment functions correctly.
Tests	Test all relay features/power system components that did not operate during an actual fault within the past maintenance interval.

You can use the SEL-487B reporting features as maintenance tools. Periodically compare the relay **METER** command output to other online meter readings to verify that the relay measures currents and voltages correctly and accurately.

Each occurrence of a power system fault tests the protection system and relay application. Review relay event reports in detail after each fault to determine the areas needing your attention. Use the event report current, voltage, and relay element data to determine whether the relay protection elements operated properly. Inspect event report input and output data to determine whether the relay asserts outputs at the correct times and whether auxiliary equipment operates properly.

At each maintenance interval, test only those items that have not operated (via fault conditions) during the maintenance interval. You do not need to perform further maintenance testing for a correctly set and connected relay that measures the power system properly and has not failed relay self-tests.

The SEL-487B is based on microprocessor technology; the relay internal processing characteristics do not change over time. For example, if time-overcurrent element operating times change, these changes occur because of alterations to relay settings and/or differences in the signals applied to the relay. You do not need to verify relay element operating characteristics as a part of maintenance checks.

SEL recommends that you limit maintenance tests on SEL relays according to the guidelines listed in *Table 6.3*. You will spend less time checking relay operations that function correctly. You can use the time you save to analyze event data and thoroughly test systems needing more attention.

Testing Features and Tools

The SEL-487B provides the following features to assist you during relay testing:

- Metering
- Event reports
- Event summary reports
- SER (Sequential Events Recorder) reports

Certain relay commands are useful in confirming relay operation. The following commands, for example, aid you in testing the relay:

- **TAR**
- **PUL**
- **TEST DB**
- **TEST FM**
- **TEST DNP**

In addition, the SEL-487B incorporates a low-level test interface you can use to interrupt the connection between the relay input transformers and the input processing module. Use the low-level test interface to apply reduced-scale test quantities to the relay; you do not need to use large power amplifiers to perform relay testing.

Test Features

Metering

The metering data show the ac currents and voltages (magnitude and phase angle) connected to the relay in primary or secondary values. In addition, metering shows many other quantities such as the voltage input to the station dc battery monitor. Compare these measured quantities in the relay against quantities from other devices of known accuracy. The metering data are available at the serial ports and communications card and at the front-panel ROTATING DISPLAY screen.

Event Reports

The relay also generates filtered and unfiltered event reports in response to faults or disturbances. Each event report contains information on currents, voltages, relay elements, control inputs, and control outputs. If you are unsure of the relay response or your test method, the event report provides you with information on the operating quantities that the relay used at the event trigger. The event report data gives you a visual tool for testing relay operating quantities. You can use the communications ports and the ACSELERATOR software to view event reports. See *Event Reports, Summaries, and Histories on page A.3.6* for a complete discussion of event reports.

Event Summary Reports

The relay generates an event summary for each event report; use these event summaries to quickly check relay operation. With event summaries, you can quickly compare the reported fault current and voltage magnitudes and angles against the reported fault location and fault type. If you question the relay response or your test method, you can obtain the full event report for a more detailed analysis.

SER Reports

The relay provides an SER report that time tags changes in relay elements, control inputs, and control outputs. Use the SER for convenient verification of the pickup and dropout of any relay element. For a complete discussion of the SER, see *SER (Sequential Events Recorder) on page A.3.31*.

Test Commands

TAR Command

Use the **TAR** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. You can see relay targets at the serial ports and from the front-panel LCD. See *TARGET on page R.7.42* and *Operation and Target LEDs on page U.5.32*.

PUL Command

Use the **PUL** command to test the control output circuits. The specified output closes if open or opens if closed. You can use the **PUL** command from the front-panel LCD. See *PULSE on page R.7.29*.

TEST DB Command

Use the **TEST DB** command for testing the communications card relay database. The **TEST DB** command can be used to override any value in the relay database. Since the relay database provides data to the communications card interfaces, the **TEST DB** command can also be used to test the data read operations of the DNP3, LAN/WAN or IEC 61850 protocols on an installed Ethernet card. Use the **MAP 1** command and the **VIEW1** command to inspect the relay database (see *MAP on page R.7.21 in the Reference Manual* and *VIEW on page R.7.50 in the Reference Manual*). You must be familiar with the relay database structure to use the **TEST DB** command effectively.

TEST DNP Command

Use the **TEST DNP** command to test the serial DNP3 interface. Values you enter in the DNP3 map are override values. Use the **TEST DNP** command to write override values in the serial DNP3 map. For more information on serial DNP3 and the SEL-487B, see *Section 5: DNP3 Communications in the Reference Manual*.

TEST FM Command

Use the **TEST FM** command to override normal Fast Meter quantities for testing purposes. You can only override reported Fast Meter values (voltages and currents). For more information on Fast Meter and the SEL-487B, see *Section 7: ASCII Command Reference in the Reference Manual*.

TEST Switch

When testing the relay, use front-panel PB4 (labeled {RELAY TEST MODE}) to disable the trip output from the relay. All protection elements are available for testing, but the pushbutton prevents the output contacts from asserting. This pushbutton only asserts after a time delay of approximately half a second to prevent the inadvertent assertion of the pushbutton. Output OUT107 asserts when **PB4** asserts and can be used to assert an alarm.

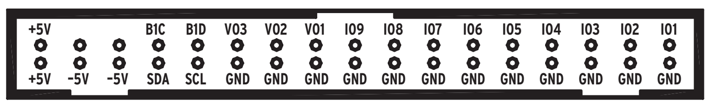
Low-Level Test Interface

The SEL-487B has a low-level test interface between the two calibrated input modules and the processing module. You can test the relay in two ways: by using secondary injection testing or by applying low-magnitude ac voltage signals to the low-level test interface.

Access the test interface by removing the relay front panel. At the right side of the relay main board is the processing module. Inputs to the processing module are multipin connectors J20 and J21, the analog or low-level test interface connections. Receptacle J20 is on the right side of the main board, with J21 located 5 cm (2 inches) behind J20; for a locating diagram, see *Figure 2.11*.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Figure 6.1 shows the connections for low-level interface J20 and *Figure 6.2* the connections for low-level interface J21. Apply only the nominal voltage levels and current levels listed in the figures to the relay. Never apply voltage signals greater than 6.6 V peak-to-peak sinusoidal signal (2.33 Vrms) to the low-level test interface. To use the low-level test interface, remove the ribbon cable from the main board J20 and J21 receptacles and substitute a test cable with the signals specified in *Figure 6.1* and *Figure 6.2*.

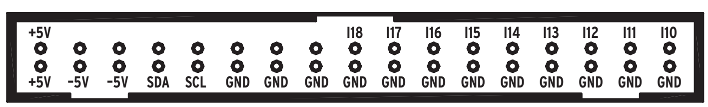


Input Module Output (J3): 66.6 mV at Nominal Current (1 A or 5 A).
446 mV at Nominal Voltage (67 V_{LN}).

Processing Module Input (J20): 6.6 V_{p-p} Maximum.

U.S. Patent 5,479,315.

Figure 6.1 Low-Level Test Interface J20



Input Module Output (J3): 66.6 mV at Nominal Current (1 A or 5 A).
446 mV at Nominal Voltage (67 V_{LN}).

Processing Module Input (J21): 6.6 V_{p-p} Maximum.

U.S. Patent 5,479,315.

Figure 6.2 Low-Level Test Interface J21

Main Board Processing Module Tests

Use signals from the Low-Level Relay Test System to test the relay processing module. Apply appropriate signals to the low-level test interface connections J20 and J21 from the Relay Test System (see *Figure 6.1*and *Figure 6.2*). These signals simulate power system conditions, taking into account PT ratio and CT ratio scaling. Use relay metering to determine whether the applied test voltages and currents produce correct relay operating quantities. The UUT Database entries for the SEL-487B in the SEL-5401 Relay Test System Software are shown in *Table 6.4*, *Table 6.5*, *Table 6.6*, and *Table 6.7*.

Table 6.4 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Y)—5 A Relay

Channel	Label	Scale Factor	Unit
1	I01	75	A
2	I02	75	A
3	I03	75	A
4	I04	75	A
5	I05	75	A
6	I06	75	A
7	I07	75	A
8	I08	75	A
9	I09	75	A
10	V01	150	V
11	V02	150	V
12	V03	150	V

Table 6.5 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—5 A Relay

Channel	Label	Scale Factor	Unit
1	I10	75	A
2	I11	75	A
3	I12	75	A
4	I13	75	A
5	I14	75	A
6	I15	75	A
7	I16	75	A
8	I17	75	A
9	I18	75	A

Table 6.6 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Y)—1 A Relay

Channel	Label	Scale Factor	Unit
1	I01	15	A
2	I02	15	A
3	I03	15	A
4	I04	15	A
5	I05	15	A
6	I06	15	A
7	I07	15	A
8	I08	15	A
9	I09	15	A
10	V01	150	V
11	V02	150	V
12	V03	150	V

Table 6.7 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—1 A Relay

Channel	Label	Scale Factor	Unit
1	I10	15	A
2	I11	15	A
3	I12	15	A
4	I13	15	A
5	I14	15	A
6	I15	15	A
7	I16	15	A
8	I17	15	A
9	I18	15	A

Test Methods

Use the following methods to conveniently test the pickup and dropout of relay elements and other relay functions:

- Target indications (element pickup/dropout)
- Control output closures
- SER reports

The tests and procedures in the following subsections are for 5 A relays. Scale values appropriately for 1 A relays. The CD included with purchase of your SEL-487B contains text files with the relay default settings. On completion of each test, use the **FILE WRITE** command to reload the default settings. See *Section 7: ASCII Command Reference in the Reference Manual* for more information.

Testing With Targets

Use the communications port **TAR** command or the front panel to display the state of relay elements, control inputs, and control outputs. Viewing a change in relay element (Relay Word bit) status is a good way to verify the pickup settings you have entered for protection elements.

View Relay Elements With Terminal Emulation Software

Use the procedure in the following steps to view a change in state of Relay Word bit I01BZ1V from a communications port. When Relay Word bit I01BZ1V asserts, the relay considers the current input from Terminal I01 in the differential calculations of Bus-Zone 1. The relay does not consider the current input from Terminal I01 in the differential calculations of Bus-Zone 1 when Relay Word bit I01BZ1V deasserts. See *Bus-Zone Configurations on page A.1.21*. From Access Level 2, use the **SHO Z** command to generate a report of the default values of the zone configuration settings. *Figure 6.3* shows an extract of the relay response.

```
=>>SHO Z <Enter>
Zone Config Group 1

.
.
.

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := FDR_1, BUS_1, P
FDR_1 to BUS_1 Connection (SELogic Equation)
I01BZ1V := DIFF_EN AND NOT TOS01
.
.
.

=>>
```

Figure 6.3 An Extract of the Relay Response to the SHO Z Command

From *Figure 6.3*, we see that Relay Word bit I01BZ1V becomes a logical 1 when DIFF_EN asserts and while TOS01 is not asserted. DIFF_EN is the front-panel pushbutton labeled {87 (DIFF) ENABLED}. The pushbutton settings include a short time delay to prevent an inadvertent assertion of Relay Word bit I01BZ1V. Press the pushbutton for half a second before the Relay Word bit asserts.

For this procedure, you must have a computer with terminal emulation software and a variable current source for relay testing. This example assumes that you have successfully established communications with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for a step-by-step procedure. Review *Changing the Default Passwords on page U.4.6* for information on how to change the default access level passwords and enter higher relay access levels.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

Step 2. View the initial element status.

a. Type **TAR I01BZ1V <Enter>**.

The relay returns a target terminal screen similar to *Figure 6.4*.

```
=>>TAR I01BZ1V <Enter>

I08BZ1V I07BZ1V I06BZ1V I05BZ1V I04BZ1V I03BZ1V I02BZ1V I01BZ1V
0       0       0       0       0       0       0       0

=>>
```

Figure 6.4 Sample Targets Display on a Serial Terminal

Step 3. View the element status change.

a. Type **TAR I01BZ1V 1000 <Enter>**.

This command causes the relay to repeat the **TAR I01BZ1V** command 1000 times.

b. Push the front-panel pushbutton labeled {87 (DIFF) ENABLED} for longer than half a second.

You will see Relay Word bit I01BZ1V (as well as Relay Word bits I05BZ1V and I02BZ1V) change status from a logical 0 to a logical 1 after half a second.

c. Press pushbutton **{87 (DIFF) ENABLED}** one more time. All Relay Word bits will deassert.

d. Press **<Ctrl+X>** to stop the relay from presenting the target display before completion of the 1000 target repeats.

View Relay Elements With the Front-Panel LCD

You can use the front-panel display and navigation pushbuttons to check Relay Word bit elements. See *Section 5: Front-Panel Operations* for more information on using the relay front panel. The following procedure again uses Relay Word bit I01BZ1V as an example.

Step 1. Display the `MAIN MENU`.

a. If the relay LCD is in the `ROTATING DISPLAY`, press the **{ENT}** pushbutton to display the `MAIN MENU` similar to the first screen of *Figure 6.5*.

Step 2. Prepare to view the elements on the front-panel LCD.

a. Press the **{Down Arrow}** navigation pushbutton to highlight the `RELAY ELEMENTS` action item (see the first screen of *Figure 6.5*).

b. Press the **{ENT}** pushbutton. You will see a `RELAY ELEMENTS` screen (the second screen of *Figure 6.5*).

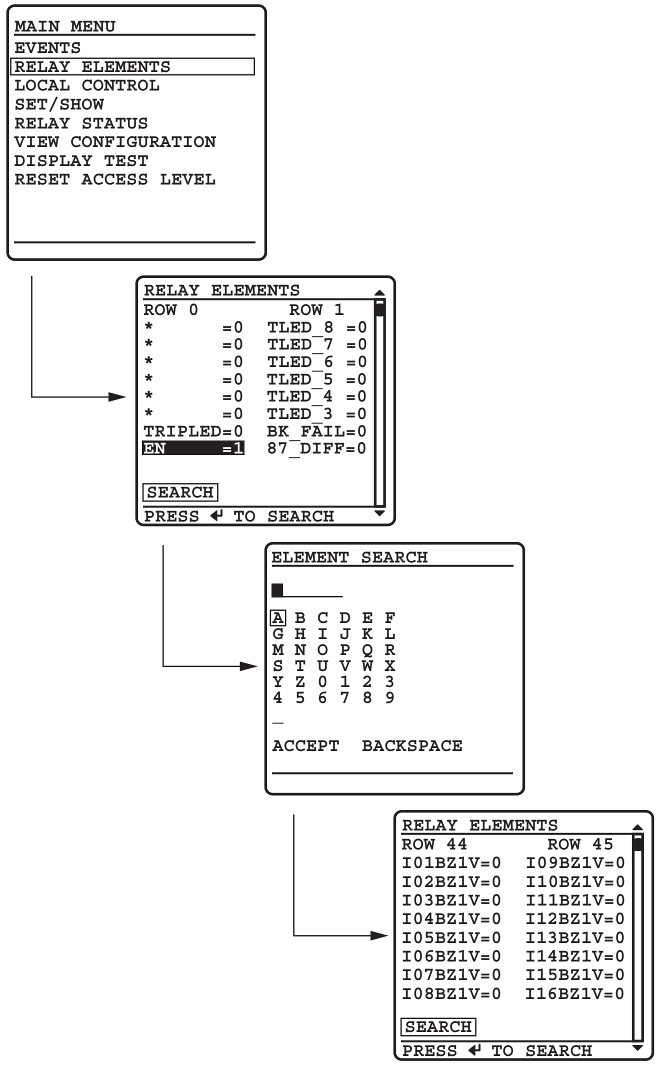


Figure 6.5 Viewing Relay Word Bits From the Front-Panel LCD

Step 3. Display Relay Word bit I01BZ1V on the front-panel LCD screen.

a. Press **{ENT}** to go to the `ELEMENT SEARCH` submenu of *Figure 6.5*.

b. Use the navigation keys to highlight `I` and then press **{ENT}** to enter the character `I` in the text input field.

c. Enter the `0`, `1`, `B`, `Z`, `1`, and `V` characters in the same manner.

d. Press **{ENT}** when the cursor jumps to `ACCEPT`. The relay displays the LCD screen containing the `I01BZ1V` element, as shown in the last screen of *Figure 6.5*.

Step 4. View the target status change.

a. Push the front-panel pushbutton labeled **{87 (DIFF) ENABLED}** for at least half a second.

b. Observe the `I01BZ1V` target on the front-panel display.

You will see the I01BZ1V element status change to 1 after half a second (I02BZ1V and I05BZ1V also assert because pushbutton **{87 (DIFF) ENABLED}** also controls these equations).

Step 5. Press pushbutton **{87 (DIFF) ENABLED}** once more. The Relay Word bits will deassert.

Step 6. Press **{ESC}** to return to the MAIN MENU.

View Relay Element Change With a Front-Panel LED

The following procedure is an example of how to use a front-panel LED to view a change-in-state for Relay Word bit I01BZ1V.

Step 1. Establish Level 2 communications with the relay.

Step 2. Set a pushbutton LED SELOGIC® control equation.

Figure 6.6 shows the steps involved in configuring the LED of front-panel pushbutton **{PB3_LED}** to assert when Relay Word bit I01BZ1V asserts.

a. From Access Level 2, use the serial port command **SET F** and press **<Enter>** three times.

b. Enter **I01BZ1V <Enter>** at the ? prompt for pushbutton PB3_LED.

c. Enter **END <Enter>** at the next prompt and **Y <Enter>** to save settings.

```
=>>SET F <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)       FP_TO   := 15     ? <Enter>
Pushbutton LED 1 (SELogic Equation)
PB1_LED := DIFF_EN # Differential Protection Enabled
? <Enter>
Pushbutton LED 2 (SELogic Equation)
PB2_LED := BF_EN # Breaker Failure Enabled
? <Enter>
Pushbutton LED 3 (SELogic Equation)
PB3_LED := NA
?  I01BZ1V <Enter>
Pushbutton LED 4 (SELogic Equation)
PB4_LED := TNS_SW # Test normal Switch Enabled
?  END <Enter>
Front Panel

Front Panel Settings

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.6 Assigning Relay Word Bit I01BZ1V to Pushbutton LED 3

Step 3. Push the front-panel pushbutton labeled **{87 (DIFF) ENABLED}** for longer than half a second. Both LED 1 (**{PB1}**) and LED 3 (**{PB3}**) assert after half a second.

Step 4. Press pushbutton **{87 (DIFF) ENABLED}** once more. Both LEDs deassert.

Step 5. Repeat *Step 2* and set PB3_LED = NA.

Testing With Control Outputs

You can set the relay to operate a control output to test a single element. Set the SELOGIC control equation for a particular output (OUT101 through OUT108, for example) to respond to the Relay Word bit for the element under test. See *Operating the Relay Inputs and Outputs on page U.4.40* for information on configuring control inputs and control outputs. *Appendix A: Relay Word Bits in the Reference Manual* lists the names of the relay element logic outputs.

Testing Relay Word Bit I01BZ1V With a Control Output

The following procedure is an example of how to set control output OUT106 to test Relay Word bit I01BZ1V. You must have a computer communicating with the SEL-487B and a device such as a test set or a VOM (volt ohmmeter) to indicate control output closure.

Step 1. Establish Level 2 communications with the relay.

Step 2. Type **SHO O <Enter>** to view output settings.

Figure 6.7 shows an extract of the relay response to the **SHO O** command, from which we see that output contact OUT106 of the main board is not used.

```
=>>SHO O <Enter>
Output

Main Board

OUT101  := TRIP01 AND NOT TNS_SW
OUT102  := TRIP02 AND NOT TNS_SW
OUT103  := TRIP03 AND NOT TNS_SW
OUT104  := TRIP04 AND NOT TNS_SW
OUT105  := TRIP05 AND NOT TNS_SW
OUT106  := NA
OUT107  := TNS_SW #RELAY TEST MODE
OUT108  := NOT (SALARM OR HALARM)

.
.
.

=>>
```

Figure 6.7 Relay Response to the SHO O Command, Showing the Main Board Information

Step 3. Assign Relay Word bit I01BZ1V to output contact OUT106 on the main board.

a. Type **SET O OUT106 <Enter>**, followed by **I01BZ1V <Enter>** at the prompt.

b. Type **END <Enter>** and **Y <Enter>** to save the settings. *Figure 6.8* shows the steps.

```
=>>SET O OUT106 <Enter>
Output

Main Board

OUT106 := NA
?  I01BZ1V <Enter>

OUT107 := TNS_SW #RELAY TEST MODE
?  END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 6.8 Steps to Assign Relay Word Bit I01BZ1V to the Main Board Output Contact OUT106

Step 4. Connect an indicating device to OUT106 on the relay rear panel. A VOM multitester on a low resistance scale can indicate an OUT106 control output closure.

Step 5. Push the front-panel pushbutton labeled {87 (DIFF) ENABLED} for longer than half a second.

When the pushbutton asserts, Relay Word bit I01BZ1V changes to logical 1 and closes the output contacts of control output OUT106. The indicating device operates.

Step 6. Push pushbutton {87 (DIFF) ENABLED} once more. Output contact OUT106 will deassert.

Step 7. Type **SET O OUT 106 <Enter>**.

Step 8. Set OUT106 to NA.

Step 9. Save the settings.

Testing With SER

You can set the relay to generate a report from the SER to test relay elements.

Use the **SET R** command to enter the elements that you want to test in the SER points.

Step 1. Type **SET R <Enter>**.

Step 2. Give descriptive names for the set state and clear state in the SEL-487B SER to simplify reading of the SER report.

See *SER (Sequential Events Recorder) on page A.3.31* for complete information on the SER.

Using SER to Test Overcurrent Elements

This test combines the SER test with inverse-time overcurrent element and definite-time overcurrent element tests. Each of the 18 terminals has an inverse-time overcurrent element as well as a definite-time overcurrent element. For this example, we will test the definite-time overcurrent element of Terminal 02 and the inverse-time overcurrent element of Terminal 01. The SER gives exact time data for testing time-overcurrent element timeouts. Subtract the time-delayed element (50P02T and 51P01T) assertion times from the instantaneous pick-up element (50P02 and 51P01) assertion times to check the operating time of the elements. Use factory default settings of the elements for the test.

The procedure in the following example shows how to set the SER trigger lists to capture the operating times of the overcurrent elements. The relay uses *Equation 6.1* and *Equation 6.2* to determine the operating time, t_p, for the 51P01 element. For a current input 50 percent greater than the default pickup, the test value, I_{TEST}, is shown below:

$$I_{TEST} = M \bullet 51P01P = 1.5 \bullet 0.5 = 0.75A \quad \textbf{Equation 6.1}$$

where:

M = The pickup multiple
51P01P = The element default pickup value (see *Table 6.8*)

Table 6.8 Time-Overcurrent Element (51P01) Default Settings

Setting	Description	Default 5 A
51P01P	Overcurrent Pickup (0.5–16 amps, secondary)	0.5
51P01C	Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U1
51P01TD	Inverse-Time Overcurrent Time Dial (0.50–15)	0.5
51P01RS	Inverse-Time Overcurrent EM Reset (Y, N)	Y
51P01TC	Inverse-Time Overcurrent Torque Cont (SELOGIC control equation)	1

The operating time (t_p) for a time dial (T_D) equal to 0.5 for the U1 (Moderately Inverse) Curve is:

$$\begin{aligned} t_p &= TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right) \text{seconds} \\ &= 0.5 \bullet \left(0.0226 + \frac{0.0104}{1.5^{0.02} - 1}\right) \text{seconds} \\ &= 0.650 \text{ seconds} \end{aligned} \quad \textbf{Equation 6.2}$$

where:

TD = Time dial

For more information on inverse-time overcurrent elements, see *Inverse Time-Overcurrent Elements on page R.1.18*. For this example, you need a computer communicating with the SEL-487B and a variable current source for relay testing.

Step 1. Establish Level 2 communications with the relay.

Step 2. Enable overcurrent elements by typing the commands as shown in *Figure 6.9*.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?2 <Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N       ?1 <Enter>
Voltage Elements (Y,N)                               EVOLT   := Y       ?> <Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Definite Time Overcurrent Elements

Terminal 01 Pickup (OFF, 0.25-100 amps,sec)          50P01P  := OFF     ? <Enter>
Terminal 02 Pickup (OFF, 0.25-100 amps,sec)          50P02P  := OFF     ?0.5 <Enter>
Terminal 02 Pickup Delay (0.00-99999 cyc)            50P02D  := 10.00   ?60 <Enter>
Inverse Time Overcurrent Element 01
51P01 O/C Pickup (0.50-16 amps,sec)                  51P01P  := 0.50    ?0.5 <Enter>
51P01 Inv-Time O/C Curve (U1-U5,C1-C5)               51P01C  := U1      ?END <Enter>
Group 1
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.9 Setting Change Description to Enable Overcurrent Elements 51P01 and 51P02

Step 3. Enter SER information. *Figure 6.10* shows how to use the **SET R** command to enter the four Relay Word bits, 51P01, 51P01T, 50P02, and 50P02T, the reporting names, set names, and clear names into the relay.

```
=>>SET R <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N       ? <Enter>

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name)

1:
?  51P01,"I01 TOC","Picked up" <Enter>
2:
?  51P01T,"I01 TOC Trip","Timed out" <Enter>
3:
?  50P02,"I02 Def. O/C","Picked up" <Enter>
4:
?  50P02T,"I02 Def. O/C Trip","Timed out" <Enter>
5:
?  END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........

=>>
```

Figure 6.10 Using the SET R Command to Enter SER Information

Step 4. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to analog input I01 and analog input I02, as shown in *Figure 6.11*.

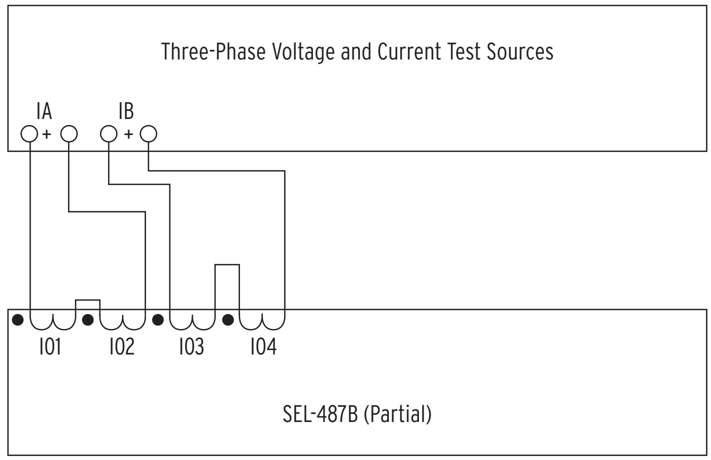


Figure 6.11 Test Connections Using Two Current Sources

Step 5. Type **SER C <Enter>**, **Y <Enter>** to clear the SER.

Step 6. Test the element.

a. Inject IA = 0.75 A and IB = 0.75 A into the relay, and keep the current source at this level longer than one second.

b. Return the current source to zero after the elements time out.

Step 7. Type **SER <Enter>** to produce an SER report (similar to that shown in *Figure 6.12*) that you can examine.

```
=>>SER <Enter>

Relay 1                                    Date: 07/24/2003  Time: 14:19:26.674
Station A                                  Serial Number: 2003005010

FID=SEL-487B-R102-V0-Z001001-D20030724

#      DATE        TIME          ELEMENT             STATE
8    04/09/2003  14:19:22.110   I02 Def. O/C        Picked up
7    04/09/2003  14:19:22.110   I01 TOC             Picked up
6    04/09/2003  14:19:22.773   I01 TOC Trip        Timed out
5    04/09/2003  14:19:23.110   I02 Def. O/C Trip   Timed out
4    04/09/2003  14:19:23.982   I02 Def. O/C        Deasserted
3    04/09/2003  14:19:23.982   I02 Def. O/C Trip   Deasserted
2    04/09/2003  14:19:23.982   I01 TOC             Deasserted
1    04/09/2003  14:19:23.982   I01 TOC Trip        Deasserted

=>>
```

Figure 6.12 Relay Response to the SER Command, Showing the TOC and Definite-Time Element Operations

Step 8. Use the SER data Point 5 and Point 8 to calculate the element operating time of the definite-time element as follows:

Operating time = Timed out–Picked up

Operating time = 23.110–22.110

Operating time = 1.0 second

Step 9. Use the SER data Point 6 and Point 7 to calculate the element operating time of the TOC element as follows:

Operating time = Timed out–Picked up

Operating time = 22.773–22.110

Operating time = 0.663 seconds

Step 10. Apply the default settings.

Checking Relay Operation

Your SEL-487B comes with all functions fully checked and calibrated so that the relay operates correctly and accurately. You can test the relay to verify proper relay operation, but you do not need to test every relay element, timer, and function in this evaluation. The following checks are valuable for confirming proper SEL-487B connections and operation:

➤ AC connection check (metering)

➤ Commissioning tests

➤ Functional tests

➤ Element verification

An ac connection check uses relay metering to verify that the relay current and voltage inputs have the proper magnitude and phase angle (see *Examining Metering Quantities on page U.4.31*). Commissioning tests help you verify that you have properly connected the relay to the power system and all auxiliary equipment. These tests confirm proper connection of control inputs and control outputs as well (see *Operating the Relay Inputs and Outputs on page U.4.40*). Brief functional tests and element verification confirm correct internal relay processing.

This subsection discusses tests for the following:

➤ Alias settings

➤ Zone selection function

➤ Sensitive differential elements

➤ Differential elements

➤ Directional element

➤ Voltage elements

Before you perform element tests, however, you should be aware of your substation layout, and you should apply the appropriate settings to the relay.

Example Substation

Figure 6.13 shows an example of a substation that requires two protection zones. The station layout consists of two busbars (BUS_1 and BUS_2), a tie breaker (TB_1 and TB_2), and two feeders (FDR_1 and FDR_2).

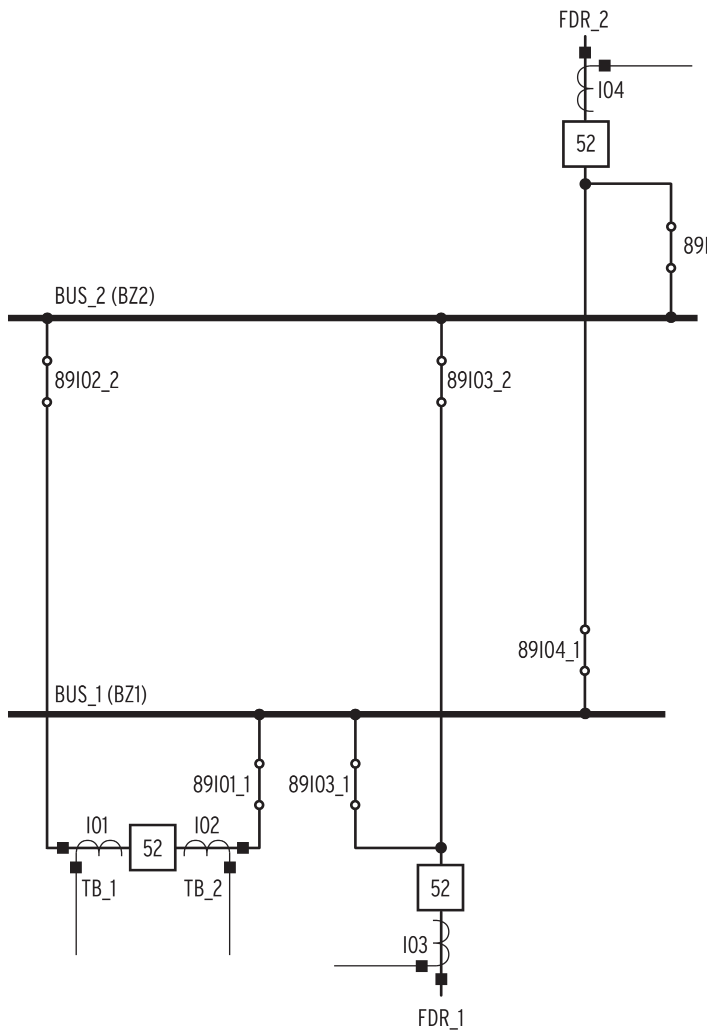


Figure 6.13 Station Layout, Comprising a Tie Breaker, Two Feeders and Two Busbars

Use front-panel pushbuttons to simulate the disconnect auxiliary contacts for the terminal-to-bus-zone SELOGIC control equations as shown in *Figure 6.14*. *Table 6.9 on page U.6.20* shows the SELOGIC control equation assignments.

NOTE: Pushbutton labels PB1 through PB8 (shown in Figure 6.14) identify the pushbuttons for this test; these labels do not appear on the relay front panel.

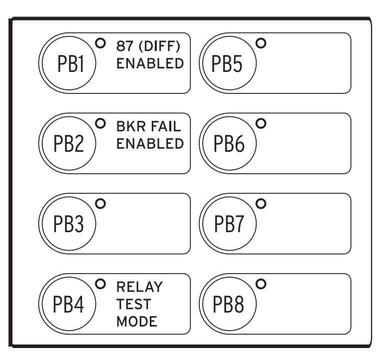


Figure 6.14 Front-Panel Operator Pushbuttons

Table 6.9 Pushbutton Assignments to Simulate Disconnect Auxiliary Contacts

Pushbutton	Relay Word Bits	Description
PB5	I01BZ1V	Connects TB_1 to BUS_1 when closed
PB6	I02BZ2V	Connects TB_2 to BUS_2 when closed
PB7	I03BZ1V	Connects FDR_1 to BUS_1 when closed
PB8	I04BZ2V	Connects FDR_2 to BUS_2 when closed

Relay Settings

Apply the appropriate settings to the relay. For the relay to match the station layout in *Figure 6.13*, change the following setting categories:

- ➤ Alias settings
- ➤ Zone configuration settings
- ➤ Protection group settings
- ➤ Protection logic settings
- ➤ Front-panel settings

Alias Settings

Change the default alias names for the four analog channels to the names indicated in *Figure 6.14*. From Access Level 2, use the **SET T** command to rename the analog channels, as shown in *Figure 6.15*.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  I01,TB_1 <Enter>
2: I02,"FDR_2"
?  I02,TB_2 <Enter>
3: I03,"FDR_3"
?  I03,FDR_1 <Enter>
4: I04,"TRFR_1"
?  I04,FDR_2 <Enter>
5: I05,"TB_1"
?  DELETE <Enter>
5: I06,"TB_2"
?  DELETE <Enter>
5: BZ1,"BUS_1"
?  END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.15 Alias Names for the Four Analog Channels

Zone Configuration Settings

Set the terminal-to-bus-zone connections to determine when the input currents from the terminals are considered in the differential calculations. We use protection latch bits in the terminal-to-bus-zone connections to emulate disconnect auxiliary contacts (see *Protection Logic Settings*). *Figure 6.16* shows the steps to enter the zone configuration settings.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000    ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600     ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TB_1, BUS_1, P
?  TB_1,BUS_1,P <Enter>
TB_1 to BUS_1 Connection (SELogic Equation)
I01BZ1V := DIFF_EN AND NOT TOS01
?  PLT05 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
I02BZ1C := TB_2, BUS_1, P
?  TB_2,BUS_2,P <Enter>
TB_2 to BUS_2 Connection (SELogic Equation)
I02BZ2V := NA
?  PLT06 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
I03BZ2C := FDR_1, BUS_2, P
?  FDR_1,BUS_1,P <Enter>
FDR_1 to BUS_1 Connection (SELogic Equation)
I03BZ1V := NA
?  PLT07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
I04BZ2C := FDR_2, BUS_2, P
?  FDR_2,BUS_2,P <Enter>
FDR_2 to BUS_2 Connection (SELogic Equation)
I04BZ2V := DIFF_EN AND NOT TOS04
?  PLT08 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
I05BZ1C := I05, BUS_1, P
?  END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.16 Zone Configuration Settings

Protection Group Settings

The sensitive differential element default settings block the differential elements from operating during CT open-circuit conditions. Disable the sensitive differential elements to prevent these elements from blocking the differential elements when we inject unbalanced test values. *Figure 6.17* shows the steps to disable the sensitive differential elements.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?N <Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?END <Enter>
Group 1

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.17 Steps to Disable the Sensitive Differential Elements

Protection Logic Settings

We use four protection latch bits, operated from four front-panel pushbuttons to simulate disconnect auxiliary contacts. *Figure 6.18* shows the steps to program the protection latch bits.

```
=>>SET L <Enter>
Protection 1
1: PLT01S := NOT DIFF_EN AND PLT04 # DIFFERENTIAL ENABLED
?  > <Enter>
21:
?  PLT07S:=PB5_PUL AND NOT PLT07 <Enter>
22:
?  PLT07R:=PB5_PUL AND PLT07 <Enter>
23:
?  PLT08S:=PB6_PUL AND NOT PLT08 <Enter>
24:
?  PLT08R:=PB6_PUL AND PLT08 <Enter>
25:
?  PLT09S:=PB7_PUL AND NOT PLT09 <Enter>
26:
?  PLT09R:=PB7_PUL AND PLT09 <Enter>
27:
?  PLT10S:=PB8_PUL AND NOT PLT10 <Enter>
28:
?  PLT10R:=PB8_PUL AND PLT10 <Enter>
29:
?  END <Enter>
Protection 1
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 6.18 Steps to Program Protection Latch Bits

Front-Panel Settings

We use four protection latch bits, operated from four front-panel pushbuttons to simulate disconnect auxiliary contacts. Each front-panel pushbutton has an LED in close proximity to the pushbutton. Program these LEDs to illuminate when the pushbuttons are in the closed position. Pushbutton assertion simulates closing disconnect auxiliary contacts, assigning the input currents to the appropriate differential elements. *Figure 6.19* shows the steps to program the LEDs.

```
=>>SET F <Enter>
Front Panel
Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)        FP_TO   := 15     ? <Enter>
Pushbutton LED 1 (SELogic Equation)
PB1_LED := DIFF_EN # Differential Protection Enabled
? <Enter>
Pushbutton LED 2 (SELogic Equation)
PB2_LED := BF_EN # Breaker Failure Enabled
? <Enter>
Pushbutton LED 3 (SELogic Equation)
PB3_LED := NA
? <Enter>
Pushbutton LED 4 (SELogic Equation)
PB4_LED := TNS_SW # Test Normal Switch Enabled
? <Enter>
Pushbutton LED 5 (SELogic Equation)
PB5_LED := NA
?  PLT05 <Enter>
Pushbutton LED 6 (SELogic Equation)
PB6_LED := NA
?  PLT06 <Enter>
Pushbutton LED 7 (SELogic Equation)
PB7_LED := NA
?  PLT07 <Enter>
Pushbutton LED 8 (SELogic Equation)
PB8_LED := NA
?  PLT08 <Enter>
Target LED 1 (SELogic Equation)
T1_LED := 87BTR
?  END <Enter>
Front Panel

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.19 Steps to Program the LEDs

Verify the Relay Settings

Step 1. Use the serial port **SHO Z** ASCII command to generate a report similar to that shown in *Figure 6.20*.

Information shown in *Figure 6.20* is an extract of important settings, not the complete relay response.

Step 2. In particular, verify the following values:

a. PTR1, PTR2, and PTR3 are all equal to 2000.

b. CTR01, CTR02, CTR03, and CTR04 are all equal to 600.

c. TAP01, TAP02, TAP03, and TAP04 are all equal to 5.

d. The terminal-to-bus-zone settings are as shown.

```
=>>SHO Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

PTR1    := 2000     PTR2    := 2000     PTR3    := 2000

Current Transformer Ratio

CTR01   := 600      CTR02   := 600      CTR03   := 600      CTR04   := 600

.
.
.

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TB_1, BUS_1, P
FDR_1 to BUS_1 Connection (SELogic Equation)
I01BZ1V := PLT05
Terminal, Bus-Zone, Polarity (P,N)
I02BZ2C := TB_2, BUS_2, P
FDR_2 to BUS_2 Connection (SELogic Equation)
I02BZ2V := PLT06
Terminal, Bus-Zone, Polarity (P,N)
I03BZ1C := FDR_1, BUS_1, P
FDR_3 to BUS_1 Connection (SELogic Equation)
I03BZ1V := PLT07
Terminal, Bus-Zone, Polarity (P,N)
I04BZ2C := FDR_2, BUS_2, P
TRFR_1 to BUS_2 Connection (SELogic Equation)
I04BZ2V := PLT08

.
.
.

TAP01   := 5.00     TAP02   := 5.00     TAP03   := 5.00     TAP04   := 5.00
TAP05   := 5.00     TAP06   := 5.00
=>>
```

Figure 6.20 Selected Information From the Relay Response to the SHO Z Command

Selected Element Tests

Zone Selection Function

Step 1. Test the zone selection logic (terminal-to-bus-zone connection).

a. Press the **{PB5}** pushbutton to simulate the closing of disconnect 89I01_1, assigning TB_1 to BUS_1.

b. Confirm that the relay assigns Terminal TB_1 to BUS_1, and includes the bus-zone BUS_1 in Protection Zone 1.

c. Type **MET Z1 <Enter>** to generate a Zone 1 meter report.

Figure 6.21 shows the relay response, confirming that Terminal TB_1 is an active terminal in BUS_1.

NOTE: 5 A relays are rated for continuous current injection of 15 A.

NOTE: When a terminal is active, the terminal name appears under the heading "Primary Currents." The heading "Bus-Zones in Protection Zone 1" shows the Bus-Zones in Protection Zone 1.

```
=>>MET Z1 <Enter>

Relay 1                                     Date: 02/21/2003  Time: 10:24:38.363
Station A                                   Serial Number: 2003001324

Current Terminals in Protection Zone 1

Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 TB_1        0.800    -5.54    P

Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01         0.011   -36.01
 V02         0.006    59.56
 V03         0.011   147.47

Bus-Zones in Protection Zone 1
BUS_1

=>>
```

Figure 6.21 Relay Response to the MET Z1 Command

Sensitive Differential Element

Step 1. Use the test connections shown in *Figure 6.11* for this test.

Step 2. Inject the current values listed in *Table 6.10* into the relay.

Table 6.10 Current for Testing the Threshold Point, O87P

Current	Value
IA	4.8∠0°
IB	4.8∠180°

Current flows through all four terminals, but because only the {PB5} pushbutton (*Step 1*, *Step a on page U.6.24*) is closed, the relay only considers the CT input from TB_1.

The CT ALARM LED asserts after approximately five seconds, and the relay triggers an event report. The relay does not trip, because the differential current is below the O87P threshold.

Step 3. Stop the injection. The CT ALARM LED deasserts.

Differential Elements

The following test verifies the characteristics for two of the six differential elements in the SEL-487B. The test plots the relay characteristic at two points. The first point is at the pickup threshold (O87P); the second point is at three per-unit restraint current. Three per unit is an arbitrary value; you may use any other convenient restraint current value.

Figure 6.22 shows the default O87P setting and the default Slope 1 setting.

Use the following equation to calculate IOP(IRT), the operating current value for any specified restraint current value:

$$\text{IOP(IRT)} = \frac{\text{SLP1}}{100} \bullet \text{IRT}$$

Equation 6.3

where:

IOP(IRT) = Operating current as a function of the restraint current
SLP1 = Differential element Slope 1 setting
IRT = Differential element restraint current

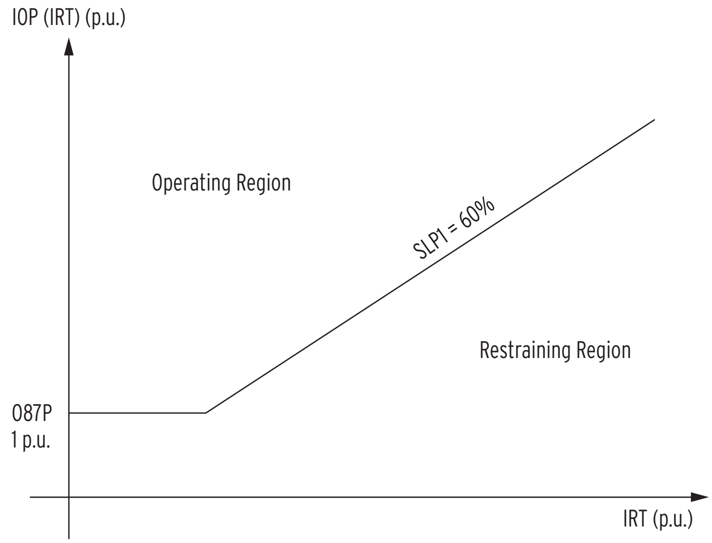


Figure 6.22 Differential Element Characteristic

Test the first point on the differential element characteristic.

Step 1. Obtain the operate current value and restraint current value.

a. Inject the current values listed in *Table 6.10* into the relay.

b. Type **MET DIF <Enter>**.

The current values should approximate those shown in *Figure 6.23*:

```
=>>MET DIF <Enter>

Relay 1                                      Date: 02/20/2003  Time: 16:58:30.046
Station A                                    Serial Number: 2003001324

Operate Currents     Restraint Currents
          (Per Unit)           (Per Unit)
ZONE          IOP                  IRT
  1           0.96                 0.96
  2           0.00                 0.00
Current Reference (A)
IREF
3000

=>>
```

Figure 6.23 Example Values Below the 87O1 Element Pickup Value in Response to the MET DIF Command

Step 2. Test the threshold point, O87P. (Pushbutton {PB5} is still asserted.)

a. Type **TAR 87O1 9999 <Enter>** to monitor the status of Relay Word bit 87O1.

b. Increase current IA until the status of Relay Word bit 87O1 changes from logical 0 to logical 1.

When the bit changes state, the TRIP, 87 (DIFF), and ZONE 1 LEDs illuminate.

c. Record the value of the injected current.

This value should be 5 A ±5% and ±0.02 • I_{NOM}.

d. Type **<Ctrl>X** to end the scrolling of Relay Word bit 87O1 status values.

e. Type **MET DIF <Enter>** to obtain the differential operate current value and differential restraint current value.

These values should approximate the differential operate current values and differential restraint current values shown in *Figure 6.24*.

f. Stop the injection.

g. Press the **{TARGET RESET}** pushbutton.

```
=>>MET DIF <Enter>

Relay 1                                     Date: 02/21/2003  Time: 10:41:35.989

Station A                                   Serial Number: 2003001324

Operate Currents     Restraint Currents
           (Per Unit)           (Per Unit)
ZONE          IOP                  IRT
  1           1.02                 1.02
  2           0.00                 0.00

Current Reference (A)
IREF
3000

=>>
```

Figure 6.24 Example Values Above the 87O1 Element Pickup Value in Response to the MET DIF Command

Test the second point on Zone 1 and Zone 2 differential element characteristic.

Step 1. Use *Equation 6.3* to calculate the per-unit operating current for a restraint current of 3 per unit.

This operating current is for the second point on the differential characteristic.

$$\begin{aligned}\text{IOP(IRT)} &= \frac{\text{SLP1}}{100} \bullet \text{IRT} \\ &= 0.6 \bullet 3 \text{ per unit} \\ &= 1.8 \text{ per unit}\end{aligned}$$

Step 2. Use *Equation 6.4* and *Equation 6.5* to calculate the two current values that result in an operating current of 1.8 per unit at a restraint current of 3 per unit.

$$\begin{aligned}I1_{pu} &= \frac{\text{IRT} + \text{IOP(IRT)}}{2} \text{per unit} \\ &= \frac{3.0 + 1.8}{2} \text{per unit} \\ &= 2.4 \text{ per unit}\end{aligned}$$

Equation 6.4

$$\begin{aligned}I2_{pu} &= \text{IRT}–I1_{pu} \text{ per unit} \\ &= 3.0–2.4 \text{ per unit} \\ &= 0.6 \text{ per unit}\end{aligned}$$

Equation 6.5

Step 3. Use *Equation 6.6* to convert the current values from per-unit values to current values in amperes:

$$\begin{aligned} I1_A &= TAP01 \bullet I1_{pu}\ A \\ &= 5 \bullet 2.4\ A \\ &= 12.0\ A \\[2ex] I2_A &= TAP02 \bullet I2_{pu}\ A \\ &= 5 \bullet 0.6\ A \\ &= 3.0\ A \end{aligned}$$

Equation 6.6

where:

TAP01 = Terminal 01 normalization factor.
TAP02 = Terminal 02 normalization factor.

Step 4. Press pushbuttons **{PB6}**, **{PB7}**, and **{PB8}**.

Step 5. Inject the current values listed in *Table 6.11* into the relay.

Table 6.11 Current for Testing the Second Point on the Relay Characteristic

Current	Value
IA	12.0∠0°
IB	3.2∠180°

The CT ALARM LED asserts after approximately five seconds, but the relay does not trip, because the differential current is below the operating value.

Step 6. Type **MET DIF <Enter>** to obtain the operate current value and restraint current value.

These values should approximate the operate current values and restraint current values shown in *Figure 6.25*:

```
>>MET DIF <Enter>

Relay 1                                     Date: 02/21/2003  Time: 11:51:01.794
Station A                                   Serial Number: 2003001324

Operate Currents     Restraint Currents
           (Per Unit)            (Per Unit)
ZONE          IOP                   IRT
  1           1.76                  3.04
  2           1.76                  3.04

Current Reference (A)
IREF
3000

=>>
```

Figure 6.25 Example Values in Response to the MET DIF Command With Two Active Zones

Step 7. Type **TAR 87R1 9999 <Enter>** to monitor the status of Relay Word bit 87R1.

Step 8. Decrease current IB until the status of Relay Word bit 87R1 changes from logical 0 to logical 1.

After this bit changes state, the **TRIP**, **87 (DIFF)**, **ZONE 1**, and **ZONE 2** LEDs illuminate.

Step 9. Record the value of IB.

Use IB to calculate IRT and IOP at the test point. IOP and IRT should each be within ±5% of the injected quantities (IRT = 15 ±5%, IOP = 9 ±5%).

Step 10. Type **<Ctrl>X** to end the scrolling of the status values of Relay Word bit 87R1.

Step 11. Type **MET DIF <Enter>** to obtain the operate current value and restraint current value.

These values should approximate the operate current values and restraint current values shown in *Figure 6.26*.

```
=>>MET DIF <Enter>

Relay 1                                      Date: 02/21/2003  Time: 12:33:53.073
Station A                                    Serial Number: 2003001324

Operate Currents     Restraint Currents
           (Per Unit)           (Per Unit)
ZONE          IOP                  IRT
  1           1.80                 3.00
  2           1.80                 3.00

Current Reference (A)
IREF
3000

=>>
```

Figure 6.26 Example Values in Response to the MET DIF Command With Two Differential Elements Asserted

Step 12. Turn off the test set.

Step 13. Press pushbuttons {PB5}–{PB8} and {TARGET RESET}.

Directional Element

Use the steps in the following example to test the directional element. Apply the same relay settings as when testing the differential element. To test the directional element characteristic, use the test connections as shown in *Figure 6.27*.

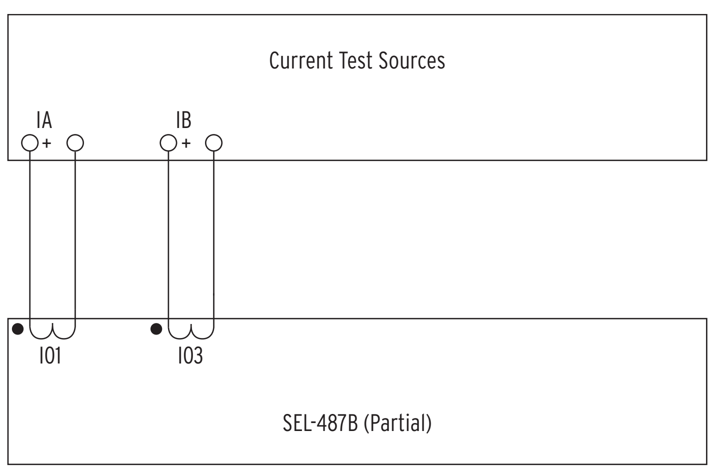


Figure 6.27 Test Connections for Testing the Directional Element

Figure 6.28 shows the directional element characteristic, the shaded area indicating an internal fault.

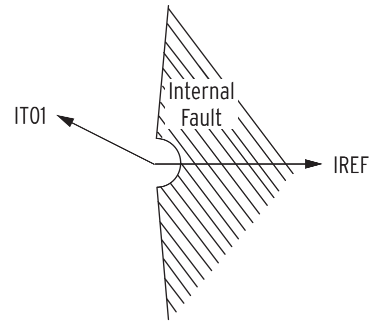


Figure 6.28 Directional Element Characteristic

The test consists of two parts. In the first part, we test the threshold of the directional element. The directional element only considers terminals with current values exceeding the threshold value in the directional calculations. In the second part, we test the boundaries of the element characteristic.

Step 1. Test the threshold value by injecting the current values shown in *Table 6.12* into the relay.

Table 6.12 Current Values for Testing the Threshold Value of the Directional Element

Current	Current Injected
IA	0.2∠0°
IB	2.0∠180°

a. Type **TAR 50DS01 <Enter>** to obtain the relay response as shown in *Figure 6.29*.

b. Verify that only Relay Word bit 50DS03 has a value of logical 1.

```
=>>TAR 50DS01 <Enter>

50DS08   50DS07   50DS06   50DS05   50DS04   50DS03   50DS02   50DS01
0        0        0        0        0        1        0        0

=>>
```

Figure 6.29 Relay Response to the TAR 50DS01 Command

c. Type **TAR 50DS01 9999 <Enter>** and slowly increase current IA.

Relay Word bit 50DS01 asserts when IA reaches a value of approximately 0.26 A.

d. Stop the injection.

e. Type **<Ctrl>X** to end the scrolling of the Relay Word bit 50DS01 status values.

Step 2. Test the boundary values.

a. Press pushbuttons **{PB5}** and **{PB7}**.

b. Inject the current values shown in *Table 6.13* into the relay.

Table 6.13 Current Values for Testing the Boundary Values of the Directional Element

Current	Current Injected
IA	2.0∠0°
IB	2.0∠90°

c. Type **TAR DE1F <Enter>** to obtain a relay response similar to that shown in *Figure 6.30*.

d. Verify that Relay Word bit DE1F is deasserted.

```
=>>TAR DE1F <Enter>

*       *       DE6F    DE5F    DE4F    DE3F    DE2F    DE1F
0       0       0       0       0       0       0       0

=>>
```

Figure 6.30 Relay Response to the TAR DE1F Command

e. Type **TAR DE1F 9999 <Enter>** and slowly decrease the angle of current IB.

   Relay Word bit DE1F asserts when the angle reaches a value of approximately 74°.

f. Quickly move the angle to –70° and continue to slowly decrease the angle of current IB.

   Relay Word bit DE1F deasserts when the angle reaches a value of approximately –74°.

g. Type **<Ctrl>X** to end the scrolling of the status values of Relay Word bit DE1F.

h. Stop the injection.

Voltage Elements

The SEL-487B includes two over- and two undervoltage elements per voltage input. We will test the four phase voltage elements for Voltage Input 1. The SEL-487B also includes two levels of negative-sequence and two levels of zero-sequence overvoltage elements. We will use the default settings for the negative-sequence and zero-sequence overvoltage elements.

Phase Over-/Undervoltage Elements

Figure 6.31 shows the steps to apply settings to the four phase voltage elements.

```
=>>SET 27P11P <Enter>
Group 1

Phase Inst Under/Over Voltage Elements
Voltage 1 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P11P  := OFF    ?60 <Enter>
Voltage 1 Level 2 U/V Pickup (OFF, 1.0-200 volts)    27P12P  := OFF    ?55 <Enter>
Voltage 1 Level 1 O/V Pickup (OFF, 1.0-200 volts)    59P11P  := OFF    ?70 <Enter>
Voltage 1 Level 2 O/V Pickup (OFF, 1.0-200 volts)    59P12P  := OFF    ?75 <Enter>
Voltage 2 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P21P  := OFF    ?END <Enter>
Group 1
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.31 Over- and Undervoltage Element Settings

Verify the operation of the phase over- and undervoltage elements.

Step 1. Connect a source of variable three-phase voltage to the relay as shown in *Figure 6.32*.

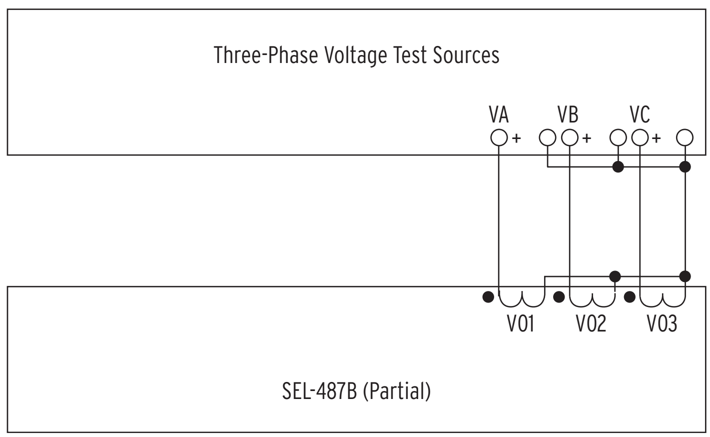


Figure 6.32 Test Connections for Testing the Voltage Elements

Step 2. Test the overvoltage elements by applying the voltage values shown in *Table 6.14* to the relay.

Table 6.14 Injected Voltage Values for Testing the Overvoltage Elements

Channel	Voltage Value
VA	$67\angle 0°$
VB	$67\angle -120°$
VC	$67\angle 120°$

a. Type in **TAR 59P11 9999 <Enter>** and raise the VA voltage until Relay Word bit 59P11 asserts.

The voltage should equal 70 V ±0.5 V and ±5%.

b. Continue to increase the applied voltage until Relay Word bit 59P12 asserts.

The voltage value should equal 75 V ±0.5 V and ±5%.

c. Type **<Ctrl>X <Enter>** to end the scrolling of the Relay Word bits status values.

d. Stop the injection.

Step 3. Test the undervoltage elements.

a. Apply the voltage values shown in *Table 6.14* to the relay.

b. Type **TAR 27P11 9999 <Enter>** and lower the VA voltage until Relay Word bit 27P11 asserts.

The voltage should equal 60 V ±0.5 V and ±5%.

c. Continue to lower the applied voltage until Relay Word bit 27P12 asserts.

The voltage value should equal 55 V ±0.5 V and ±5%.

d. Type **<Ctrl>X** to end the scrolling of Relay Word bit 27P11 status values.

e. Stop the injection.

Negative- and Zero-Sequence Voltage Elements

Verify the operation of the negative- and zero-sequence overvoltage elements.

Step 1. Use the **SHO** serial port command and verify the settings shown in *Table 6.15*.

Table 6.15 Voltage Element Settings for Testing the Negative- and Zero-Sequence Overvoltage Elements

Setting	Value
59Q1P	20
59Q2P	40
59N1P	20
59N2P	40

Step 2. Apply the voltage values shown in *Table 6.14* to the relay.

a. Type in **TAR 59Q1 9999 <Enter>** and lower the VA voltage until Relay Word bits 59Q1 and 59N1 assert.

The voltage should equal 47 V ±1 V and ±5% of setting.

b. Continue to lower the applied voltage until 59Q2 and 59N2 assert.

The voltage should equal 27 V ±1 V and ±5% of setting.

c. Type **<Ctrl>X** to end the scrolling of Relay Word bit status values.

d. Stop the injection.

Relay Self-Tests

The SEL-487B continuously runs many self-tests to detect out-of-tolerance conditions. These tests run simultaneously with relay protection and automation logic without degrading SEL-487B performance.

Status Warning and Status Failure

The relay reports out-of-tolerance conditions as a status warning or status failure. For conditions that do not compromise relay protection, yet are beyond expected limits, the relay issues a status warning and continues to operate. A severe out-of-tolerance condition causes the relay to declare a status failure and enter a protection-disabled state. During a protection disabled state, the relay suspends protection element processing and trip logic processing and de-energizes all control outputs. When disabled, the **ENABLED** front-panel LED is not illuminated. The relay signals a status warning by pulsing the HALARM Relay Word bit (hardware alarm) to logical 1 for five seconds. For a status failure, the relay latches the HALARM Relay Word bit at logical 1. SEL-487B relays will restart on certain diagnostic failures. When this occurs, the relay will log a `Diagnostic Restart` in the SER, and the HALARM Relay Word bit will assert for five seconds. See *Appendix A: Firmware and Manual Versions* for affected firmware revisions.

To provide remote status indication, connect the b contact of OUT108 to your control system remote alarm input and program the output SELOGIC control equation to respond to NOT (SALARM OR HALARM). See *Alarm Output on page U.2.33* for information on connecting this alarm output for the SEL-487B.

If you repeatedly receive status warnings, check relay operating conditions as soon as possible. Take preventive action early during the development of potential problems to avoid system failures. For any status failure, contact your Technical Service Center or the SEL factory immediately (see *Technical Support on page U.6.38*).

The relay generates an automatic status report at the serial ports for a self-test status failure if you set Port setting AUTO := Y. The relay issues a status message with a format identical to the **STATUS** command output (see *Status Warning and Status Failure on page U.6.34*), but includes the power supply information from the **STA A** response. The relay also displays status warning and status failure automatic messages on the front-panel LCD. Use the serial port **STATUS** and **CSTATUS** commands and the front-panel `RELAY STATUS` menu to display status warnings and status failures. See *STATUS on page R.7.40*, *Checking Relay Status on page U.4.10*, and *RELAY STATUS on page U.5.29* for more information on automatic status notifications and on viewing relay status.

Status

Figure 6.33 on page U.6.35 is the **STATUS A** report showing all status information obtained with terminal emulation software.

Firmware Version Number

At the top of each status report, the relay displays the present firmware version number that identifies the software program that controls relay functions. The firmware version is the four-place designator immediately following the relay model number (the first characters in the firmware identification string). The first character in the four-place firmware version number is R (representing

Release). For example, in *Figure 6.33*, the firmware version number is R100. SEL numbers subsequent firmware releases sequentially; the next revision following R100 is R101. See *Appendix A: Firmware and Manual Versions* for firmware version information.

```
=>>STA A <Enter>

Relay 1                 Date: 07/24/2003 Time: 13:53:00.359
Station A               Serial Number: 2003003020

FID=SEL-487B-R102-V0-Z001001-D20030724 CID=0xf418

Failures
 No Failures

Warnings
 No Warnings

Channel Offsets (mV) W=Warn  F=Fail
 CH1 CH2 CH3 CH4 CH5 CH6 CH7 CH8 CH9 CH10 CH11 CH12 MOF
  -2  -2  -2  -2  -2  -2  -2  -2  -2  -9   -9   -9  -3
 CH13 CH14 CH15 CH16 CH17 CH18 CH19 CH20 CH21       MOF2
  -9   -9   -9   -9   -9   -9   -2   -2   -3         -9

Power Supply Voltages (V) W=Warn  F=Fail
 3.3V_PS 5V_PS N5V_PS 15V_PS  N15V_PS
   3.30  5.01  -4.96  14.95   -15.03

Temperature
  28.3 degrees Celsius

Communication Interfaces
 Communications Card 1
 SEL-2701-R103-V0-Z000000-D20020501 Ethernet
  Normal 0x0000

Active High Accuracy Time Synchronization Source: NONE
 IRIG-B Source ABSENT

SELogic Relay Programming Environment Errors
 No Errors

Relay Enabled

=>>
```

Figure 6.33 Relay Status Information Obtained With the STATUS A Serial Port Command

CSTATUS

The relay reports status information in Compressed ASCII format when you issue the **CST** command. The Compressed ASCII status message is similar to the following:

```
=>>CSTA <Enter>
"RID","SID","FID","03e2"
"Relay 1",">>","SEL-487B-R102-V0-Z001001-D20030724","0b81"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0ACA"
2,19,2003,10,50,23,526,"045D"
"CPU_RAM","CPU_Prog","SELBOOT","CPU_Settings","DSP_RAM","DSP","DSP_Chksum","DSP_
TIMEOUT","CPU_CARD_RAM","CPU_DSP_RAM","FRONT_PANEL","CAL_BOARDA","CAL_BOARDB","C
omm_Card","Comm_Card_Code","QUART","Analog_Conv","IO_1","IO_2","IO_3","IO_4","42
45"
"Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok"," "," ","Ok","O
k","Ok","Ok","Ok","Ok","173E"
"AtoD_Offset","Master_Offset","Master_Offset2","3.3V_PS","5V_PS","N5V_PS","15V_P
S","N15V_PS","Temp_Status","Temp","FPGA","ADC_FPGA","2694"
"Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok",31.5,"Ok","Ok","0DC1"
"Fast_Fiber_Port","MBA","MBB","Active_Time_Source","SELogic_Math","FM_Test","CCr
d_Test","DNP_Test","Relay_Status","Port_F_Transp","Port_1_Transp","Port_2_Transp
","Port_3_Transp","Port_5_Transp","4029"
"Not_Installed","Inac","Inac"," ","Ok","Disabled","Disabled","Disabled","Enabled
","0","0","0","0","0","1C03"

=>>
```

Figure 6.34 Relay Status Information Obtained With the CSTATUS Serial Port Command

Relay Troubleshooting

Inspection Procedure

Complete the following inspection procedure before disturbing the system. After you finish this inspection, proceed to *Troubleshooting Procedures*.

Step 1. Confirm that power is on.

Do not turn the relay off.

Step 2. Measure and record the control power voltage at the relay **POWER** terminals marked **+** and **–** on the rear-panel terminal strip.

Step 3. Measure and record the voltages at all control inputs.

Step 4. Measure and record the state of all control outputs.

Step 5. Inspect the serial communications ports cabling to be sure that a communications device is connected to at least one communications port.

Troubleshooting Procedures

Troubleshooting procedures for common problems are listed in *Table 6.16*. The table lists each symptom, possible causes, and corresponding diagnoses/solutions. Related SEL-487B commands are listed in bold capitals. See *Section 7: ASCII Command Reference in the Reference Manual* for details on SEL-487B commands and *Section 8: Settings in the Reference Manual* for details on relay settings.

Table 6.16 Troubleshooting Procedures (Sheet 1 of 3)

Possible Cause	Diagnosis/Solution
Dark Front Panel	
Power is off.	Verify that substation battery power is operational.
Input power is not present.	Verify that power is present at the rear-panel terminal strip.
Blown power supply fuse.	Replace the fuse. See *Power Supply Fuse Replacement on page U.2.31*.
Poor contrast adjustment.	Press and hold **{ESC}** for two seconds. Press **{Up Arrow}** and **{Down Arrow}** pushbuttons to adjust contrast.
Status Failure Notice on Front Panel	
Self-test failure.	Contact the SEL factory or your Technical Service Center. The OUT108 relay control output b contacts will be closed if you programmed NOT HALARM to OUT108, see *Alarm Output on page U.2.33*.
Alarm Output Asserts	
Power is off.	Restore power.
Blown power supply fuse.	Replace the fuse. See *Power Supply Fuse Replacement on page U.2.31*.
Power supply failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Main board or interface board failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.

Table 6.16 Troubleshooting Procedures (Sheet 2 of 3)

Possible Cause	Diagnosis/Solution
Other self-test failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
System Does Not Respond to Commands	
No communication.	Confirm cable connections and types. If OK, type **<Ctrl+X>**, then **<Enter>**.This resets the terminal program.
Communications device is not connected to the system.	Connect a communications device.
Incorrect data speed (baud rate) or other communications parameters.	Configure your terminal port parameters to the particular relay port settings. Use the front panel to check port settings. See *SET/SHOW on page U.5.26*.
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications. See *Communications Ports Connections on page U.2.35*.
Communications cabling error.	Check cable connections.
Handshake line conflict; system is attempting to transmit information, but cannot do so.	Check communications cabling. Use SEL communications cables, or cables you build according to SEL specifications. See *Communications Ports Connections on page U.2.35*.
System is in the XOFF state, halting communications.	Type **<Ctrl+Q>** to put the system in the XON state.
Terminal Displays Meaningless Characters	
Data speed (baud rate) is set incorrectly.	Check the terminal parameters configuration. See *Communications Ports Connections on page U.2.35*.
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Faults	
Relay is set improperly.	Review the relay settings. See *Section 1: System Configuration Guideline and Application Examples in the Applications Handbook*.
Improper test settings.	Restore operating settings.
PT or CT connection wiring error.	Confirm PT and CT wiring.
Input voltages and currents phasing, and rotation errors.	Use relay metering. Use the **TRI** event trigger command and examine the generated event report. See *Examining Metering Quantities on page U.4.31*.
The analog input (flat multipin ribbon) cable between the input module board and the main board is loose or defective.	Reseat both ends of the analog input cable, observing proper ESD precautions. See *Installing Optional I/O Interface Boards on page U.2.13*.
Check the relay self-test status.	Take preventive action as directed by relay STATUS WARNING and STATUS FAILURE information. See *Relay Self-Tests on page U.6.34* and *Checking Relay Status on page U.4.10*.

Table 6.16 Troubleshooting Procedures (Sheet 3 of 3)

Possible Cause	Diagnosis/Solution
Tripping Output Relay Remains Closed Following a Fault	
Auxiliary contact control inputs are improperly wired.	Check circuit breaker auxiliary contacts wiring.
Control output relay contacts have burned closed.	Remove relay power. Remove the control output connection. Check continuity; a contacts will be open and b contacts will be closed. Contact the SEL factory or your Technical Service Center if continuity checks fail.
I/O interface board failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Warning	
Power supply voltage(s) are out-of-tolerance.	Log the STATUS WARNING. If repeated warnings occur, take preventive action.
A/D converter failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Failure	
Power supply voltage(s) are out-of-tolerance.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
A/D converter failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
A/D OFFSET WARN Status Warning	
Loose ribbon cable between the input module board and the main board.	Reseat both ends of the analog input cable.
A/D converter drift.	Log the STATUS WARNING. If repeated warnings occur, contact the SEL factory or your Technical Service Center.
Master offset drift.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 USA
Phone: +1.509.332.1890
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

Appendix A

Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

To find the firmware revision number in your relay, view the status report using the serial port **STATUS** command. The status report displays the Firmware Identification (FID) label:

FID=SEL-487B-Rxxx-Vx-Z001001-Dxxxxxxxx

You can also view the FID label from the front panel. From the ROTATING DISPLAY front-panel screen, press the **{ENT}** pushbutton to advance to the MAIN MENU screen. Use the **{Down Arrow}** pushbutton to highlight the RELAY STATUS option, and press the **{ENT}** pushbutton. The FID label displays on the screen:

SEL-487B-Rxxx-Vx-Z001001-Dxxxxxxxx

In the FID label, the firmware revision number follows the R and the release date follows the D.

For example:

FID=SEL-487B-R102-V0-Z001001-D20030724

is firmware revision number 102, release date July 24, 2003.

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History (Sheet 1 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-R124-V0-Z008004-D20131111	➤ Manual update only (see *Table A.5*).	20140516
SEL-487B-R124-V0-Z008004-D20131111	➤ Corrected Display Point settings conversion to preserve the Display Point layout on the HMI after an upgrade (if the Display Point settings contain 20 or more characters the SEL-487B relays could disable when firmware versions R100–R115 are upgraded to firmware versions R116–R123).	20131111
SEL-487B-R123-V0-Z008004-D20130220	➤ Improved DNP Multidrop (EIA-485) communication to operate at data rates faster than 9600 bps. ➤ Corrected DNP SER Reporting in the Extended DNP Map for Serial DNP. ➤ Fixed rotating display to show correct configuration zones. ➤ Add out-of-range check for DC Offset calculation. ➤ Corrected erroneous error messages when front panel LB_ELE1 and LB_ELE2 have blank settings. ➤ Corrected a possible relay vector when two relays, configured to use SEL protocol, are connected through serial ports.	20130220

Table A.1 Firmware Revision History (Sheet 2 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-R122-V0-Z008004-D20111031	➤ Manual update only (see *Table A.5*).	20120810
SEL-487B-R122-V0-Z008004-D20111031	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20111215
SEL-487B-R122-V0-Z008004-D20111031	➤ Manual update only (see *Table A.5*).	20111109
SEL-487B-R122-V0-Z008004-D20111031	➤ Added CCOK bit to indicate the Ethernet card is alive. ➤ Added real-time watchdog to quickly detect Ethernet card failures. ➤ Added setting warning when native Relay Word bit names are used as alias name settings.	20111031
SEL-487B-R121-V0-Z006004-D20101109	➤ Manual update only (see *Table A.5*).	20110211
SEL-487B-R121-V0-Z006004-D20101109	➤ Updated for compatibility with SEL-2702 R111.	20101109
SEL-487B-R120-V0-Z005004-D20100628	➤ Added the ability to recognize additional interface board 4 ordering options.	20100628
SEL-487B-R119-V0-Z005004-D20100506	➤ Corrected the mechanism by which the secondary meter command accesses the setting data to calculate secondary meter values.	20100506
SEL-487B-R118-V0-Z005004-D20090519	➤ Corrected handling of DNP fault summary records when EVELOCK = 0.	20090519
SEL-487B-R117-V0-Z005004-D20090205	➤ Added EPORT port setting so user can disable ports. ➤ Added MAXACC port setting so user can restrict maximum privileges on a port. ➤ Extended password length from 6 to 12 characters.	20090205
SEL-487B-R116-V0-Z004004-D20080110	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20081022
SEL-487B-R116-V0-Z004004-D20080110	➤ Added Check Zone 1. ➤ Added Open CT Detector logic. ➤ Added alarm points and SER settings parameter HMI Alarm in order to enable automatic HMI display of alarm points. ➤ Added analog display points. ➤ Expanded to 96 display points and changed format to display on a single line. ➤ Added support for expanded HMI features: 12 operator control pushbuttons, 24 target LEDs, double-height display points and tri-colored LEDs. ➤ Added settings PB1_HMI through PB12HMI for assigning alarm point, display point, SER or event summary screens to the selectable operator pushbuttons. ➤ Added SER events on the front-panel screen. ➤ Added settings DISP_ER and TYPE_ER for enabling and configuring automatic HMI display of event summary screens. ➤ Added setting NUM_ER to specify the number of event summary screens viewed through the operator pushbutton. ➤ Added programmable supervision and position status feedback to the standard Local Bits. ➤ Added setting SCROLD for changing the ROTATING DISPLAY update rate. ➤ Corrected transition from ROTATING DISPLAY to manual mode when using navigational arrows.	20080110

Table A.1 Firmware Revision History (Sheet 3 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added new DNP setting MAPSEL and implemented extended binary input map. ➤ Implemented DNP single-event mode. ➤ Added Fast Message commands to read database regions. ➤ Modified HMI password entry so that characters are not echoed to the screen. ➤ Added Ethernet card information in the **ID** command. ➤ Updated how SER points are reported through DNP after initial DNP setup. ➤ Updated **EVE C** command to default to full length.	
SEL-487B-R115-V0-Z003003-D20070315	➤ Made improvements for manufacturability.	20070315
SEL-487B-R114-V0-Z003003-D20070220	➤ Expanded diagnostics coverage to include additional failure modes that will result in a relay restart.	20070220
SEL-487B-R113-V0-Z003003-D20060905	➤ Corrected measurement errors found in R110, R111, and R112 firmware for SEL-487B relays configured for 1 A nominal current inputs.	20060905
SEL-487B-R112-V0-Z003003-D20060814	➤ Modified diagnostic failure mode management. Certain diagnostic test errors will result in a relay restart. Relay will log `Diagnostic Restart` in the SER if this event occurs.	20060814
SEL-487B-R111-V0-Z003003-D20060727	➤ Fixed problem found in firmware version R110 that caused the SEL-487B to disable when serial port communications were autoconfigured using an SEL-2032 or SEL-2030 Communications Processor.	20060727
SEL-487B-R110-V0-Z003003-D20060630	➤ Added IEC 61850 support for optional Ethernet card.	20060703
SEL-487B-R109-V0-Z002002-D20060413	Note: This firmware version requires the use of R109 or higher firmware on any installed SEL-2701 Ethernet Card. ➤ Improved accuracy of time-tagged DNP LAN/WAN binary inputs.	20060413
SEL-487B-R108-V0-Z002002-D20051123	Note: This firmware version requires the use of R108 or higher firmware on any installed SEL-2701 Ethernet Card. ➤ Added DNP LAN/WAN support when using the SEL-2701 Ethernet Card. ➤ Added second file transfer session to allow access to SEL-2701 settings files (SET_DNP*n*.TXT) via FTP. ➤ SET_DNP*n*.TXT files from the SEL-2701 are available in the relay file system and can be accessed via FTP or the ASCII **FILE** command. ➤ Added time-stamped SER data from the relay into TARGET region of the SEL-2701 DNP3 database. ➤ Added the D1 region to DNP LAN/WAN in order to make incoming analog data available to the relay via objects RA001 to RA256. ➤ Zone supervision Setting E87ZSUP from “Y” to “N” will now reset individual zone supervision logic to “1”. ➤ Enhanced the **PORT 5** command to allow transparent access to the SEL-2701 user interface from the host relay.	20051123
SEL-487B-R107-V0-Z001001-D20051121	➤ Corrected Zone Supervision Setting E87ZSUP so that changing this setting from “Y” to “N” resets individual zone supervision logic settings to 1.	20051121
SEL-487B-R106-V0-Z001001-D20050220	➤ Corrected issue where a conflict in DNP processing and communications could suspend all relay communications.	20050220

Table A.1 Firmware Revision History (Sheet 4 of 4)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-R105-V0-Z001001-D20041129	➤ Modified the Protection Math Variable (PMV) function to prevent equations containing parentheses from overwriting existing values. ➤ Added Security Enhancement when used with the SEL-2701 Ethernet Processor.	20041129
SEL-487B-R104-V0-Z001001-D20040609	➤ Corrected issue where the dc battery monitor may report incorrect values for Vdc. ➤ Corrected issue where turning off power may cause a low-set 87, 50, or 51 element to inadvertently operate.	20040609
SEL-487B-R103-V0-Z001001-D20031112	➤ Manual update only (see *Table A.5*).	20040401
SEL-487B-R103-V0-Z001001-D20031112	➤ Includes RSTTRGT in the trip unlatch logic. ➤ MIRRORED BITS® communications underrun value changed from 1 in 3 to 1 in 7 for paced mode.	20031112
SEL-487B-R102-V0-Z001001-D20030724	➤ Initial version.	20030724

Table A.2 lists the Ethernet card firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.2 Ethernet Card Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2702-R115-V0-Z002002-D20190325 SLBT-2701-R103-V0-Z000000-D20080820	➤ Resolved an issue where certain Ethernet traffic could cause the relay to safely restart.	20190325
SEL-2702-R114-V0-Z002002-D20190308 SLBT-2701-R103-V0-Z000000-D20080820	Note: This firmware did not production release.	—
SEL-2702-R113-V0-Z002002-D20111215 SLBT-2701-R103-V0-Z000000-D20080820	➤ Added support for database references in IEC 61850 configuration files.	20111215
SEL-2702-R112-V0-Z002002-D20110715 SLBT-2701-R103-V0-Z000000-D20080820	➤ Improved port failover performance of 100BASE-FX fiber channel.	20111031
SEL-2702-R111-V0-Z002002-D20101109 SLBT-2701-R103-V0-Z000000-D20080820	➤ Added HTTP server for SEL-487B web services.	20101109
SEL-2702-R110-V0-Z001001-D20090205 SLBT-2701-R103-V0-Z000000-D20080820	➤ Improved security (see www.selinc.com/privacy.htm for details).	20090205
SEL-2702-R109-V0-Z001001-D20081022 SLBT-2701-R103-V0-Z000000-D20080820	➤ Updated IEC 61850 firmware to streamline MMS processing and improve TCP/IP connections. ➤ Improved security (see www.selinc.com/privacy.htm for details). ➤ Corrected issue that could cause the Ethernet card to fail under heavy DNP traffic.	20081022
SEL-2702-R107-V0-Z001001-D20080107 SLBT-2701-R102-V0-Z000000-D20051107	➤ Enhanced IEC 61850 with KEMA certifications updates. ➤ Added indication of ICD/CID file parse failure to the SEL-2702 User interface (**ID**, **STA**, **GOO** commands).	20080110

Table A.2 Ethernet Card Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2702-R101-V0-Z000000-D20060808 SLBT-2701-R102-V0-Z000000-D20051107	➤ Added support for pulse operations on DNP LAN/WAN control points, both paired and unpaired. ➤ Added ability to sense local operations and update IEC 61850 origination category.	20060808
SEL-2702-R100-V0-Z000000-D20060630 SLBT-2701-R102-V0-Z000000-D20051107	➤ Initial version.	20060703

The optional Ethernet card must be paired with a compatible SEL-487B version. You may need to upgrade your SEL-487B firmware to access features in new versions of the Ethernet cards. *Table A.1* include notes on SEL-487B modifications that support new features of the Ethernet cards.

To find the firmware revision number in your Ethernet card, first connect to the SEL-487B with the **ACC** command. View the Firmware Identification (FID) labels with the **VERSION** command. Look for the Ethernet card FID label in the response under Communications Card:

FID=SEL-2701-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

In the FID label, the 4 digits after "SEL" indicate which Ethernet card is installed. The firmware revision number follows the R and the release date follows the D.

For example:

SEL-2701-R108-V0-Z002001-D20051205

is for an SEL-2701 Ethernet card, firmware revision number 108, release date December 5, 2005.

Table A.3 lists Ethernet card firmware versions with compatible SEL-487B firmware versions.

Table A.3 Compatible SEL-487B and Ethernet Card Firmware Versions

SEL-487B Firmware	Ethernet Card	Ethernet Card Firmware
R121 or higher	SEL-2702	R111 or higher
R116–R120	SEL-2702	R103–R110
R110–R115	SEL-2702	R100–R101
R108–R109	SEL-2701	R108 or higher
R107 or lower	SEL-2701	R105 or lower

Newer Ethernet card firmware (R106 and higher) uses a different software library from earlier versions and is unable to process version 001 CID files. ACSELERATOR Architect® SEL-5032 Software generates CID files from ICD files so the ICD file version number and CID file version number are the same. If downloaded to the Ethernet port, an incompatible CID file will generate file parse errors during processing and disable the IEC 61850 protocol.

If you perform an Ethernet card firmware upgrade that spans different file version compatibilities, the relay may not be able to process the stored CID file. See the *Ethernet Port Firmware Upgrade Instructions* for CID file conversion procedures.

See *Table A.4* for compatibilities between ACSELERATOR Architect software ICD/CID file, and Ethernet card firmware versions.

Table A.4 ACSELERATOR Architect CID File Compatibility

Architect Software Version	Architect ICD/CID File Version	Ethernet Card Firmware
All versions	Ver 001	R100–R106
1.1.69.0 or higher	Ver 002 (all)	R107 or higher

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.5 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.5 Instruction Manual Revision History (Sheet 1 of 10)

Revision Date	Summary of Revisions
20210514	**Applications Handbook** Section 1 ➤ Updated *End-Zone Protection*, *Breaker Status Logic*, *End-Zone Protection* in *Application 2: Single Bus and Tie Breaker (Single Relay)*. ➤ Updated *Zone Configuration Group Settings* in *Application 4: Single Bus and Transfer Bus With Buscoupler.* ➤ Updated *Zone Configuration Group Settings* and *Protection Group Settings* in *Application 7: Double and Transfer Bus (Outboard CTs)*. **Reference Manual** Section 1 ➤ Updated *Table 1.29: Summary of the Event for Fault F3 Shown in Figure 1.49* and *Table 1.30: Summary of the Event for Fault F3 Using the Accelerated Trip Function*. ➤ Updated *Single CT Application* and *Circuit Breaker Status Logic*.
20190308	**User's Guide** Appendix A ➤ Updated for Ethernet firmware version R114-V0.
20140516	**User's Guide** Section 1 ➤ Edited AC Voltage Inputs information in *Specifications.* Section 5 ➤ Edited Clock Status information in *Operation and Target LEDs.* Appendix B ➤ Replaced entire appendix with updated *SEL-400 Series Upgrade/Conversion Instructions.* **Application Handbook** Section 1 ➤ Edited CT Connections information in *CT Requirements.* **Reference Manual** Section 3 ➤ Edited *Table 3.1: SEL-487B Communications Protocols.* ➤ Edited *Table 3.4: Ethernet Card Network Configuration Settings.*

Table A.5 Instruction Manual Revision History (Sheet 2 of 10)

Revision Date	Summary of Revisions
	Section 5 ➤ Edited *Table 5.10: SEL-487B DNP3 Default Data Map.* ➤ Edited *Table 5.25: DNP LAN/WAN Application Example Custom Data Map.* Section 6 ➤ Edited Firmware Upgrades in *Features.* Section 8 ➤ Edited *Table 8.69: Ethernet Settings.* Appendix A ➤ Edited *Table A.1: Alphabetical List of Relay Word Bits.* ➤ Edited *Table A.2: Row List of Relay Word Bits.*
20131111	**User's Guide** Appendix A ➤ Updated for firmware version R124.
20130220	**User's Guide** Appendix A ➤ Updated for firmware version R123.
20120810	**User's Guide** Section 1 ➤ Updated *Specifications*. **Application Handbook** Section 2 ➤ Updated *Figure 2.1: Typical Station DC Battery System*.
20111215	**User's Guide** Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *Figure 2.14: Relay Chassis Dimensions*. ➤ Updated *Figure 2.28: Typical External AC/DC Connections for a Three-Relay Application*. ➤ Updated *Differential Elements*. Appendix A ➤ Updated for Ethernet card firmware version R113.
20111109	**User's Guide** Section 1 ➤ Updated Type Test information in *Specifications*.
20111031	**User's Guide** Section 1 ➤ Added UL Compliance information in *Specifications*. Appendix A ➤ Updated for firmware version R122. Appendix B ➤ Added filename information to *Table B.1: Firmware File Name*.
20110211	**User's Guide** Appendix B ➤ Added *EPORT Setting*.

Table A.5 Instruction Manual Revision History (Sheet 3 of 10)

Revision Date	Summary of Revisions
20101109	**User's Guide** Appendix A ➤ Updated for firmware version R121. **Applications Handbook** **Section 5** ➤ Added *HTTP*. **Reference Manual** **Section 8** ➤ Added *Table 8.75 HTTP Settings*.
20100628	**User's Guide** Section 1 ➤ Updated for additional standard contact output I/O boards. Appendix A ➤ Updated for firmware version R120.
20100506	**User's Guide** Appendix A ➤ Updated for firmware version R119.
20090519	**User's Guide** Appendix A ➤ Updated for firmware version R118.
20090205	**User's Guide** Section 4 ➤ Updated *Changing the Default Passwords* to reflect added Access Level C. ➤ Updated *Figure 4.5: Access Level Structure*. ➤ Updated *Table 4.3: SEL-487B Access Levels* and *Table 4.4: SEL-487B Access Level Commands and Passwords*. ➤ Updated *Communications Ports Access Levels* to reflect new Access Level C port settings. ➤ Updated steps under *Passwords*. Appendix A ➤ Updated for firmware version R117. ➤ Updated for Ethernet card firmware version R110. **Reference Manual** Section 7 ➤ Added **CAL** command. ➤ Modified *Password* to reflect the extended password length from 6 to 12 characters. Section 8 ➤ Updated *Table 8.64: Protocol Selection*.
20081022	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R109 and SELBOOT firmware version R103.
20080110	**User's Guide** Section 1 ➤ Added *Check Zone* to *Functional Overview*. ➤ Updated *Table 1.1: Application Highlights* to include the independent Check Zone in application highlights. ➤ Updated *Operating Temperature* in *Specifications* to include Ethernet card information. ➤ Corrected 10BASE-FL and 100BASE-FX ordering options in *Communication Ports: Fiber Optic (optional)* in *Specifications*.

Table A.5 Instruction Manual Revision History (Sheet 4 of 10)

Revision Date	Summary of Revisions
	Section 4 ➤ Updated *Figure 4.12: Using Text-Edit Mode Line Editing* to SET Display Points and *Figure 4.13: Using Text-Edit Mode Line Editing to Delete a Display Point* for new Display Point format. ➤ Updated *Figure 4.14: Default Alias Settings* and *Figure 4.15: Using Text-Edit Mode Line Editing to Set Aliases* for new Aliases and prompt format. ➤ Added note to indicate that the latest 200 SER events are viewable on the front panel. ➤ Updated *Figure 4.26: Setting an SER Element: Terminal Emulation Software* to reflect new SER setting parameter HMI Alarm. ➤ Edited *Operating the Relay Inputs and Outputs* to include Local Bit supervision. Section 5 ➤ Updated *Figure 5.1: Front Panel, 12 Pushbutton (9U Version)* for 12 pushbuttons. ➤ Updated *Front-Panel Layout* for HMI changes: expanded pushbuttons, expanded target LEDs, and tri-color LEDs. ➤ Updated *Screen Scrolling* to include Alarm Points. ➤ Added alarm points screen to *Figure 5.4: ROTATING DISPLAY* and updated to include double-height Display Points. ➤ Edited *Front-Panel Layout* to include SCROLD setting option. ➤ Added *Alarm Points* and *Example 5.1: Creating an Alarm Point*. ➤ Updated *Display Points* to allow for analog quantity display points and to include Text Size parameter. ➤ Updated *Figure 5.10: Display Points Screen* and *Table 5.4* to include double-height Display Points. ➤ Added *Table 5.5: Display Point Settings—Analog* and *Table 5.6: Display Point Settings—Boolean and Analog Examples*. ➤ Modified *Events* to explain event summary access options. ➤ Added description of SER event viewing on the front panel in the *Front-Panel Menu and Screens*. ➤ Added Local Control bit supervision and display logic to *Local Control Bits*. ➤ Modified *Front-Panel Automatic Messages* to include alarm points. ➤ Updated *Operation and Target LEDs* for HMI changes: expanded target LEDs and tricolor LEDs. ➤ Updated *Figure 5.41: Factory Default Front-Panel Target Areas (16 or 24 LEDs)* and *Table 5.11: Front-Panel Target LEDs* for expanded target LEDs. ➤ Added *Voltage Status, Miscellaneous Status and Clock Status* for expanded target LEDs. ➤ Modified *Front-Panel Operator Control Pushbuttons* to include alarm points, display points, SER and event summary viewing options. Section 6 ➤ Updated *Figure 6.15: Alias Names for the Four Analog Channels* for new Aliases and prompt format. ➤ Updated *Figure 6.18: Steps to Program Protection Latch Bits* to reflect new Protection Logic default settings. ➤ Updated *Figure 6.25: Example Values in Response to the MET DIF Command With Two Active Zones* and *Figure 6.26: Example Values in Response to the MET DIF Command With Two Differential Elements Asserted* to correct IOP and IRT calculated values. Appendix A ➤ Updated for firmware version R116. ➤ Updated for Ethernet card firmware version R107. ➤ Added *Table A.3: Compatible SEL-487B and Ethernet Card Firmware Versions* and explanatory text for multiple ICD/CID versions. **Application Handbook** Section 1 ➤ Updated *Figure 1.23: Assigning Alias Names* for new aliases and prompt format. ➤ Updated *Zone Supervision* to include the independent Check Zone. ➤ Updated *Table 1.4: Primary Plant Data* to include the independent Check Zone. ➤ Updated *Application 1: Single Bus and Tie Breaker (Three Relays)* to include the independent Check Zone and new Aliases. ➤ Added *Table 1.15: Alias Name for the Check Zone*.

Table A.5 Instruction Manual Revision History (Sheet 5 of 10)

Revision Date	Summary of Revisions
	Section 2 ➤ Corrected *Equation 2.2*. ➤ Added MET CZ1 and MET SEC CZ1 to *Metering*. ➤ Updated *MET DIF* to include the independent Check Zone and explained derivation of IREF. Section 3 ➤ Updated *Duration of Data Captures and Event Reports* to include 60 and 120 cycle event reports. ➤ Updated *Table 3.5: EVE Command* to specify that EVE C defaults to full length. ➤ Added note to indicate the latest 200 SER events are viewable on the front panel. ➤ Modified *Setting SER Points and Reporting Names* to reflect new SER setting parameter HMI Alarm. Section 4 ➤ Updated *Table 4.3: SEL Communications Processor Data Collection Automessages* to include the following: 20METER2, 20TARGET2, 20STATUS2, 20HISTORY2, 20LOCAL2, 20ANALOGS2, 20STATE2, 20D12. ➤ Updated *Figure 4.6* for new Aliases and prompt format. **Reference Manual** Section 1 ➤ Updated *Busbar Protection Element* to include independent Check Zone. ➤ Updated *External Fault Detection Logic* and *Figure 1.9: External Fault Detection Logic* to remove EXFDO setting. ➤ Added *Check Zone Protection Elements*. ➤ Added *Check Zone Sensitive Differential Element*. ➤ Updated *Zone Supervision Logic* to include independent Check Zone. ➤ Added *Table 1.7: Default Values for the Check Zone Supervision Settings*. ➤ Added *Check Zone Selection*. ➤ Added *Open CT Detector Logic*. ➤ Added *Figure 1.41: Breaker Failure Clearing Times* to show breaker failure clearing times. ➤ Added *Check Zone Differential Trip Output*. Section 2 ➤ Added Multiple Setting Groups. Section 3 ➤ Updated **ID**, **STA**, and **GOO** commands to describe ICD/CID file parse failure indication. ➤ Updated titles in *Table 3.23: SEL-487B Communications Card Database Structure—LOCAL Region* through *Table 3.30: SEL-487B Communications Card Database Structure—D1 Region*. ➤ Added details and examples to indicate how to get SOE-quality timestamped data over a DNP LAN/WAN connection in *Communications Card Database*. Section 5 ➤ Updated *Table 5.6: SEL-487B Port DNP Protocol Settings* for new setting EVELOCK. ➤ Updated *Table 5.7: SEL-487B DNP Map Settings* for new setting MAPSEL. ➤ Edited *Default Data Map* to explain new reference maps. ➤ Updated *Table 5.10: SEL-487B DNP3 Default Data Map* to include two reference maps and new indices 76, 79, and 178. ➤ Added new bit values to *Table 5.12: SEL-487B Object 1, 2 Relay Word Bit Mapping*. ➤ Added new bit values to *Table 5.13: Object 1, 2 Front-Panel Targets*. ➤ Updated *Reading Relay Even Data* for new single-event mode. ➤ Updated *Figure 5.3: SEL-487B Example Settings* for new setting MAPSEL. ➤ Updated *Table 5.17: SEL-487B Port 3 Example Settings* for new setting EVELOCK. ➤ Updated *Custom Data Mapping* to indicate how to get SOE-quality timestamped data over a DNP LAN/WAN connection. ➤ Corrected settings type, range and descriptions in *Table 5.20: SEL-487B DNP LAN/WAN Map Settings*. ➤ Added *Binary Inputs*, *Analog Inputs*, *Binary Outputs*, *Analog Outputs*, and *DNP Map Command* sections and added details to indicate how to get SOE-quality timestamped data over a DNP LAN/WAN connection. ➤ Corrected setting menu paths and descriptions in *Table 5.27: DNP LAN/WAN Application Example Binary Input Map*.

Table A.5 Instruction Manual Revision History (Sheet 6 of 10)

Revision Date	Summary of Revisions
	➤ Added *Figure 5.5: Add Binary Inputs to SER Point List* and explanatory text in order to indicate how to get SOE-quality timestamped data over a DNP LAN/WAN connection. ➤ Corrected *Table 5.24: SEL-487B DNP LAN/WAN Object 12 Control Point Operation* code selection operation for Control Points CB1–CB18. Section 6 ➤ Added *Binary Inputs*, *Analog Inputs*, *Binary Outputs*, *Analog Outputs*, and *DNP Map Command* sections and added details to indicate how to get SOE-quality timestamped data over a DNP LAN/WAN connection. ➤ Added and edited tables to document new ICD file versions supported by ACSELERATOR Architect Revision 1.1.69.0. ➤ Added Table 6.7: Logical Node Summary. ➤ Updated *Table 6.8: Logical Device: PRO (Protection)* through *Table 6.11, Logical Device: ANN (Annunciation)* to document new ICD file versions. ➤ Updated *Table 6.11: Logical Device: ANN (Annunciation)* to document new ICD file versions and correct PB LED Bits. Section 7 ➤ Updated *Table 7.9: CEV Command Options Description* to specify that CEV C command defaults to full length. ➤ Updated *Table 7.33: EVE Command Options Description* to specify that EVE C command defaults to full length. ➤ Added information to the ID subsection to specify that the ID command contains Ethernet card information. ➤ Added MET CZ1 command. ➤ Added MET SEC CZ1 command. ➤ Updated SET Z command to include independent Check Zone. ➤ Updated SHO Z command to include independent Check Zone. Section 8 ➤ Added Check Zone name to Alias Settings. ➤ Updated *Figure 8.1: Changing a Default Name to an Alias* for new Alias prompt format. ➤ Updated *Table 8.1: Default Alias Settings* for new Aliases. ➤ Updated *Table 8.13: Data Reset Control for RSTDNPE*. ➤ Updated *Table 8.16: Zone Configuration Settings Categories* to include Open CT Detection and independent Check Zone. ➤ Added *Table 8.23: Zone Open CT Detection*. ➤ Added *Table 8.24: Terminal-to-Check-Zone Connections*. ➤ Added *Table 8.25: Check Zone Supervision*. ➤ Updated *Table 8.26: Group Settings Categories* to include independent Check Zone. ➤ Added *Table 8.29: Check Zone Sensitive Differential Element*. ➤ Added *Table 8.31: Check Zone Restrained Differential Element*. ➤ Updated *Table 8.41: Protection Free-Form* SELogic *Control Equation* to reflect new Protection Logic default settings. ➤ Added new front-panel settings categories to *Table 8.50: Front-Panel Settings Categories*. ➤ Updated *Table 8.51: Front-Panel Setting* for HMI changes: tricolor LEDs, expanded pushbuttons, and expanded target LEDs. ➤ Added new setting SCROLD to *Table 8.52: Selectable Screens for the Front Panel*. ➤ Added new front-panel settings *Table 8.53: Selectable Operator Pushbuttons* and *Table 8.54: Front-Panel Event Display*. ➤ Split Display Points and Aliases table into two separate tables, *Table 8.55: Boolean Display Points and Aliases* and *Table 8.56: Analog Display Points and User Text and Formatting*. ➤ Added *Table 8.58: Local Bit* SELOGIC. ➤ Updated SER Points and *Figure 8.2: Setting an SER Point to Report TRGTR Relay Word Bit Status* to reflect new SER setting parameter HMI Alarm. ➤ Updated *Table 8.61: Event Reporting* for new 60 and 120 cycle event report lengths. ➤ Clarified Event Reporting Digital Elements capacity. ➤ Updated *Figure 8.3: Steps to Add the Output From Coupler Security Logic 1* to the Event Report to reflect new SER setting parameter HMI Alarm. ➤ Updated *Table 8.67: DNP3 Protocol Serial Port Settings* for new setting EVELOCK. ➤ Added *Table 8.75: DNP3 Reference Map Selection*.

Table A.5 Instruction Manual Revision History (Sheet 7 of 10)

Revision Date	Summary of Revisions
	Appendix A ➤ Updated *Table A.1: Alphabetic List of Relay Word Bits* to include Check Zone, front-panel expanded HMI, and DNP event control information. ➤ Added *Table A.2: Row List of Relay Word Bits*. Appendix B ➤ Added IOPCZ1, IOPCZ1F, IRTCZ1 and IRTCZ1F to *Table B.1, Analog Quantities Sorted by Function* and *Table B.2, Analog Quantities Sorted Alphabetically.*
20070315	**User's Guide** Appendix A ➤ Updated for firmware version R115.
20070220	**User's Guide** Appendix A ➤ Updated for firmware version R114.
20060905	**User's Guide** Appendix A ➤ Updated for firmware version R113.
20060814	**User's Guide** Preface ➤ Added cautions and a warning in English and French. Section 2 ➤ Corrected two 7U Version rear-panel diagrams. ➤ Updated Ethernet card rear-panel layouts. Section 6 ➤ In *Status Warning and Status Failure* added information about the relay restarting on certain diagnostic failures. Appendix A ➤ Updated for firmware version R112. ➤ Updated for Ethernet card firmware version R101. Appendix B ➤ Replaced SEL-487B firmware upgrade instructions with SEL-400 Series Relays Firmware Upgrade Instructions. **Applications Handbook** Section 3 ➤ Added diagnostic restart to the list of conditions captured by the SER. Section 4 ➤ Deleted incorrect information about analog quantities. Section 5 ➤ Documented additional support for paired control outputs (BO). Section 8 ➤ Clarified multiple client access for Unbuffered Reports. ➤ Added Protocol Implementation Conformance Statement (PICS).
20060727	**User's Guide** Appendix A ➤ Updated for firmware version R111.

Table A.5 Instruction Manual Revision History (Sheet 8 of 10)

Revision Date	Summary of Revisions
20060703	**User's Guide** Section 2 ➤ Included network port configurations and safety warnings in *Network Connections*. Appendix A ➤ Updated for firmware revision R110. **Applications Handbook** Section 5 ➤ Revised FTP File Structure description in *FTP*. ➤ Specified CID file location in *FTP*. **Reference Manual** Section 3 ➤ Added Ethernet card commands to *Ethernet Card Commands*. ➤ Added "keep alive" settings ETCPKA, KAIDLE, KAINTV, and KACNT to *Ethernet Network Operation Settings*. ➤ Revised FTP File Structure description in *File Structure*. Section 5 ➤ Increased CCINs from 32 to 128 (DNP LAN/WAN map) and adjusted indices as necessary. Section 6 ➤ Added new IEC 61850 section (replaced the UCA2 section). Section 7 ➤ Added information about new **ID** command response for an Ethernet card with IEC 61850 support. Appendix A ➤ Increased CCINs from 32 to 128 (Relay Word bits) and adjusted row numbers for those and all subsequent rows. Glossary ➤ Added IEC 61850 entries. Miscellaneous ➤ Removed GOMSFE appendix. ➤ Removed references to UCA2 and GOMSFE. ➤ Modified GOOSE references to describe IEC 61850 GOOSE.
20060413	**User's Guide** Appendix A ➤ Updated for firmware version R109.
20051123	Revised entire manual to include new DNP3 LAN/WAN functionality. **User's Guide** Appendix A ➤ Updated for firmware version R108.
20051121	**User's Guide** Appendix A ➤ Updated for firmware version R107.
20050220	**User's Guide** Section 1 ➤ Added 7U chassis information. ➤ Corrected minimum wire insulation rating. ➤ Removed references to ACSELERATOR QuickSet® SEL-5030 software HMI screen. ➤ Corrected specifications. Section 2 ➤ Added 7U chassis information. ➤ Added instructions on how to use optoisolated inputs with ac control signals.

Table A.5 Instruction Manual Revision History (Sheet 9 of 10)

Revision Date	Summary of Revisions
	Section 4 ➤ Removed references to ACSELERATOR HMI screen. Section 5 ➤ Removed references to ACSELERATOR HMI screen. Section 6 ➤ Removed references to ACSELERATOR HMI screen. Appendix A ➤ Updated for firmware version R106. **Applications Handbook** Section 1 ➤ Removed reference to "SEL TWO_CT" program. Section 4 ➤ Explained restrictions for Fast Meter protocol. **Reference Manual** Section 1 ➤ Corrected coupler security logic. Section 2 ➤ Corrected *Figure 2.9: R_TRIG Timing Diagram* and *Figure 2.10: F_TRIG Timing Diagram*. Section 4 ➤ Corrected RBADPU range. Section 6l ➤ Corrected **SHO P** description ➤ Corrected Directional Element Test. Section 7 ➤ Corrected RBADPU range.
20041129	**User's Guide** Appendix A ➤ Updated for firmware version R105.
20040609	**User's Guide** Section 4 ➤ Deleted space between C and V in **SER CV** command. Appendix A ➤ Updated for firmware version R104. **Applications Handbook** Section 1 ➤ Corrected paragraph following *CT Grounding*. ➤ Corrected text following *Figure 1.40: Forming Bus-Zone-to-Bus-Zone Connections With and Without a Circuit Breaker*. ➤ Corrected text in figure *Figure 1.66: Differential Trip Logic for Differential Element 1*. **Reference Manual** Section 5 ➤ Corrected text following *Collision Avoidance*.

Table A.5 Instruction Manual Revision History (Sheet 10 of 10)

Revision Date	Summary of Revisions
20040401	**User's Guide** Section 1 ➤ Updated Metering Accuracy information in *Specifications*. **Applications Handbook** Section 1 ➤ Changed the zone supervision settings (SELOGIC equation) of the check zone in Application 1 to prevent loss of multiple zones.
20031112	**User's Guide** Appendix A ➤ Updated for firmware version R103. **Reference Manual** Section 1 ➤ Added SELOGIC control equation setting RSTTRGT to *Figure 1.58: Trip Logic for Breaker 1* logic diagram. ➤ Added text explaining that assertion of SELOGIC control equation setting RSTTRGT is one of four methods to unlatch the trip logic. Section 2 ➤ Clarified description of first execution bit PFRTEX in *Table 2.6: First Execution Bit Operation on Power Up; Table 2.7: First Execution Bit Operation on Automation Settings Change;* and *Table 2.8: First Execution Bit Operation on Protection Settings Change and Group Switch.*
20030724	➤ Initial version.

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Appendix B

Firmware Upgrade Instructions

Overview

This instruction will guide you through the process of upgrading the relay's firmware.

Important Considerations

EPORT Setting

SEL-421, SEL-451, and SEL-487B relays with the Enable Port (EPORT) setting found in each Port 1, Port 2, and Port 3 setting class must have the port enabled (EPORT = Y) on all serial ports prior to beginning this procedure. Failure to do so will result in the relay failing to respond after the **L_D** command is given in *Start SELBOOT on page U.B.10*. The factory default for the EPORT settings for Port 1, Port 2, and Port 3 is EPORT = Y.

The EPORT setting was added to the relays at different times. If your relay has a firmware version prior to those listed below, the EPORT setting is not available and there is no need to check the EPORT setting. If your relay presently has SELBOOT firmware revision R101 or later, there is no need to check the EPORT setting.

SEL-400 Series Relay	Firmware Version
SEL-421-0, -1	No EPORT settings
SEL-421-2,-3	R120 and later
SEL-451-1	R202 and later
SEL-451-2,-4	R120 and later
SEL-487B	R117 and later

Display Point Settings

When upgrading an SEL-487B-0 Relay from firmware version R115 or earlier to firmware versions R116-R123, a problem occurs if the relay Display Point labels exceed 19 characters per setting. To prevent this problem, reduce Display Point settings to 19 characters or fewer prior to upgrading the relay. Failure to do so could result in the relay disabling upon restart. Once the firmware upgrade is complete, the Display Point settings can be relabeled.

To prevent this firmware upgrade issue, an upgrade to the latest firmware version (R124 or higher) is recommended.

Required Equipment

You will need the following items before beginning the firmware upgrade process:

- Personal computer (PC)
- Terminal emulation software that supports Xmodem/CRC protocol
- SEL-C234A cable, SEL-C662 USB-to-232 converter, or equivalent
- Disk containing the firmware upgrade file(s)
- Relay Firmware Upgrade Instructions

Optional Equipment

These items help you manage relay settings and understand procedures in the relay upgrade process:

- ACSELERATOR® SEL-5030 Software program
- SEL-487B Relay manual

Upgrade Procedure

The upgrade kit you received contains the firmware needed to upgrade the SEL-487B Relay. The kit may also contain firmware needed to upgrade the Ethernet card and SELBOOT program. See *Table B.1* to identify which firmware files you received in the upgrade kit.

Table B.1 Firmware Upgrade Files

Product	File Name	File Type
SEL-400 series relays SELBOOT	S*nnn*4*xx*.s19[a]	SEL-400 series SELBOOT firmware (can be downloaded to an SEL-400 series relay).
SEL-400 series relays	R*nnn*4*xx*.s19[a]	SEL-400 series relay firmware (can be downloaded to an SEL-400 series relay).
SEL-2701/SEL-2702 Ethernet Processor	R*nnn*27*xx*.s19[a]	SEL-2701/SEL-2702 firmware (can be downloaded to an Ethernet card).
SEL-2701/SEL-2702 SELBOOT	S*nnn*27*xx*.s19[a]	SEL-2701/SEL-2702 SELBOOT firmware (can be downloaded to an Ethernet card).

[a] *nnn* in the file name will always represent the device firmware revision number.

NOTE: SEL strongly recommends that you upgrade firmware at the location of the relay and with a direct connection from the personal computer to one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

The firmware upgrade can be performed in one of two ways:

- Method One: Use the Firmware Loader provided within ACSELERATOR QuickSet® SEL-5030 Software. The Firmware Loader automates the firmware upgrade process and is the preferred method. The Firmware Loader can be used to upgrade only relay firmware (R*nnn*4*xx* files). If upgrading SELBOOT (S*nnn*4*xx*) or SEL-2701 (S*nnn*27*xx*) firmware is required, use Method Two.
- Method Two: Connect to the relay in a terminal session and upgrade the firmware using the steps documented in *Method Two: Using a Terminal Emulator on page U.B.8*.

Method One: Using ACSELERATOR QuickSet Firmware Loader

To use the ACSELERATOR QuickSet Firmware Loader, you must have ACSELERATOR QuickSet. See the PC Software section of the relay instruction manual for instructions on how to obtain and install the software. Once the software is installed, perform the firmware upgrade as follows.

A Obtain Firmware File

NOTE: The Firmware Loader can be used to load only relay firmware (Rnnn4xx). If you need to upgrade relay SELBOOT or Ethernet card firmware, use Method Two.

The firmware file is usually provided on a CD-ROM. Locate the firmware file on the disk. The file name is of the form R*nnn*4*xx*, where R*nnn* is the firmware revision number, 4*xx* indicates the relay type, and .s19 is the firmware file extension. Copy the firmware file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B Remove Relay From Service

Step 1. If the relay is in service, follow your company practices for removing a relay from service. Typically, these practices include disabling input and output control functions.

Step 2. Apply power to the relay.

Step 3. Connect a communications cable and determine the port speed.

If using the EIA-232 front port to upgrade firmware, determine the port speed as follows:

a. From the relay front panel, press the **ENTER (ENT)** pushbutton.

b. Use the arrow pushbuttons to navigate to `SET/SHOW`.

c. Press the **ENTER (ENT)** pushbutton.

d. Use the arrow pushbuttons to navigate to `PORT`.

e. Press the **ENTER (ENT)** pushbutton.

f. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port, Port F).

g. Press the **ENTER (ENT)** pushbutton.

h. Use the arrow pushbuttons to navigate to `Communication Settings`.

i. Press the **<Enter>** key to view the selected port communications settings. Write down the value for each setting.

j. Once the port settings have been recorded, press the **<Esc>** key four times to return to the `MAIN MENU`.

k. Connect an SEL C234A EIA-232 serial cable, SEL C662 USB-to-232 converter, or equivalent communications cable to the relay serial port and to the PC.

C Establish Communications With the Relay

Use the **Communications > Parameters** menu of ACSELERATOR QuickSet to establish a connection using the communications settings determined in *Step 3*. See the PC Software section of the relay instruction manual for additional information.

D Save Settings and Other Data

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Step 1. Select **Tools > Firmware Loader** and follow the on-screen prompts.

Step 2. In the Step 1 of 4 window of the Firmware Loader, click the ellipsis button and browse to the location of the firmware file. Select the file and click **Open**. See *Figure B.1*.

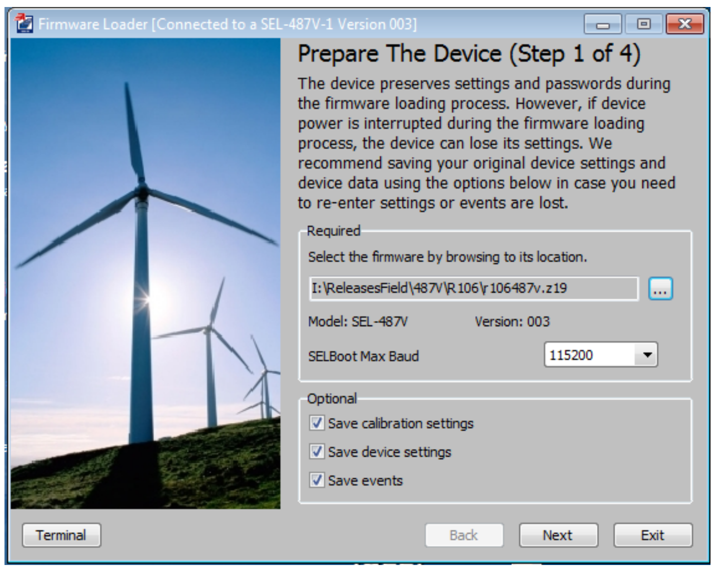

Figure B.1 Prepare the Device (Step 1 of 4)

Step 3. Check the **Save calibration settings** box in the Step 1 of 4 window of the Firmware Loader. These factory settings are required for proper operation of the relay and must be reentered in the unlikely event they are erased during the firmware upgrade process. The Firmware Loader saves the settings in a text file on the PC.

Step 4. Check the **Save device settings** box if you do not have a copy of the relay settings. It is possible for relay settings to be lost during the upgrade process.

Step 5. Check the **Save events** box if there are any event reports that have not been previously saved. The event history is cleared during the upgrade process.

Step 6. Click **Next**.

The Firmware Loader reads the calibration settings and saves them in a text file on the PC. Make note of the file name and the location.

If **Save device settings** was selected, the Firmware Loader reads all of the settings from the relay. The software may ask if you want to merge the settings read from the relay with existing design templates on the PC. Click **No, do not merge settings with Design Template**. The Firmware Loader will suggest a name for the settings, but the suggested name can be modified as desired.

If **Save events** was selected, the Event History window will open to allow the events to be saved. See the PC Software section of the relay instruction manual for more information.

Step 7. If you use the Breaker Wear Monitor, click the **Terminal** button in the lower left portion of the Firmware Loader to open the terminal window. From the Access Level 1 prompt, issue the **BRE** command and record the internal and external trip counters, internal and external trip currents for each phase, and breaker wear percentages for each phase.

Step 8. Enable Terminal Logging capture (see the PC Software section of the relay instruction manual) and issue the following commands to save stored data. It is possible for these data to be lost during the firmware upgrade process.

a. **MET E**—accumulated energy metering
b. **MET D**—demand and peak demand
c. **MET M**—maximum/minimum metering
d. **COMM A** and **COMM B**—MIRRORED BITS® communications logs
e. **PROFILE**—Load Profile
f. **SER**—Sequential Events Report

E Start SELBOOT

In the Step 2 of 4 window of the Firmware Loader, click **Next** to disable the relay and enter SELBOOT. See *Figure B.2*.

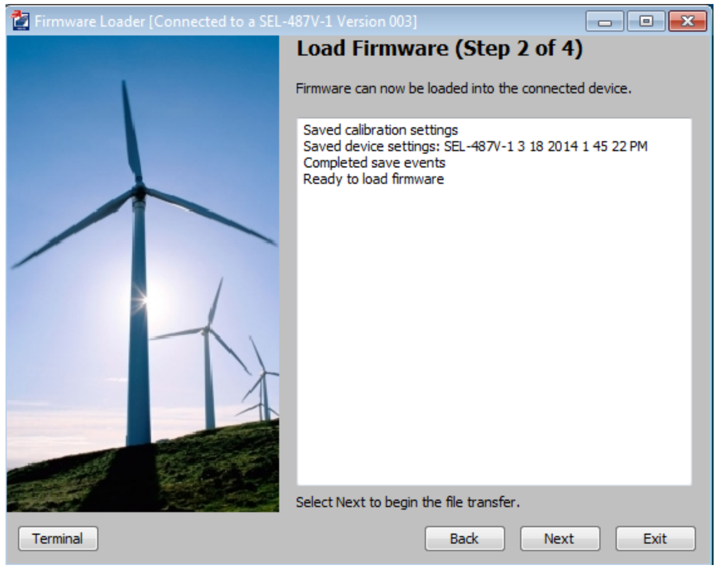

Figure B.2 Load Firmware (Step 2 of 4)

F Maximize Port Baud Rate

This step is performed automatically by the software.

G Upload New Relay Firmware

This step is performed automatically by the software. The software will erase the existing firmware and start the file transfer to upload the new firmware. Upload progress will be shown in the **Transfer Status** window. The entire firmware upload process can take longer than 10 minutes to complete.

When the firmware upload is complete, the relay will restart. The Firmware Loader automatically re-establishes communications and issues an **STA** command to the relay.

In cases where the relay does not restart within two minutes of the firmware upload completion (as indicated by the PC application), and no error messages appear on the relay HMI, cycle power to the relay. The firmware loader application should then resume. Answer **Yes** if the Firmware Loader prompts you to continue.

H Verify Relay Self-Tests

The Step 3 of 4 window of the Firmware Loader will indicate that it is checking the device status and when the check is complete (see *Figure B.3*).

The software will notify you if any problems are detected. You can view the relay status by opening the terminal using the Terminal button in the lower left portion of the Firmware Loader. If status failures are shown, open the terminal and see *Solving Firmware Upgrade Issues on page U.B.18*.

Click **Next** to go to the completion step.

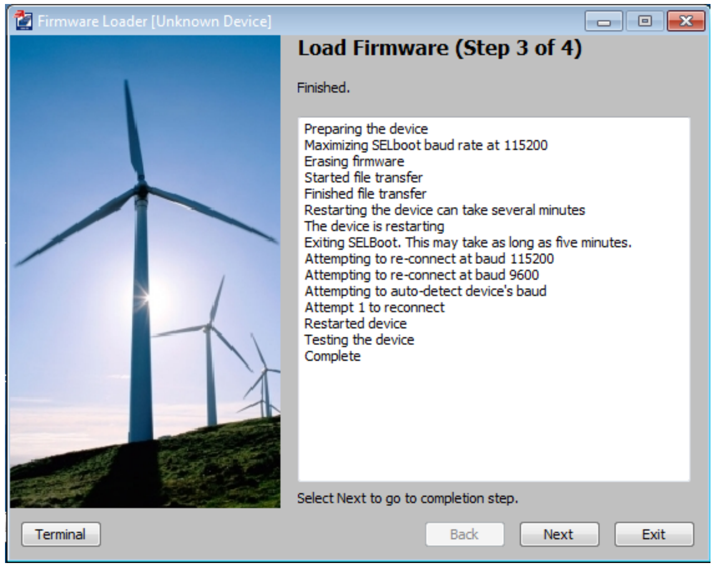

Figure B.3 Load Firmware (Step 3 of 4)

I Verify Relay Settings

If there are no failures, the relay will enable. In the Step 4 of 4 window (see *Figure B.4*), the Firmware Loader will give you the option to compare the device settings. If any differences are found, the software will provide the opportunity to restore the settings.

Figure B.4 Verify Device Settings (Step 4 of 4)

J Return Relay to Service

Step 1. Open the terminal window using the **Terminal** button in the lower left portion of the Firmware Loader.

Step 2. Use the **ACC** command with the associated password to enter Access Level 1.

Step 3. Issue the **ID** command and compare the firmware revision (R*nnn*) displayed in the FID string against the number from the firmware envelope label. If the numbers match, proceed to *Step 5*.

Step 4. For a mismatch between a displayed FID and the firmware envelope label, reattempt the upgrade or contact SEL for assistance.

Step 5. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data to see if the relay retained breaker wear data through the upgrade procedure. If the relay did not retain these data, use the **BRE W** command to reload the percent contact wear values recorded in *Save Settings and Other Data on page U.B.4*.

Step 6. Apply current and voltage signals to the relay.

Step 7. Type **MET <Enter>** or use the ACSELERATOR QuickSet HMI to verify that the current and voltage signals are correct.

Step 8. Use the **TRI** and **EVE/CEV** commands or **Tools > Events > Get Events** menu in ACSELERATOR QuickSet to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report. If these values do not match, check the relay settings and wiring.

Step 9. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay. This step reestablishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Step 10. Follow your company procedures for returning a relay to service.

Method Two: Using a Terminal Emulator

These instructions assume you have a working knowledge of your PC terminal emulation software. In particular, you must be able to modify the serial communications parameters (data speed or baud rate, data bits, parity, and similar parameters), disable any hardware or software flow control in the computer terminal emulation software, select a transfer protocol (1K Xmodem, for example), and transfer files (send and receive binary files).

The programs (firmware) that run in the SEL-400 series relays and Ethernet cards reside in Flash memory. To load new firmware versions, follow these instructions. The SEL-400 series relays and Ethernet cards have two programs that you may need to upgrade: the regular, or “executable” program and the SELBOOT program.

A Obtain Firmware File

The firmware file is usually provided on a CD-ROM. Locate the firmware file on the disk. The file name is of the form R*nnn*4*xx*, where R*nnn* is the firmware revision number, 4*xx* indicates the relay type, and .s19 is the firmware file extension. Copy the firmware file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B Prepare the Relay

If the relay is in service, follow your company practices for removing a relay from service. Typically, these practices include disabling input and output control functions.

C Save Settings and Other Data

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Enter Access Level 2

Step 1. Using the communications terminal, at Access Level 0 type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.
You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**, and then type the correct password to go to Access Level 2.
You will see the Access Level 2 =>> prompt.
For more information, see *Making an EIA-232 Serial Port Connection on page U.4.5*.

View FID

Step 4. Type **STA A <Enter>** to view the SEL-400 series relay and Ethernet card status and firmware identifier (FID). The results of a typical **STA A** command are shown in *Figure B.5*.
Note the FID identifier number(s) for use in *Download Existing Firmware to Your Computer on page U.B.11* and *Verify Relay Self-Tests on page U.B.16* of this document.

```
=>>STA A <Enter>
Relay 1                                Date: 12/07/2005  Time: 11:10:25.246
Station A                              Serial Number: 200405xxxx

FID=SEL-451-1-R106-V0-Z003003-D20051107     CID=0xd806

Failures
   No Failures
Warnings
   No Warnings

Channel Offsets (mV)   W=Warn   F=Fail

  CH1    CH2   CH3   CH4   CH5   CH6   CH7   CH8   CH9   CH10  CH11  CH12  MOF
    1      1     1     1     1     1     1     1     1      1     1     1    1

Power Supply Voltages (V)   W=Warn   F=Fail

3.3V_PS   5V_PS   N5V_PS   15V_PS   N15V_PS
   3.28    5.02    -4.99    14.94    -14.98

Temperature
  34.7 degrees Celsius

Communication Interfaces
  Communications Card 1
   SEL-2701-R107-V2-Z002001-D20051123  Enet All
   Normal 0x0000
   Active virtual terminal sessions: 0

Active High Accuracy Time Synchronization Source: IRIG-B
   IRIG-B Source PRESENT

SELogic Relay Programming Environment Errors
   No Errors

Relay Enabled
```

Figure B.5 Example Relay STA A Command Results

Backup Relay Settings

The relay preserves the settings and passwords during the firmware upgrade process. However, if relay power is interrupted during the firmware upgrade process, the relay can lose the settings. Make a copy of the original relay settings in case you need to reenter settings.

Use one of the following methods to back up relay settings.

- ➤ If you have not already saved copies of the relay settings, use ACSELERATOR QuickSet to read and save the relay settings. See *Create and Manage Relay Settings on page U.3.8*.
- ➤ Alternatively, you can use the terminal to download all the relay settings.

  See the **FILE READ** command in *Section 7: ASCII Command Reference*.

  For file retrieval procedures see *Event Report Oscillography on page A.3.6*.

D Start SELBOOT

Step 1. Establish/confirm binary transfer terminal communication.

Use a terminal program that supports 1K Xmodem transfer protocol to communicate with the relay.

Step 2. Prepare to control the relay at Access Level 2. If the relay is not already at Access Level 2, use the procedure in *Enter Access Level 2 on page U.B.9*.

Step 3. Start the relay SELBOOT program.

a. Type **L_D <Enter>**.

The relay responds with the following message:

`Disable relay to send or receive firmware (Y/N)?`

b. Type **Y <Enter>**.

The relay responds with the following message:

`Are you sure (Y/N)?`

c. Type **Y <Enter>**.

The relay responds with the following message:

`Relay Disabled`

Step 4. Wait for the SELBOOT program to load.

The front-panel LCD screen displays the SELBOOT R*yyy* firmware number (e.g., `SELBOOT R100`); R*yyy* is the SELBOOT revision number and is a different revision number from the relay firmware revision number. The LCD also displays the present relay firmware (e.g., `SEL-451-R102`), and `INITIALIZING`.

When finished loading the SELBOOT program, the relay responds to the terminal with the SELBOOT !> prompt; the LCD shows the SELBOOT and relay firmware revision numbers.

Step 5. Press **<Enter>** to confirm that the relay is in SELBOOT; you will see another SELBOOT !> prompt.

Establish a High-Speed Serial Connection

Step 1. At the SELBOOT prompt, type **BAU 115200 <Enter>** (see *Figure B.6)*.

Step 2. Set your terminal program for a data speed of 115200 bps.

Step 3. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication at 115200 bps is successful.

E Download Existing Firmware to Your Computer

Only follow this step if you want to save a backup copy of the existing relay firmware on your computer. If you do not need to perform this step, proceed to *Upload New Relay Firmware on page U.B.12*.

The PC needs approximately 4 MB of free disk space to store the relay firmware.

Step 1. Type **SEN <Enter>** to initiate the firmware transfer from the relay to the PC.

The relay responds as shown in *Figure B.6*.

Step 2. Select the **Receive File** function with **1K Xmodem** protocol in your terminal emulation software.

Step 3. Name the file with the R-number from the FID from *View FID on page U.B.9* to clearly identify the firmware version (e.g., 451_R102.s19).

Be sure to add the .s19 suffix.

Step 4. Start the terminal emulation software receive program.

Receiving firmware takes approximately 10 minutes at 115200 bps. The front-panel LCD shows `SENDING CODE`. After the transfer, the relay responds with the following message:

`Transfer completed successfully`

F Upload New SELBOOT Firmware to the Relay

NOTE: Loading the incorrect SELBOOT firmware to either the relay or Ethernet card may cause the relay to malfunction, requiring factory repair.

NOTE: Do not cycle power to the relay during the SELBOOT firmware upgrade process. Doing so may cause the relay to malfunction, requiring factory repair.

Upgrading SELBOOT firmware in SEL-400 series relays is typically not required as part of a normal relay firmware upgrade process. However, occasionally core functions of the relay are enhanced, and the SELBOOT firmware must be upgraded to enable the enhanced functions. If a SELBOOT upgrade for the relay is not indicated in your upgrade kit, skip this step, and continue on to *Upload New Relay Firmware on page U.B.12*. Please note that there may also be SELBOOT upgrades for the Ethernet card of the relay. The Ethernet card uses a separate SELBOOT firmware file. See *Table B.1* for file names.

To begin the relay SELBOOT upgrade, start at the SELBOOT prompt !>.

Step 1. Type **REC BOOT** command at the SELBOOT prompt, and answer **Y** when prompted to erase the existing SELBOOT firmware.

```
!>REC BOOT <Enter>

Caution! -  This command erases the SELboot firmware.
Are you sure you want to erase the existing firmware? (Y/N)
```

Step 2. After erasing the existing SELBOOT firmware, the relay will prompt to begin file transfer. Press any key to begin the file transfer to the relay.

Step 3. Using an Xmodem file transfer protocol, point the sending software tool to the relay SELBOOT file (S*nnn*4*xx*.s19) that is to be uploaded to the relay.

Upon successful negotiation of the new SELBOOT firmware file, the old SELBOOT software will be erased, and the new SELBOOT firmware will be written to the relay's Flash memory. SELBOOT will then automatically restart using the new SELBOOT firmware.

```
Erasing old SELboot

Writing new SELboot to flash

Press any key to begin transfer, then start transfer at the PCC
Restarting SELboot
```

Step 4. Once the relay has restarted in SELBOOT, the SELBOOT !> prompt will appear in the terminal window. Remain in SELBOOT and continue to *Upload New Relay Firmware*.

G Upload New Relay Firmware

Step 1. From the SELBOOT !> prompt, type **REC <Enter>**.

The relay responds with the prompt shown in *Figure B.6*. The end of the relay response is

`Are you sure you want to erase the existing firmware? (Y/N)`

Step 2. Type **Y <Enter>**.

The relay responds, `Erasing`, and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay responds, `Erase successful`, and prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

```
!>BAU 115200 <Enter>
!><Enter>
!>SEN <Enter>

Program is ready to be transmitted.
Begin transfer at PC.
Transfer completed successfully.

!>REC <Enter>
Caution! - This command erases the device firmware.
If you erase the firmware, new firmware must be loaded into the device
before it can be put back into service.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing

Erase successful
Press any key to begin transfer, then start transfer at the PCCC <Enter>
```

Figure B.6 Transferring New Firmware

NOTE: The relay displays one or more "C" characters while waiting for your PC terminal emulation program to send the new firmware. If you do not start the transfer quickly (within about 18 seconds), the relay times out and responds `Remote system is not responding`. If this happens, begin again at Upload New Relay Firmware.

Step 3. Press **<Enter>** to begin uploading the new firmware.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K Xmodem for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19).

Step 6. Begin thUpload New Relay Firmware on page U.B.12e file transfer.

The usual transfer time at 115200 bps with 1K Xmodem is about 10 minutes. The LCD screen shows `SELBOOT Ryyy LOADING CODE` while the relay loads the new firmware.

NOTE: The relay restarts in SELBOOT if relay power fails while receiving new firmware after the old firmware is erased. At power-up, the relay defaults to a data speed of 9600 bps. Continue the upgrade procedure beginning at Establish a High-Speed Serial Connection on page U.B.11 to increase the serial connection data speed. Then continue the firmware upgrade process again at Upload New Relay Firmware on page U.B.12.

Step 7. Wait for firmware load completion.

When finished loading the new firmware, the relay responds, `Transfer completed successfully` and displays the SELBOOT !> prompt. The LCD screen displays `SELBOOT Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELBOOT revision number, *xx* is the particular model of the SEL-400 series relays being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-487B-R105.

H Download Existing Ethernet Card Firmware to the Host Computer

Only follow this step if you want to save a backup copy of the existing SEL-2701 or SEL-2702 Ethernet card firmware on your computer. If you do not need to perform this step, proceed to *Upload New Firmware to the Ethernet Card on page U.B.14*.

The PC needs approximately 4 MB of free disk space to store the Ethernet card firmware.

Step 1. From the relay SELBOOT prompt !> type **SEN 5 <Enter>** to initiate the firmware transfer from the Ethernet card to the PC.

The relay responds as shown in *Figure B.7*.

Step 2. Select the **Receive File** function with **1K Xmodem** protocol in your terminal emulation software.

Step 3. Name the file with the R-number of the FID from *View FID on page U.B.9* to clearly identify the firmware version (e.g., 2701_R100.s19).

Be sure to add the .s19 suffix.

Step 4. Start the terminal emulation software receive program.

Receiving firmware takes approximately 10 minutes at 115200 bps. The front-panel LCD shows `SENDING CODE`. After the transfer, the relay responds with the following message:

`Transfer completed successfully`

IMPORTANT: When the Ethernet card is part of a relay upgrade, you **must** stay in SELBOOT for the entire upgrade process (relay and Ethernet card). Exiting SELBOOT at any point other than Step K (Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT on page U.B.15) during the upgrade process may cause the relay to reset to an incorrect part number.

```
!>SEN 5 <Enter>

Program is ready to be transmitted.
Begin transfer at PC from card.
```

Figure B.7 Sending Ethernet Card Firmware to the Host Computer

I Upload New SELBOOT Firmware to the Ethernet Card

Some upgrades of the Ethernet card require an upload of a new version of the SEL-2701 or SEL-2702 SELBOOT firmware. Refer to the SEL-400 Series Relays Upgrade and Conversion Paths document found on the upgrade CD-ROM to determine if your relay needs new SELBOOT firmware. If your relay does not need new SELBOOT firmware, proceed to *Upload New Firmware to the Ethernet Card on page U.B.14*. The following steps describe how to complete this operation. Note that it is important that power be maintained continuously to the relay during this process.

Upgrade Warning

SEL-2701 firmware releases prior to R108 are not compatible with the SEL-2701 SELBOOT version R102. A `SLBT FAIL` (Hex 0x0004) message will appear if a **STA <Enter>** command is issued as shown in *Verify Relay Self-Tests on page U.B.16*. If the `SLBT FAIL` message is shown after the **STA** command is issued, contact SEL for assistance.

Step 1. While still in SELBOOT, type **REC BOOT 5 <Enter>** at the SELBOOT !> prompt. This will prompt the Ethernet card to begin receiving new SELBOOT firmware.

The Ethernet card responds with the prompt shown in *Figure B.8*.

Step 2. Type **Y <Enter>** when the relay responds `Are you sure you want to erase the existing firmware? (Y/N)`.

The relay responds `Erasing` and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

```
!>REC BOOT 5 <Enter>
Caution! - This transfer erases the card's SELboot firmware.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing

Press any key to begin transfer, PCC <Enter>
```

Figure B.8 Transferring New SELBOOT Firmware to the Ethernet Card

Step 3. Press **<Enter>** to begin uploading the new firmware to the Ethernet card.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K Xmodem for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19).

Step 6. Begin the file transfer.

The usual transfer time at 115200 bps with 1K Xmodem is about five minutes. The LCD screen shows `SELBOOT Ryyy LOADING CODE` while the relay loads the new firmware.

Step 7. Wait for firmware load completion.

When finishing loading the new firmware, the relay responds `File Successfully Transferred to Card` after which the relay will respond `Card will now attempt to restart`. Once the Ethernet card re-initializes, the relay will respond with `Card has successfully restarted`, and displays the SELBOOT !> prompt. The LCD screen displays `SELBOOT, Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELboot revision number, *xx* is the particular model of SEL-400 series relay being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-487B-R105.

J Upload New Firmware to the Ethernet Card

If your relay has an Ethernet card, read the SEL-400 Series Relays Upgrade and Conversion Paths document found on the upgrade CD-ROM to determine if new Ethernet card firmware is needed as part of the upgrade process. If your relay does not need new Ethernet card firmware, proceed directly to *Verify Relay Self-Tests on page U.B.16*.

Step 1. While the relay is still in SELBOOT, type **REC 5 <Enter>** at the SELBOOT prompt !>. This will prompt the Ethernet card to begin receiving new firmware.

Step 2. Type **Y <Enter>** when the relay responds `Are you sure you want to erase the existing firmware? (Y/N)`, as shown in *Figure B.9*.

The relay responds `Erasing`, and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

```
!>REC 5 <Enter>
Caution! - This transfer erases the card's firmware.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing

Press any key to begin transfer, PCC <Enter>
```

Figure B.9 Transferring New Firmware to the Ethernet Card

Step 3. Press **<Enter>** to begin uploading the new firmware to the Ethernet card.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K Xmodem for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19).

Step 6. Begin the file transfer.

The usual transfer time at 115200 bps with 1K Xmodem is about 5 minutes. The LCD screen shows `SELBOOT Ryyy LOADING CODE` while the relay loads the new firmware.

IMPORTANT: When the Ethernet card is part of a relay upgrade, you **must** stay in SELBOOT for the entire upgrade process (relay and Ethernet card). Exiting SELBOOT at any point other than Step K (Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT on page U.B.15) during the upgrade process may cause the relay to reset to an incorrect part number.

Step 7. Wait for firmware load completion.

When finished loading the new firmware, the relay responds `File Successfully Transferred to Card.` and displays the SELBOOT !> prompt. The LCD screen displays `SELBOOT, Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELBOOT revision number, *xx* is the particular model of SEL-400 series relay being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-487B-R105.

K Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT

Step 1. Type **<Enter>** to confirm relay communication.

The terminal displays the SELBOOT !> prompt.

Step 2. Type **BAU 9600 <Enter>** to reduce the data speed to your nominal serial communications speed (9600 bps in this example).

Step 3. Set your terminal emulation program to match the nominal data speed.

Step 4. Type **<Enter>** to confirm that you have reestablished communication with the relay.

The relay responds with the SELBOOT !> prompt.

Exit SELBOOT

Step 5. Type **EXI <Enter>** to exit the SELBOOT program.

After a slight delay, the relay responds with the following message:

```
CAUTION: Initial relay restart. DO NOT cycle power
during this time. Please wait 3 minutes for restart
completion.
```

L Verify Relay Self-Tests

Step 1. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on your terminal screen.

Step 2. Remove input power to the relay.

a. Allow at least 10 seconds during the removal of relay power to ensure that the power supply has shut down.

b. Reapply input power to the relay.

c. Wait 5 minutes after power-up of the relay to allow the relay to detect any hardware changes made during the upgrade process.

Step 3. Enter Access Level 1 using the **ACC** command and Access Level 1 password.

Step 4. Enter Access Level 2 using the **2AC** command and Access Level 2 password.

Step 5. Type **STA <Enter>** to check the relay status and accept new hardware changes if needed.

Step 6. Verify that all relay self-test parameters are within tolerance.

Step 7. View the front-panel **ENABLED** LED and confirm that the LED is illuminated.

Unless there is a serious problem, the **ENABLED** LED illuminates without any intervention, and the relay retains all settings.

If the relay does not enable within five minutes of the `Initial relay restart` message, contact your Technical Service Center or the SEL factory for assistance (see *Technical Support on page B.20).*

M Verify Relay Settings

Step 1. Prepare to control the relay at Access Level 2; use the procedure in *Enter Access Level 2 on page B.9*.

Step 2. Type **VER <Enter>** to confirm the new firmware.

Step 3. Match the firmware revision number with the FID number on the screen.

Step 4. Use one of the following methods to review your settings.

➢ Use the ACSELERATOR QuickSet **Read** menu.

If the settings do not match the settings that you recorded in *Backup Relay Settings on page B.10*, use ACSELERATOR QuickSet to restore relay settings.

➢ Type **SHOW <Enter>**.

You can reissue the settings with the **SET** commands (see *Section 7: ASCII Command Reference* for information on the **SHOW** and **SET** commands).

Step 5. Type **STA <Enter>** to check relay status.

Step 6. Verify that all relay self-test parameters are within tolerance.

N Return the Relay to Service

Step 1. Follow your company procedures for returning a relay to service.

Step 2. Type **MET <Enter>** to view power system metering.

Step 3. Verify that the current and voltage signals are correct.

Step 4. Type **TRI <Enter>** and then type **EVE <Enter>** to view the event report for the event just triggered.

Step 5. Verify that the current and voltage signals are correct in the event report.

Step 6. Autoconfigure the communications processor port if an SEL-2032, SEL-2030, or SEL-2020 Communications Processor is connected to the relay.

This step reestablishes automatic data collection between the SEL communications processor and the SEL-400 series relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

The relay is now ready for your commissioning procedure.

Verify IEC 61850 Operation (Optional)

SEL-400 series relays with optional IEC 61850 protocol require the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or if new Ethernet card firmware does not support the current CID file version. If you transfer an invalid CID file, the relay will disable the IEC 61850 protocol, as it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

Perform the following steps to verify that the IEC 61850 protocol is still operational after an Ethernet port firmware upgrade and if not, re-enable it. This procedure assumes that IEC 61850 was operational with a valid CID file immediately before initiating the Ethernet port firmware upgrade. If the IEC 61850 protocol was not configured prior to the upgrade, skip to *Solving Firmware Upgrade Issues on page U.B.18*. Refer to *Section 6: IEC 61850 Communications* for help with IEC 61850 configuration.

Step 1. Establish a Telnet connection to the Ethernet card.

a. From a command line prompt, type **Telnet [IP address] port** (e.g., **Telnet 192.168.0.213 1024**).

b. Press **<Enter>** until you see the = prompt.

Step 2. Issue the **STA**, **ID**, and **GOO** commands.

Step 3. Verify that there are no error messages regarding IEC 61850 or CID file parsing.

If the responses to the **STA**, **ID**, or **GOO** commands contain IEC 61850 or CID error messages, continue with the following steps to re-enable the IEC 61850 protocol. Otherwise, skip to *Solving Firmware Upgrade Issues*.

If the IEC 61850 protocol has been disabled due to an upgrade-induced CID file incompatibility, you can use ACSELERATOR Architect® SEL-5032 Software to convert the existing CID file and make it compatible again.

a. Install the ACSELERATOR Architect upgrade that supports your required CID file version.

b. Run ACSELERATOR Architect and open the project that contains the existing CID file for the relay.

c. Download the CID file to the relay.

Upon connecting to the relay, ACSELERATOR Architect will detect the upgraded Ethernet port firmware and prompt you before converting the existing CID file to a supported version. Once converted, downloaded, and processed, the valid CID file allows the relay to re-enable the IEC 61850 protocol.

Step 4. In the Telnet session, issue the **STA**, **ID**, and **GOO** commands.

Step 5. Verify that no IEC 61850 error messages are in the **STA** or **ID** command responses.

Step 6. Verify the GOOSE transmitted and received messages are as expected.

Solving Firmware Upgrade Issues

If a status failure message is returned in response to the **STA** command, perform the following steps.

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Type **STA C <Enter>**. Answer **Y <Enter>** to the `Reboot the relay and clear status` prompt. The relay will respond with `Rebooting the relay`. Wait for about 30 seconds, then press **<Enter>** until you see the Access Level 0 = prompt.

Step 3. Use the **ACC** command with the associated password to enter Access Level 1.

Step 4. Type **STA <Enter>**.

If there are no fail messages and you are using Method One, click **Next** in Step 3 of 4 of the Firmware Loader and go to *Verify Relay Settings on page U.B.7*.

If there are no fail messages and you are using Method Two, go to *Verify Relay Settings on page U.B.16*.

If there are fail messages, continue with *Step 5*.

IMPORTANT: Step 6 will cause the loss of settings and other important data. Be sure to retain relay settings and other data downloaded from the relay at the start of the firmware upgrade process. Relay calibration level settings will not be lost.

Step 5. Use the **2AC** command with the associated password to enter Access Level 2.

Step 6. Type **R_S <Enter>** to restore factory default settings in the relay.

The relay asks whether to restore default settings. If the relay does not accept the **R_S** command, contact SEL for assistance.

Step 7. Type **Y <Enter>**.

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the ENABLED LED illuminates. This LED is labeled either EN or ENABLED, depending on the relay model.

Step 8. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful.

Step 9. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

Step 10. Use the **CAL** command and type the corresponding password to enter the relay Calibration settings level.

Step 11. Type **SHO C <Enter>** to verify the relay calibration settings.

If using Method One and the settings do not match the settings contained in the text file you recorded in *Save Settings and Other Data on page U.B.4*, contact SEL for assistance.

If using Method Two and the settings do not match the settings contained in the text file you recorded in *Prepare the Relay on page U.B.9*, contact SEL for assistance.

Step 12. Use the **PAS *n*** (***n* = 0**, **1**, **2**, **B**, **P**, **A**, **O**, **C**) command to set the relay passwords.

Step 13. Restore the relay settings:

a. If you have SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by issuing the necessary **SET *n*** commands.

Step 14. If any failure status messages still appear on the relay display, see the Testing and Troubleshooting section in your relay instruction manual or contact SEL for assistance.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Section 1
System Configuration Guideline and Application Examples

Overview

Configuring the system is the most challenging of the many activities associated with using the SEL-487B Busbar Protective Relay. System configuration includes renaming (aliasing) terminals and bus-zones, assigning input contacts to selected relay logics, declaring terminal-to-bus-zone connections, declaring bus-zone-to-bus-zone connections, configuring buscouplers and check zones, and assigning logics to relay outputs. System configuration requires careful consideration of the following items because they both influence the number of SEL-487B relays and ordering options needed:

- primary layout of the substation
- choice of protection elements

For example, substations with six or fewer terminals require only one relay. To monitor both 89A and 89B contacts, however, you must equip this relay with the correct number of interface boards to ensure an adequate number of input contacts.

The following discussion provides general guidelines and outlines general factors that should be considered when using ASCII commands to configure your relay. The section also provides application examples for some of the more common busbar layouts. Included in this section are the following topics:

- Input, logic, and output assigning process
- Relay differential element composition
  - Single-relay application
  - Three-relay application
- CT requirements
  - CT connections
  - CT sizing
  - CT ratio selection
  - CT grounding
  - Polarity
- Disconnect requirements
- Alias names
- Bus-zone configurations

  - Terminal configurations
  - Buscoupler and bus section (tie breaker) configurations
- Bus-zone-to-bus-zone connections
- Zone supervision
- Trip logic
- Output assignments
- Summary
- Application 1: Single bus and tie breaker (three relays)
- Application 2: Single bus and tie breaker (single relay)
- Application 3: Breaker-and-a-half
- Application 4: Single bus and transfer bus with buscoupler
- Application 5: Double bus with buscoupler
- Application 6: Double and transfer bus with two busbars
- Application 7: Double and transfer bus (outboard CTs)
- Application 8: Double and transfer bus (inboard CTs)

Input, Logic, and Output Assigning Process

Figure 1.1 shows a block diagram of the SEL-487B input, logic, and output assigning process for system configuration and protection element settings. Digital input sources include disconnect and breaker auxiliary contacts, breaker failure initiate signals, and breaker close signals. Current and potential transformers provide analog inputs. Use alias settings to assign more meaningful names to primitive Relay Word bits and/or analog names, or use the primitive names of the input quantities to configure and set the relay. The relay has many ready-made logic functions available; however, assign these functions before they become operative. System configuration includes terminal-to-bus-zone and bus-zone-to-bus-zone assignments, zone supervision, and zone-switching supervision settings. Scheme settings include enable settings, differential and sensitive differential element settings, directional element settings, selected relay logic settings, and output assignment.

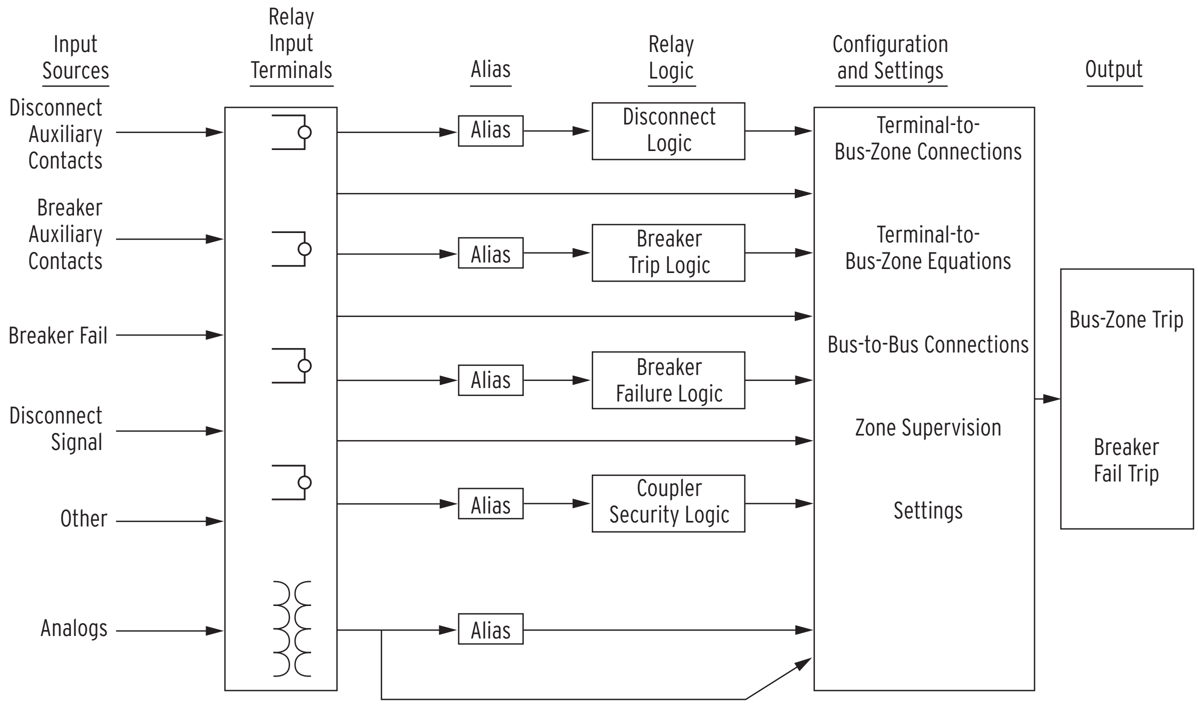


Figure 1.1 Block Diagram of the Input, Logic, and Output Assigning Process for System Configuration Protection Element Settings

Relay Differential Element Composition

Each SEL-487B accepts up to 18 current inputs (I01 through I18) and then assigns these inputs to any of six differential elements (BZ1 through BZ6). *Figure 1.2* shows a block diagram of the arrangement.

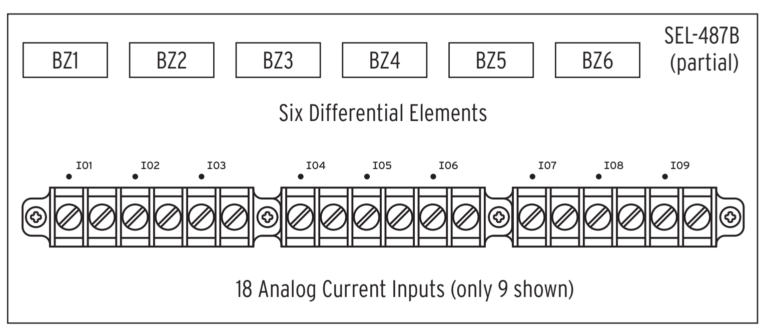


Figure 1.2 Block Diagram Showing Nine Current Inputs and Six Differential Elements

Single-Relay Application

Because differential calculations occur on a per-phase basis, each phase of a three-phase system must bear a unique identification. *Figure 1.3* shows a typical single-line diagram of a station consisting of two busbars (NORTH and SOUTH), a tie breaker (Z), and four terminals.

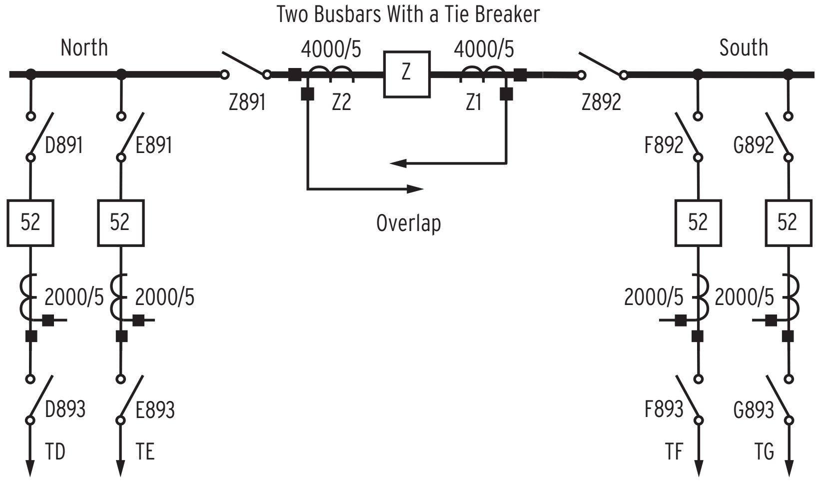


Figure 1.3 Single-Line Diagram of a Station With Two Busbars and a Tie Breaker

Because the station has no more than six terminals, a single SEL-487B suffices. *Figure 1.4* shows the SEL-487B and a three-phase representation of TD, one of the terminals at the station.

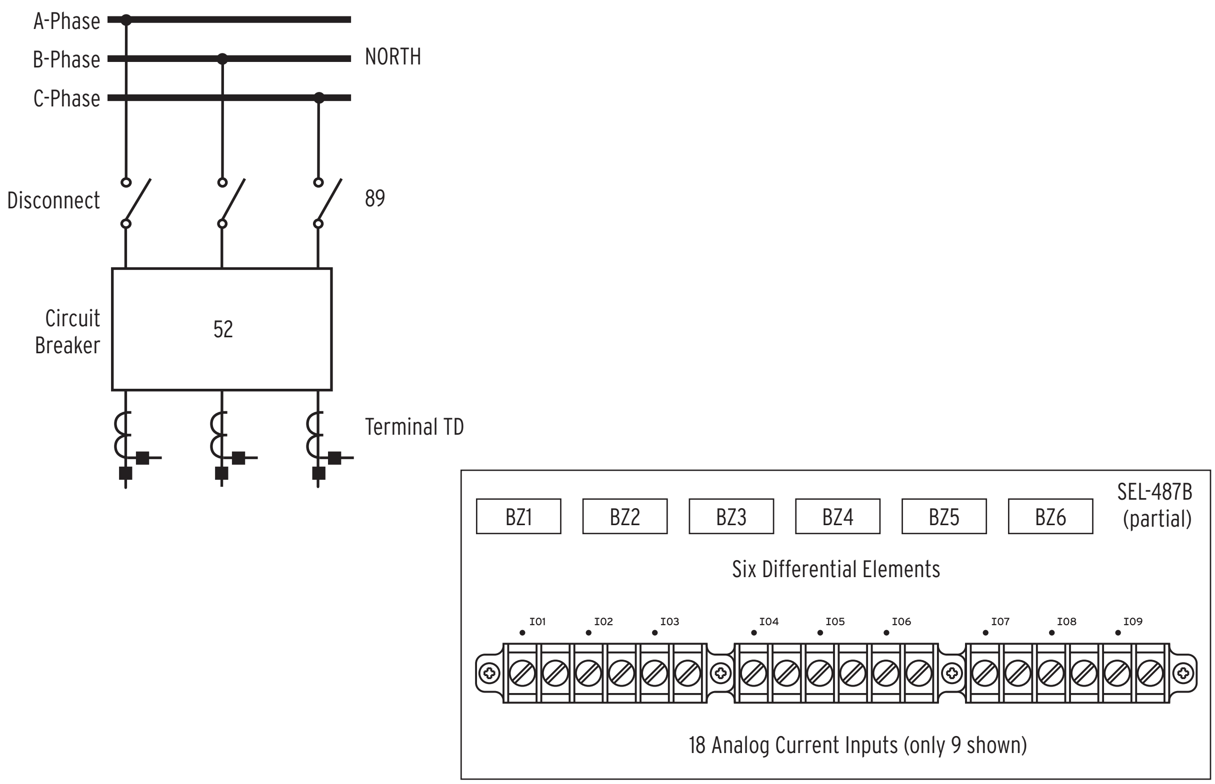


Figure 1.4 Three-Phase Diagram of Terminal TD, the NORTH Busbar, and the SEL-487B

Because differential calculations for each protection zone require an individual differential element, assign an individual differential element to each phase. This assignment uses three of the available six differential elements in the relay for Busbar NORTH. In this example, assign the phases and differential elements as shown in *Figure 1.5*. Each assignment is a software assignment, as indicated by the dotted lines; no electrical wires are required.

Assign the A-phase differential element of Busbar NORTH to differential element BZ1

Assign the B-phase differential element of Busbar NORTH to differential element BZ2

Assign the C-phase differential element of Busbar NORTH to differential element BZ3

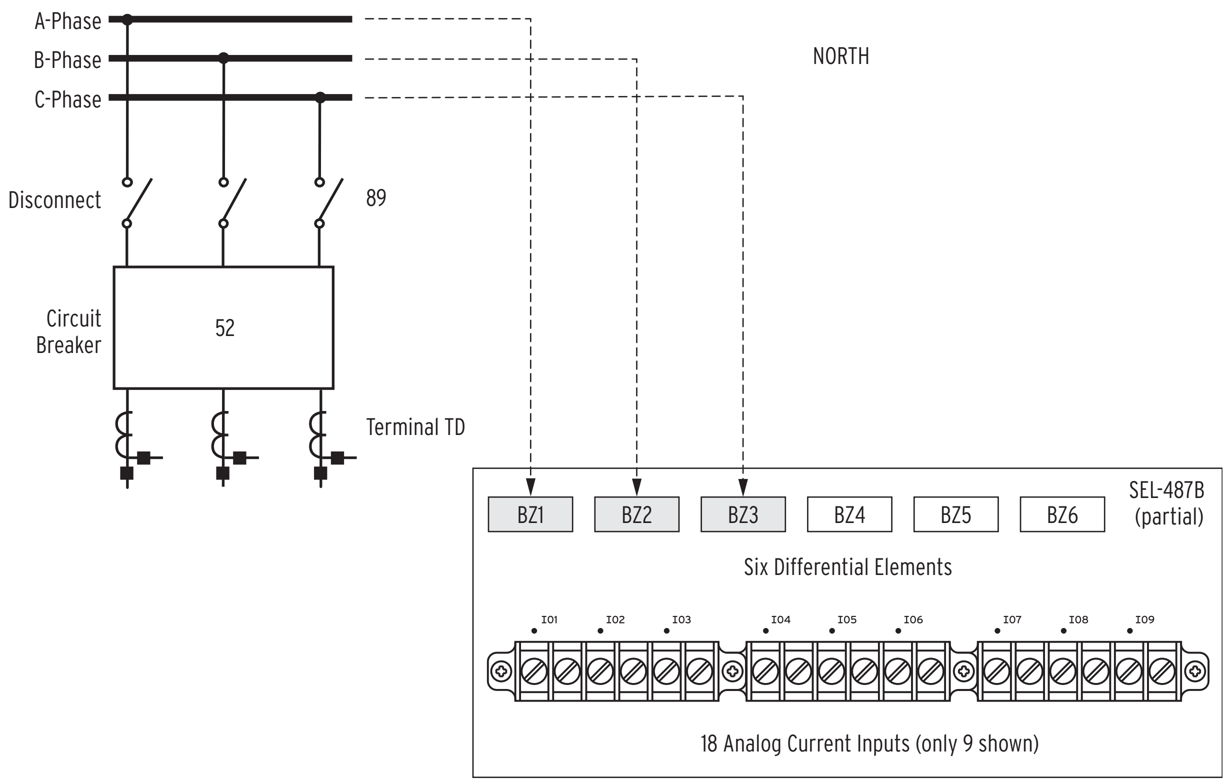


Figure 1.5 A Three-Phase Zone Requires Three Differential Elements

To make the bus-zone labels more substation specific, assign the following alias names to the bus-zones, as shown in *Figure 1.6*:

For the A-phase differential element BZ1, assign NORTH_A

For the B-phase differential element BZ2, assign NORTH_B

For the C-phase differential element BZ3, assign NORTH_C

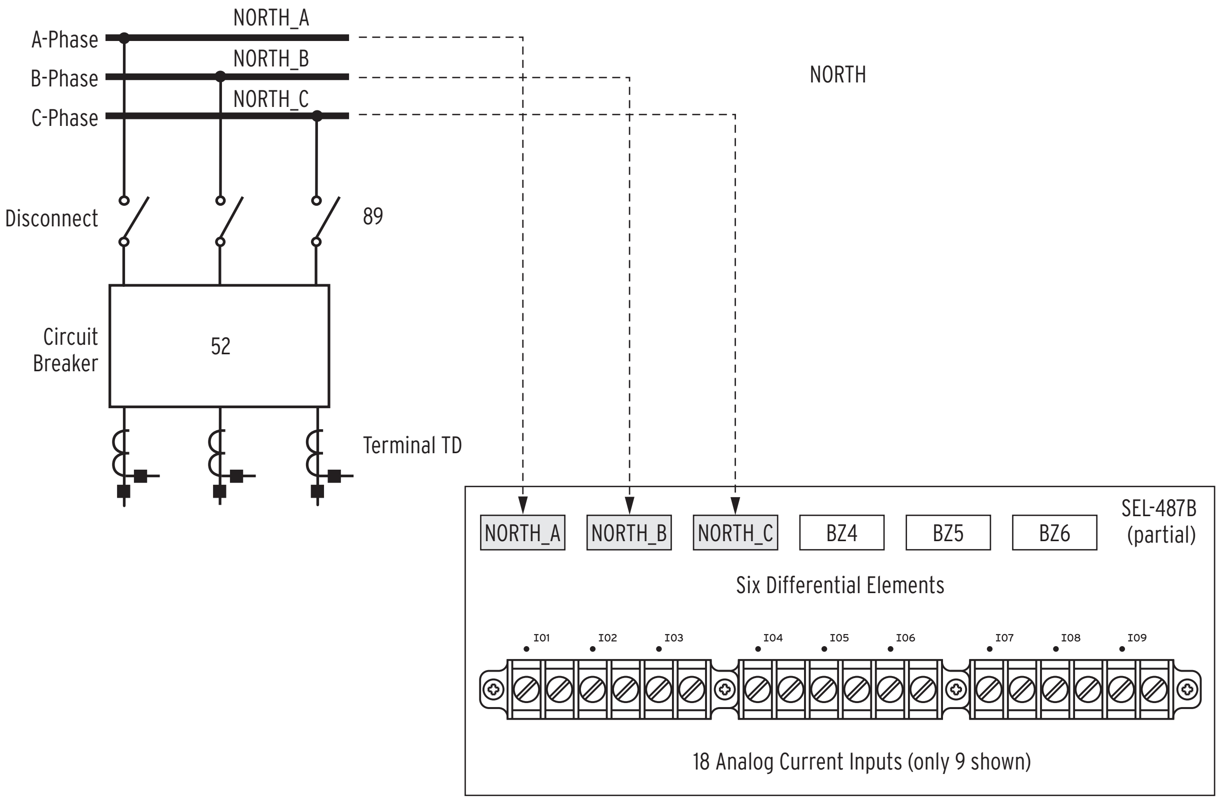


Figure 1.6 Three Differential Elements With Alias Names for a Three-Phase Bus-Zone in a Single Relay Application

For the current inputs in a single-relay application, wire A-phase, B-phase, and C-phase to adjacent terminal connections such as I01, I02, and I03, as shown in *Figure 1.7*. These connections are copper wires connecting the CTs to the relay.

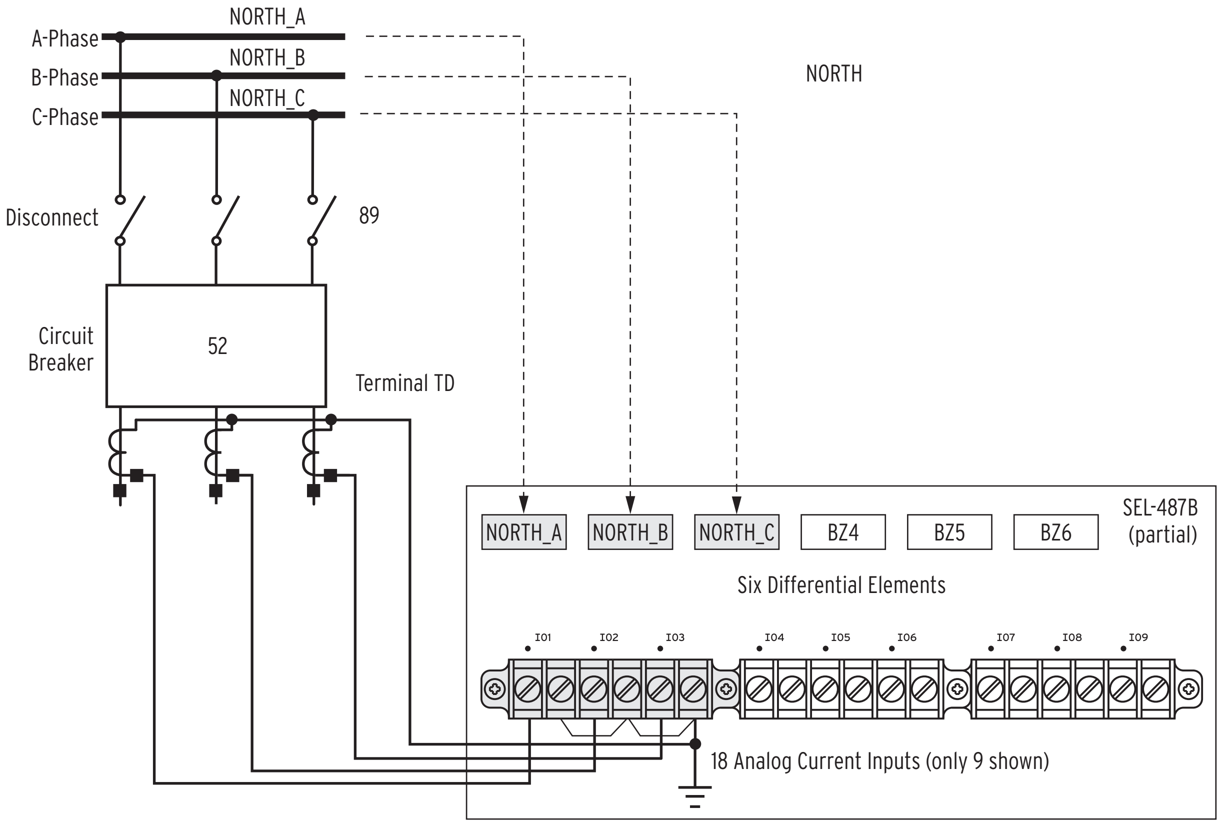


Figure 1.7 Three Differential Elements and Three CT Inputs in a Single-Relay Application

Reference *Figure 1.3* and continue CT connections by wiring the CT inputs from TE (I04 through I06) and Z1 (tie breaker configured in overlap) to I07 through I09. Connect the CTs from Z2, TF, and TG, following the same procedure to complete protection for both bus-zones.

Digital inputs control the dynamic assignment of input currents to differential elements. If you need dynamic zone selection, wire into the relay the auxiliary contacts from the disconnect (89), the circuit breaker (52), or any other conditions that must ultimately be considered in the zone selection logic. *Figure 1.8* shows the disconnect and circuit breaker wiring for Terminal TD.

Only the differential elements are enabled for this example. If you need other functions such as breaker failure protection, wire those inputs to the relay. You need all six zones and all 18 current channels to configure the remaining terminals in the same way. *Figure 1.9* shows the complete station analog channel configuration.

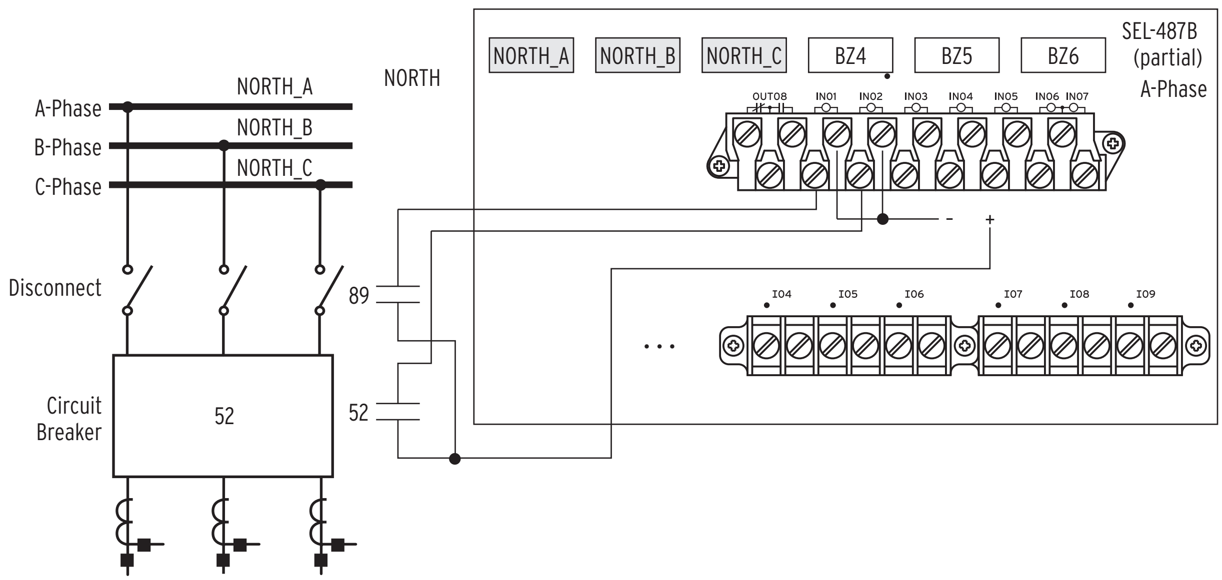


Figure 1.8 Disconnect and Circuit Breaker Wiring for Terminal TD

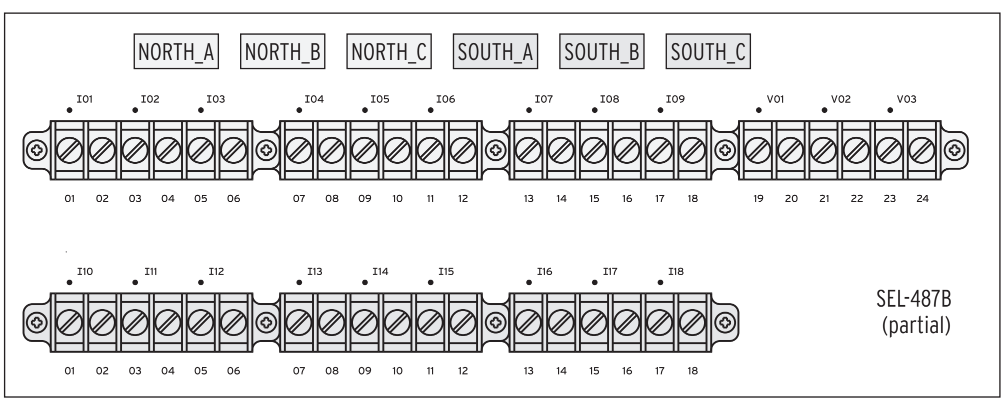


Figure 1.9 Complete Station Configuration, Using Two Three-Phase Bus-Zones and All 18 Current Inputs in a Single-Relay Application

Three-Relay Application

Consider now the same station, configured with three relays instead of one. In the three-relay application, a total of 18 differential elements are available. As before, the label NORTH in the single-line diagram consists of A-phase, B-phase, and C-phase, and each of the three phases is assigned to a differential element. NORTH still requires three differential elements, but the application uses one differential element from each of the three relays, as shown in *Figure 1.10*, instead of three elements in the same relay.

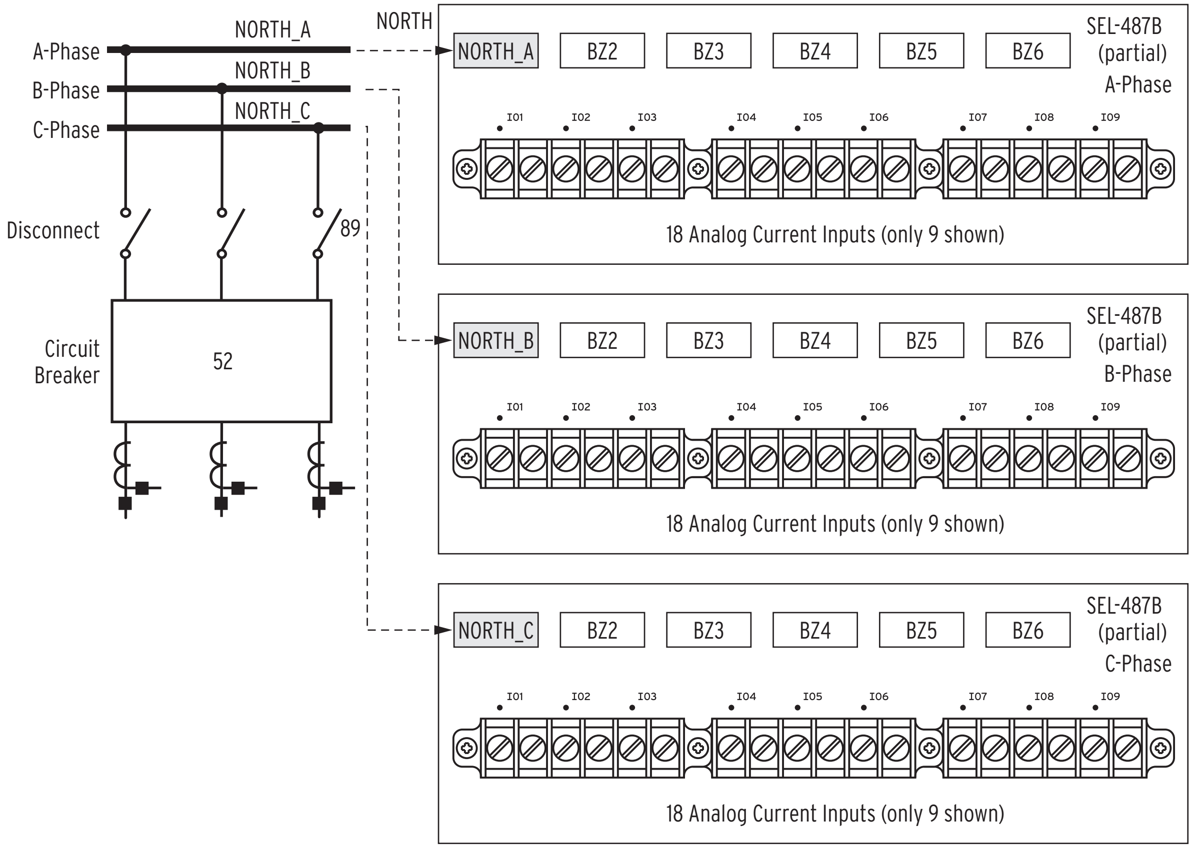


Figure 1.10 One Differential Element From Each of the Three Relays in a Three-Relay Application

Instead of wiring A-phase, B-phase, and C-phase to adjacent terminal connections on the same relay, as with the single-relay application shown in *Figure 1.7*, wire each phase to a separate relay. For example, wire A-phase to the A-Phase SEL-487B Terminal I01, B-phase to the B-Phase SEL-487B Terminal I01, and C-phase to the C-Phase SEL-487B Terminal I01, as shown in *Figure 1.11*.

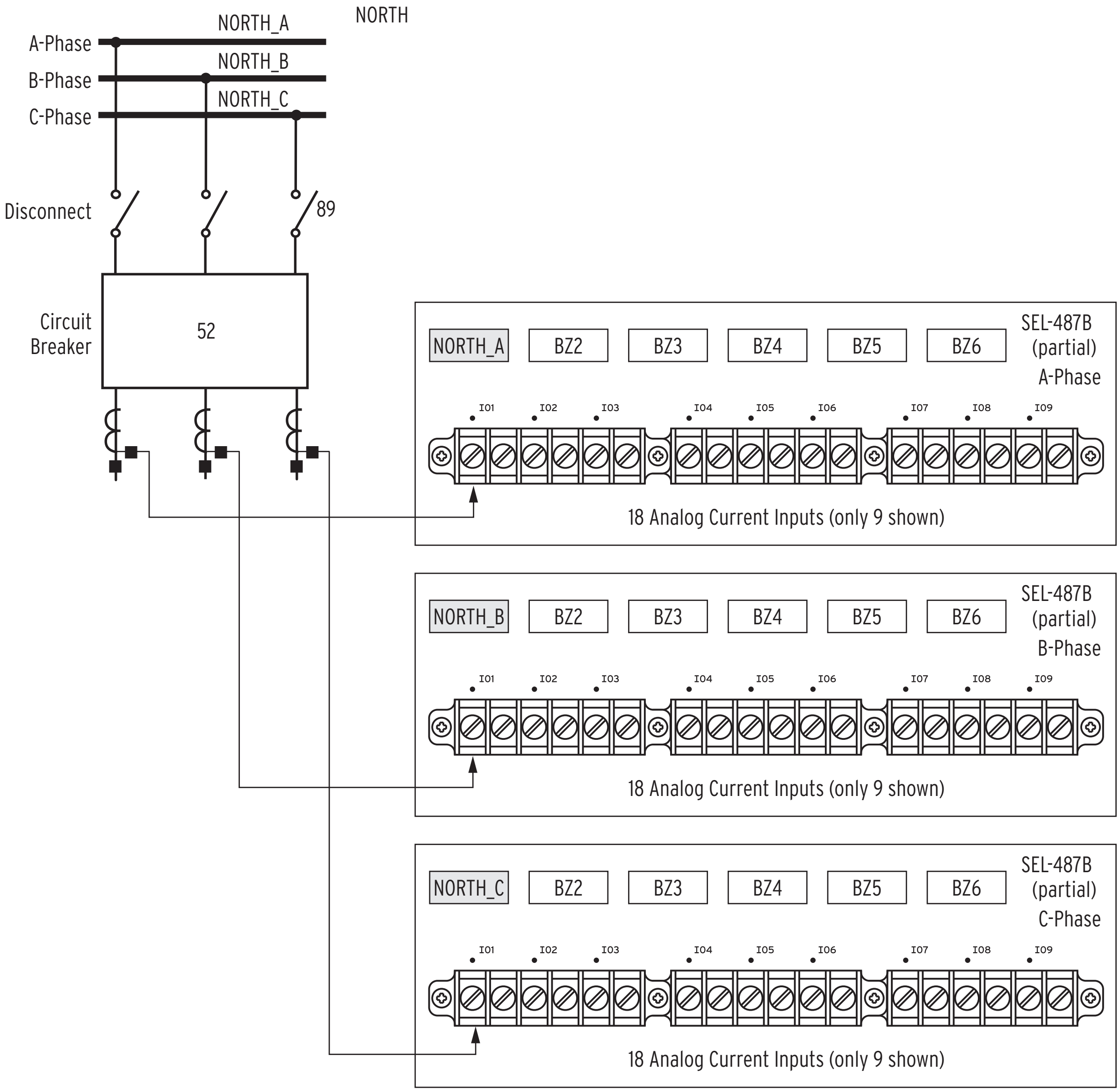


Figure 1.11 CT Wiring in a Three-Relay Application Showing One CT Input to Each of the Three Relays

Figure 1.12 shows the CT wiring for one of the three relays with all A-phase inputs of the station, and two bus-zones assigned. B-phase and C-phase relays have similar arrangements.

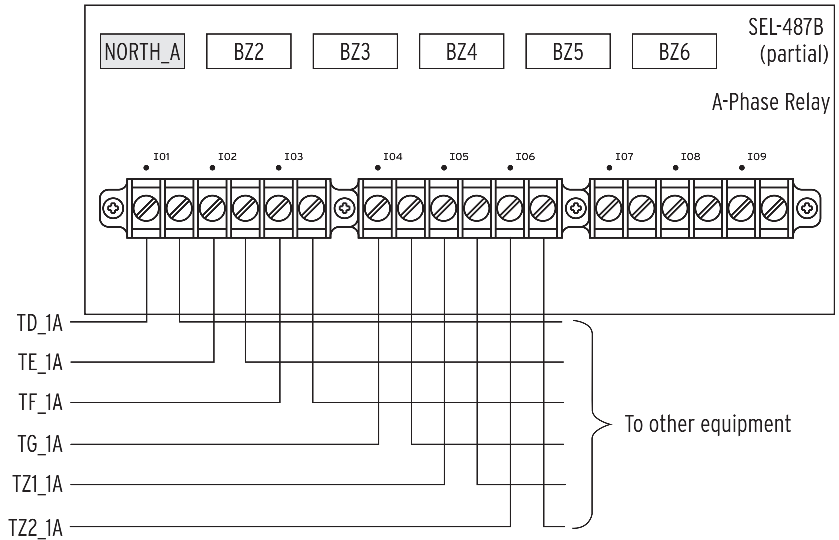


Figure 1.12 CT Wiring for A-Phase Relay, With All A-Phase Inputs of the Station and Two Bus-Zones Assigned

Because the differential elements are in three different relays, each of these relays must receive the same information from the digital inputs. *Figure 1.13* shows jumpers between relays for the case where only one 89 contact and one 52 auxiliary contact are available.

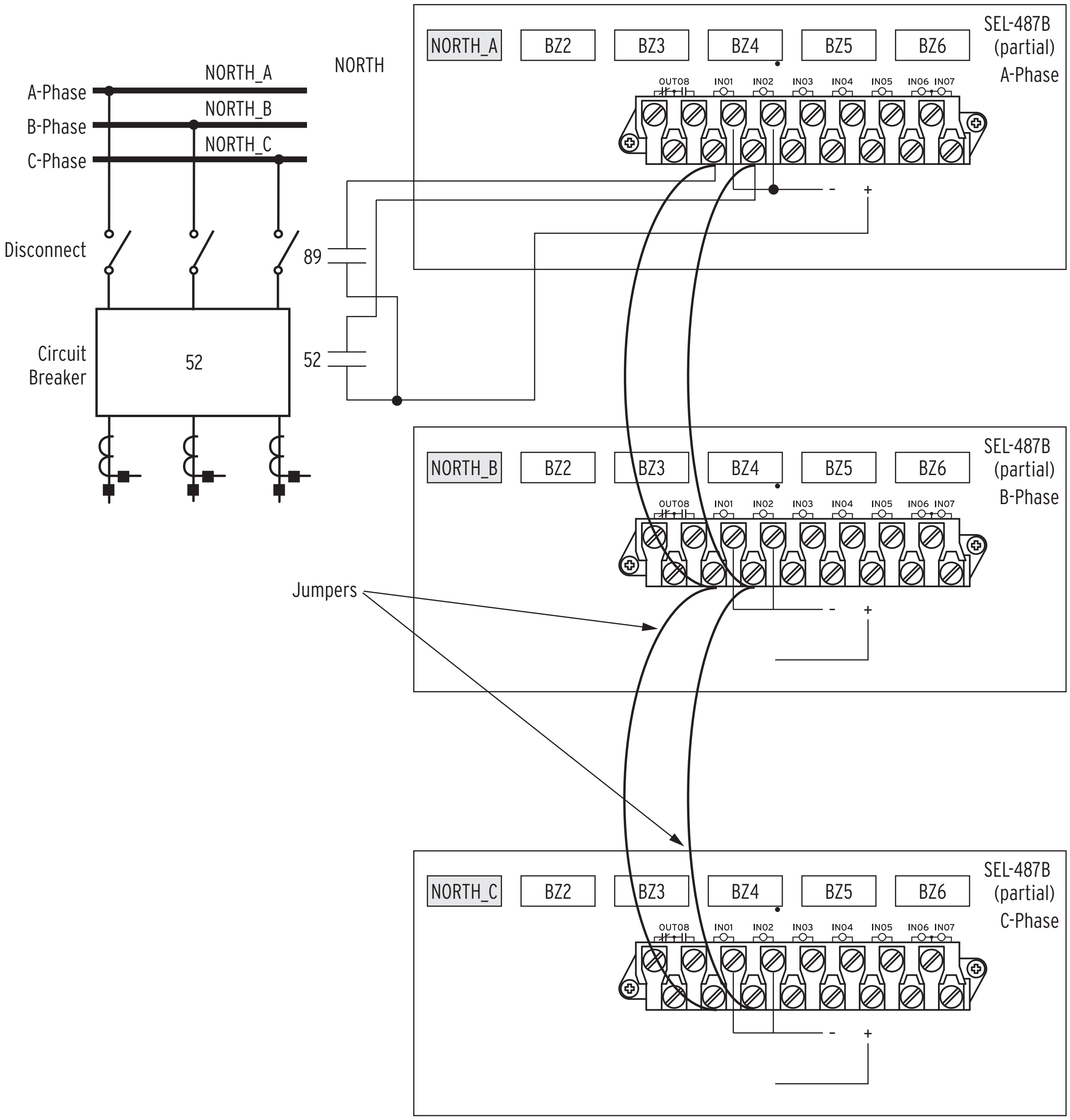


Figure 1.13 Jumpers Between Relays from Digital Inputs 52 and 89

CT Requirements

CT Connections

Connect all CTs to the relay in wye configuration.

CT Sizing

Sizing a CT to avoid saturation for maximum asymmetrical fault current is ideal but not always possible. Such sizing requires CTs with C voltage ratings greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

As a rule of thumb, CT performance will be satisfactory if the CT secondary maximum symmetrical external fault current multiplied by the total secondary burden in ohms is less than half the C voltage rating of the CT.

CT Ratio Selection

For correct operation, the relay algorithm requires that the CTs not saturate for 2 ms following an external fault inception. The IEEE Document *C37.110 Guide for the Application of Current Transformers Used for Protective Relaying Purposes* contains guidelines that will provide a conservative recommendation of the proper CT characteristics needed for low impedance bus differential protection using the SEL-487B. SEL also offers an executable CT saturation program called SEL Two_CTs to assist in determining the CT performance. This program is available on the Product Literature CD-ROM.

For installations with different CT ratios, be sure that the highest/lowest CT ratio does not exceed 10. The SEL-487B selects the highest CT ratio and calculates settings TAP01 through TAP18, provided that the ratio TAP_{MAX}/TAP_{MIN} is less than or equal to 10. If the ratio TAP_{MAX}/TAP_{MIN} is greater than 10, select a different CT ratio.

CT Grounding

Because each of the 18 current channels is independent, be sure to apply a ground to each set of three CTs forming the current input from each terminal. Such grounding connections are usually in the form of short jumpers on the rear of the relay that together create a common connection among terminals. For example, in a three-relay application that uses all 18 terminals, apply 17 jumpers to create a common ground connection point (a single-relay that uses all 18 terminals requires 5 jumpers). Then connect this common point at one location to the station ground mat. Be sure to make ground connections in accordance with ANSI/IEEE® C57.13.3-1983.

Polarity

IEEE Std C37.110-1996 provides the following definition of polarity:

> The designation of the relative instantaneous directions of the currents entering the primary terminals and leaving the secondary terminals during most of each half cycle. Primary and secondary terminals are said to have the same polarity when, at a given instant during most of each cycle, the current enters the identified, similarly marked primary lead and leaves the identified, similarly marked secondary terminals in the same direction, as though the two terminals formed a continuous circuit.

Figure 1.14 shows some of the common polarity marks used to indicate CT polarity.

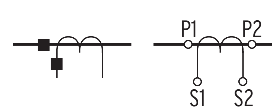


Figure 1.14 Polarity Marks

Polarity marks are also declared on the relay analog input terminals as dots above the relay terminal. When connecting the CTs to the relay, always make sure the wire connected to the polarity terminal on the CT (S1) is also connected to the polarity marked terminal on the relay (Y01, Y03, etc.). *Figure 1.15* shows the polarity marks on the relay.

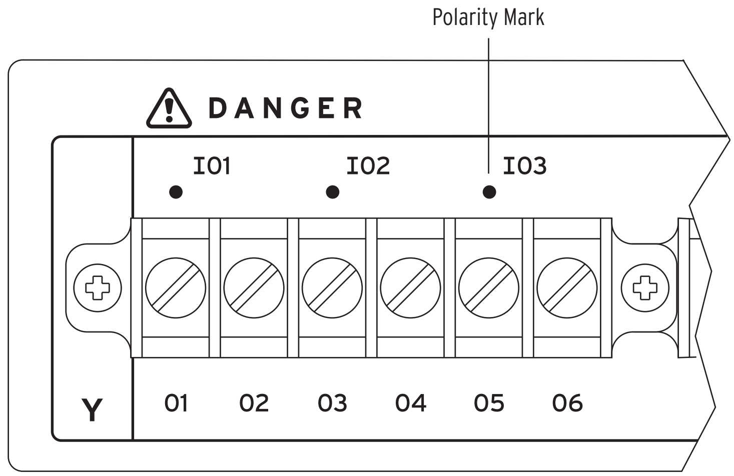


Figure 1.15 Polarity Marks Above the Odd-Numbered CT Terminals at the Rear of the Relay

Connecting the CT terminal with polarity marking to the relay terminal with polarity marking eliminates one possible source of polarity error; the polarity declaration in the software remains the only other potential source of polarity error.

Guideline for Establishing CT Polarity

Use either the ASCII **SET Z** command or the ACSELERATOR QuickSet® SEL-5030 Software to enter relay zone configuration group settings. Prompts in the following steps are those that appear with use of the ASCII **SET Z** command.

Perform the following on the premise that the wire connected to the polarity terminal on the CT is also connected to the polarity terminal on the relay:

Step 1. Start at the CT polarity markings.

Step 2. Move toward the protected bus-zone and determine polarity.

- ➢ Polarity is positive (P) when the movement is through the CT, (*Figure 1.16*), or
- ➢ Polarity is negative (N) when the movement is away from the CT (*Figure 1.17*).

Where **Bus-Zone** is the busbar that will be entered as the **Bus-Zone** argument of the **Terminal**, **Bus-Zone**, and **Polarity (P, N)** prompt, as shown in *Figure 1.16* and *Figure 1.17*.

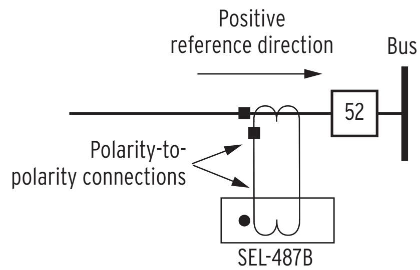


Figure 1.16 Positive Reference Direction

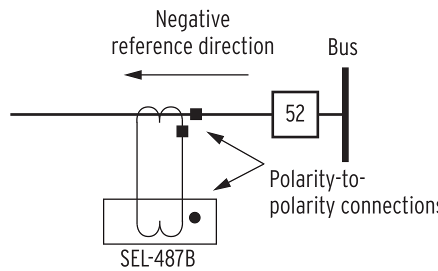


Figure 1.17 Negative Reference Direction

Disconnect Requirements

Disconnect auxiliary contacts provide Zone Selection Logic with the information required to dynamically assign the appropriate current inputs to the correct differential elements. To ensure correct differential element operation, the contacts must comply with the requirements listed in *Table 1.1*.

Table 1.1 Disconnect Auxiliary Contact Requirements to Ensure Correct Differential Element Operation

Operation	Requirement
From disconnect open to disconnect close operation.	Assign the currents to the applicable differential element before the disconnect reaches the “arcing” point, the point where primary current starts to flow.
From disconnect close to disconnect open operation.	Remove the current from the applicable differential element only once the disconnect has passed the “arcing” point, the point where primary current has stopped flowing.

Figure 1.18 shows the disconnect auxiliary contact requirements with respect to the arcing point. The position of 0% travel in *Figure 1.18* indicates the position when the main contacts are fully open, and the 100% position when the main contacts are fully closed.

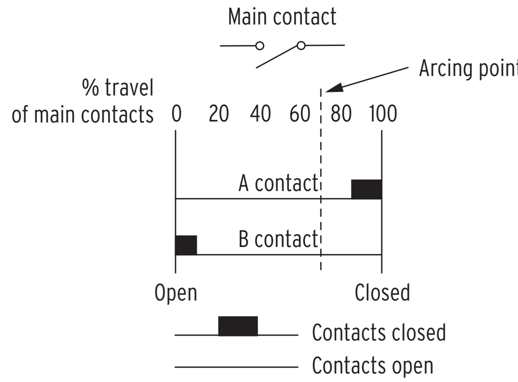


Figure 1.18 Disconnect Auxiliary Contact Requirements With Respect to the Arcing Point for an Open-to-Close Disconnect Operation

When both 89A and 89B contacts are available, use the disconnect monitoring logic in the SEL-487B to establish the principle of

(disconnect) NOT OPEN = (disconnect) CLOSED

Applying this principle, the relay properly coordinates the primary current flow and the CT current assignment to the appropriate differential element. When both 89A and 89B disconnect auxiliary contacts are available, use the disconnect monitoring logic to monitor the disconnect operating time and disconnect status. *Table 1.2* shows the four possible disconnect auxiliary contact combinations and the way the relay interprets these combinations.

Table 1.2 Disconnect A and B Auxiliary Contact Status Interpretation

Case	89A01	89B01	Disconnect Status (89 CLnn)
1	0	0	Closed (1)
2	0	1	Open (0)
3	1	0	Closed (1)
4	1	1	Closed (1)

Table 1.2 (Disconnect Status column) shows that the output from the disconnect monitor logic interprets the disconnect as always closed, except for Case 2. With this interpretation, the relay assigns the input currents to the applicable differential elements for Case 1, Case 3, and Case 4. The following discussion considers the four cases in more detail.

Disconnect Open to Close Operation

Figure 1.19 shows the disconnect main contact starting to travel in an open-to-close operation. Auxiliary contact B is still closed, and auxiliary contact A is open. *Table 1.2* shows this as Case 2; the disconnect is considered open, and the current is removed from all differential elements. This is the only combination of auxiliary contacts for which the relay considers the disconnect main contacts to be open.

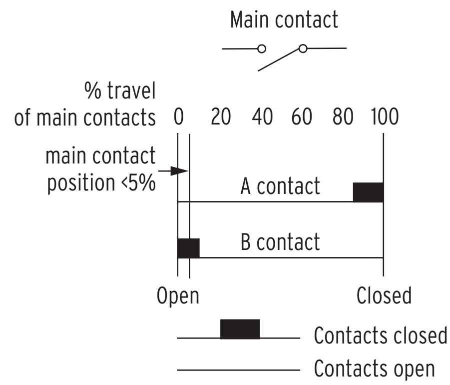


Figure 1.19 Disconnect Main Contacts and Auxiliary Contact A Open, Auxiliary Contact B Closed; Disconnect Is Considered Open

Intermediate Position

Figure 1.20 shows the intermediate position (Case 1 in *Table 1.2*) in a disconnect open-to-close operation, with both A and B auxiliary contacts open for a period of time. Enter this time duration as the disconnect switch alarm timer setting value (89ALP*nn*). By choosing the auxiliary contacts that will change status as soon as disconnect travel starts and close only near the end of travel, the intermediate position time duration can be accurately measured. Should the disconnect remain in the intermediate position for longer than the 89ALP*nn* (*nn* = 1 though 48) time setting, the disconnect switch alarm timer expires and asserts 89AL*nn*, the disconnect monitor alarm.

NOTE: The relay includes 48 alarm timers that provide individual time settings for 48 disconnect logic circuits. These individual timers are useful in installations where the disconnect travel times differ substantially. In particular, sequentially operated devices (pantographs, for example) have travel times much longer than normal disconnects. Relay Word bit 89OIP represents the OR combination of Relay Word bits 89OIP01 through 89OIP48, and Relay Word bit 89AL is respectively the OR combination of Relay Word bits 89AL01 through 89AL48.

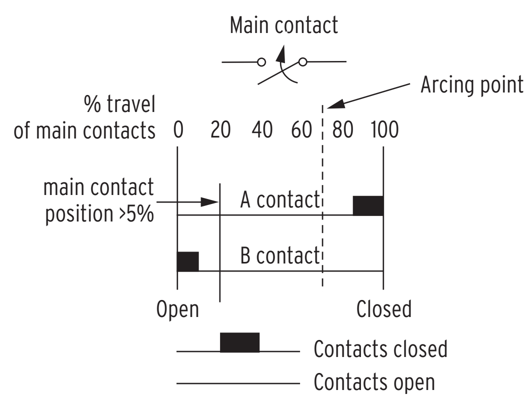


Figure 1.20 Intermediate Position With Both Auxiliary Contacts Open; the Disconnect Is Considered Closed

When auxiliary contact B opens, the disconnect is considered closed (Case 1 in *Table 1.2*). When the disconnect is considered closed, the CT currents are assigned to applicable differential elements, and the disconnect switch alarm timer starts to time. Because disconnect auxiliary contact B opens well in advance of the arcing point, the CT currents are assigned to applicable differential elements before primary current flows.

Auxiliary Contact A Closes

Figure 1.21 shows contact status after auxiliary contact A closes, with the main contact past the arcing point and approaching the end of the close operation.

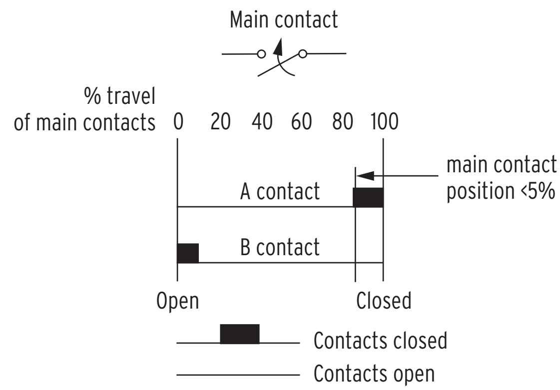


Figure 1.21 The Main Contact Has Completed 95% of Travel; Contact A Is Closed, Contact B Is Open, and the Disconnect Is Considered Closed

When the A contact closes, the disconnect switch alarm timer stops and the Disconnect Monitoring Logic considers the disconnect main contact to be closed.

Disconnect Open and Closed Simultaneously

Case 4 is an illegitimate condition, with the disconnect auxiliary contacts showing the disconnect main contact to be open and closed simultaneously. Timer 89ALP*nn* times for this condition and asserts Relay Word bit 89AL*nn* when the disconnect auxiliary contacts remain in this condition for a period exceeding the timer setting. The relay considers the disconnect main contact closed during this period, and the CTs are considered in the differential calculations.

Close-to-Open Operation

For the close-to-open operation, CT currents must remain assigned to the differential elements for as long as primary current flows. When the auxiliary contact A opens (Case 1), we again enter the intermediate position, as depicted in *Figure 1.20*. In the intermediate position, the CT currents are still assigned to the differential elements, and the disconnect switch alarm timer (89ALnn) starts to time. Only when auxiliary contact B closes (*Figure 1.19*) are the CT currents removed from the differential elements, which are safely past the arcing point.

Many disconnect switches provide only auxiliary contact B. *Table 1.3* shows the two possible disconnect auxiliary contact positions and status interpretations.

Table 1.3 Disconnect Auxiliary Contact Status Interpretation When Only Auxiliary Contact B Is Available

89B01	Disconnect Position
0	Closed
1	Open

Alias Names

Any Relay Word bit, analog quantity, or default terminal name can be renamed with more meaningful names to improve the readability of fault analysis and customized programming. Observe the following restrictions when renaming:

- Maximum of seven digits
- Valid characters are listed below:
  - 0, 1 . . . 9
  - A, B . . . Z (uppercase only)
  - _ (underscore)

No Relay Word bit, analog quantity, or terminal name may appear more than once in the alias settings. Alias names cannot correspond to an already existing Relay Word bit, analog quantity, or terminal name. When an alias is removed, all settings that referenced that alias revert back to the original (primitive) name. For example, assign the alias name OVER to the primitive name 50P01, and then enter OVER into some protection SELOGIC® control equations. When the alias OVER is removed, all protection SELOGIC control equations will revert to the primitive name (50P01) instead of to the alias name (OVER). The torque-control setting for the time-overcurrent element would change from 51P01TC := OVER to 51P01TC := 50P01. However, if 50P01 were set to a new alias, the element would use the new alias name. For example, if alias 50P01,OVER were set and you entered 50P01,O_C, the 50P01 element would use the alias O_C.

Duplicate alias names and blank entries are not allowed. All settings accept aliases, and when an alias exists for an element, the relay displays the alias for that element. Aliases appear in event reports, settings (set and show), and the **TAR** command. *Figure 1.22* shows a feeder called New York that is wired to the analog channel I01. Feeder New York connects to Bus-Zone NORTH when the disconnect auxiliary contact wired to IN205 closes.

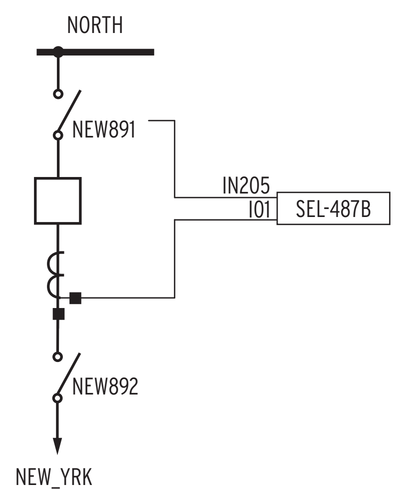


Figure 1.22 Alias Name Example for NEW_YRK Terminal

The following steps describe how to set the I01 and BZ1 aliases:

Step 1. Type **SET T <Enter>** to use the alias function.

The syntax is "existing name" comma "alias name." For example, the primitive name for the CT input is I01, and we want to change this to the more descriptive feeder name, "New York." Including the space, the number of characters is eight, one more than the allowable number of seven. Changing the name to "New Yrk" reduces the character count to seven, but the name still contains two types of characters not permitted (a space and four lowercase letters (ew rk)).

Step 2. Type **LIST <Enter>** at the `=>>` prompt to view all existing alias names.

From the display, we see that Terminal I01 and Bus-Zone BZ1 already have alias names.

Step 3. Type **I01,NEW_YRK <Enter>** as shown in *Figure 1.23*.

The prompt shows the existing default value, if any.

Step 4. Type **> 7 <Enter>** after assigning the new alias to Terminal I01 to move to the BZ1 line.

Step 5. Enter **BZ1,NORTH <Enter>** to set the new alias for BZ1.

Step 6. Type **> <Enter>** to move directly to the end of the list.

Step 7. Type Y <Enter> at the `Save Settings (Y,N)?` prompt to save the settings.

Step 8. Type **END <Enter>**.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
.
.
.

68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"

1: I01,"FDR_1"
?  I01,NEW_YRK <Enter>
2: I02,"FDR_2"
?  >7 <Enter>
7: BZ1,"BUS_1"
?  BZ1,NORTH <Enter>
8: BZ2,"BUS_2"
?  > <Enter>
70:
?  END <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"NEW_YRK"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"NORTH"
8: BZ2,"BUS_2"
.
.
.

69: TLED_24,"IRIGLED"

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.23 Assigning Alias Names

Bus-Zone Configurations

Dynamic zone selection is the process the relay uses to assign or remove CT currents from the differential elements as a function of the boolean value (logical 0 or logical 1) of a particular SELOGIC control equation. The SELOGIC control equation is a setting in the form of I*nn*BZ*k*V:= (*nn* = 01 through 18, and *k* = 1 through 6). When setting SELOGIC control equations, use a separate SELOGIC control equation for each busbar to which the terminal can connect.

In general, a terminal can be identified as either a normal terminal (feeders, lines, transformers, etc.) or as a tie breaker (buscoupler). For terminals, typical inputs are disconnect auxiliary contacts and, in some cases, circuit breaker auxiliary contacts. Buscouplers have specific logic and configuration options that require inputs in addition to disconnect and circuit breaker auxiliary contacts to ensure security and dependability.

When configuring bus-zone protection, the goal is to accomplish the following:

- Protect the busbars for all operating conditions
- Eliminate all dead zones
- Open the minimum number of breakers when tripping
- Implement the check zone without disconnect supervision, if a check zone is required

When the terminal-to-bus-zone SELOGIC control equation (I*nn*BZ*k*V) is logical 0, differential calculations do not consider the CT inputs from that specific terminal, and no trip outputs from the differential elements are issued to that terminal. Of particular concern are instances when more than one disconnect for any particular terminal are closed at the same time. When this happens, parallel paths form, possibly resulting in the unbalance of multiple zones, as shown in *Figure 1.24* and *Figure 1.25*. Under balanced conditions, the current toward the busbars equals the current away from the busbars, and the differential current in any differential element is practically zero.

In practice, the most popular implementation for preventing misoperation when parallel paths form is to combine the parallel paths into a single zone and route the CTs to a single differential element. Another option is to configure one zone as a check zone by combining all terminals at a specific voltage level into a single zone independent of the terminal-to-bus-zone SELOGIC control equations. Using the check zone as a second trip criterion prevents relay misoperation in the case of parallel paths.

In general, apply the following rules when setting terminal-to-zone SELOGIC control equations:

- Observe the correct CT polarity
- Avoid parallel operating conditions
- When parallel paths are unavoidable, take necessary precautions

Two situations exist where parallel paths are unavoidable: when two disconnects are closed simultaneously and when using inboard (bushing) CTs.

Two Disconnects Closed Simultaneously

Figure 1.24 shows a double busbar layout in which two disconnects can be closed simultaneously. With the tie breaker (TZ) connected in overlap, CT1 and CT2 form Differential Element 1, and CT3 and CT4 form Differential Element 2. There are no parallel paths in *Figure 1.24*, and both differential elements are balanced. Calculate the differential currents with the following expression:

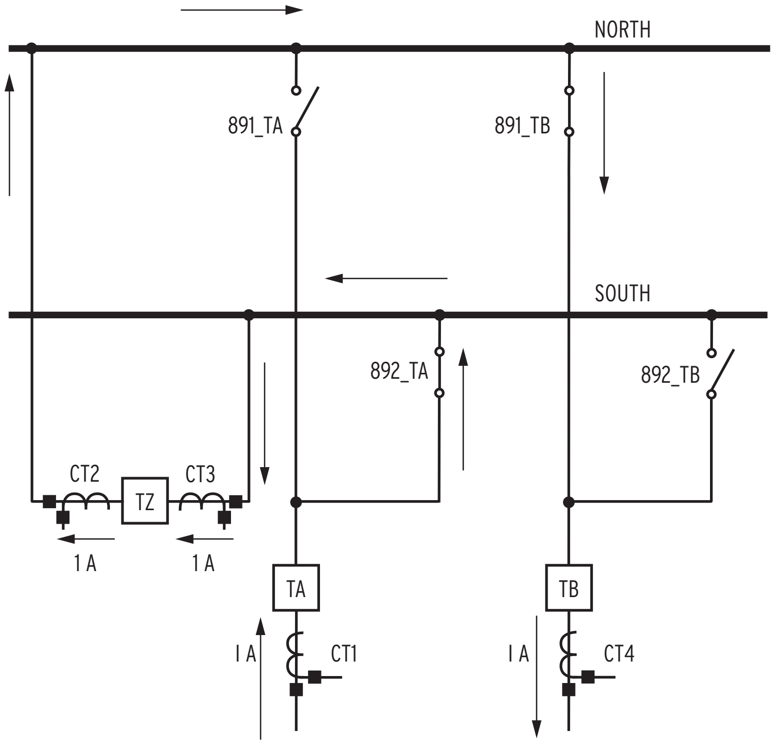
$$I_{DIFF1} = \sum_{1}^{n} I_n$$

Equation 1.1

where:

I_{DIFF1} = The differential current calculated in Differential Element 1

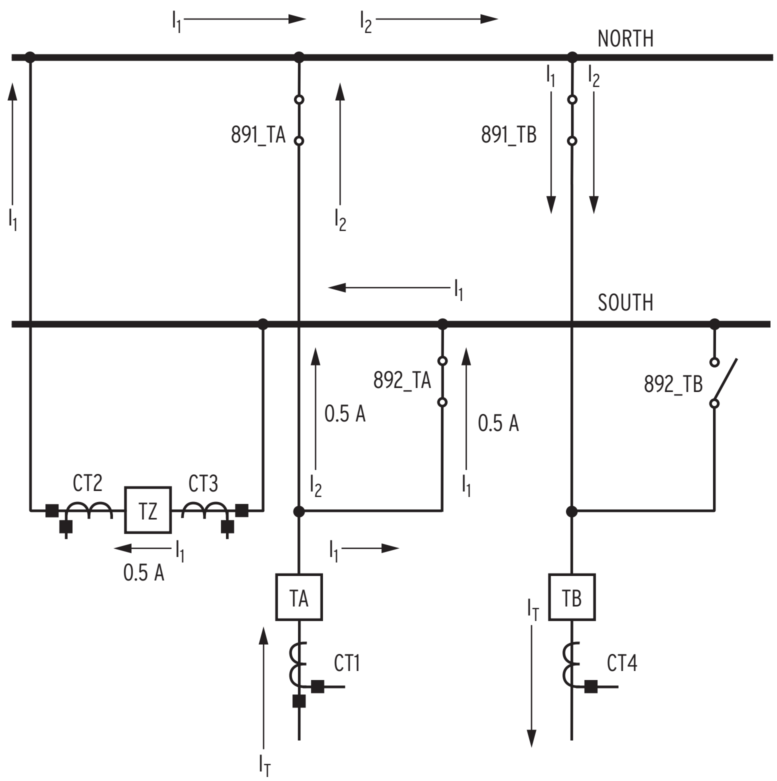
I_n = CT currents from the *n* terminals assigned to Differential Element 1



I_{DIFF1} = CT1 - CT2 = 1 - 1 = 0
I_{DIFF2} = CT3 - CT4 = 1 - 1 = 0

Figure 1.24 Both Differential Elements Balanced

Closing 891_TA in *Figure 1.25* forms a parallel path between the two busbars, and both differential elements are unbalanced.



I_{DIFF1} = CT1 + CT2 = 1 – 0.5 = 0.5
I_{DIFF2} = CT3 + CT4 = 0.5 – 1 = –0.5
$I_1 + I_2 = I_T$

Figure 1.25 Both Differential Elements Unbalanced

To prevent misoperation, combine the two bus-zones by stating the conditions governing the combinations during setting of bus-zones-to-bus-zones connections. When using bushing (inboard) CTs, combining bus-zones involves including a circuit breaker as part of the connection. You can include a circuit breaker provided that the circuit breaker auxiliary contact is wired to the relay and included in the bus-zones-to-bus-zones settings.

Inboard (Bushing) CTs

Figure 1.26 shows an outboard CT, and *Figure 1.27* shows an inboard CT. Defining a CT as inboard or outboard only has meaning when a terminal is on transfer. To define the terms, refer to the area between the circuit breaker and the CT, and determine the connection to the transfer bus.

- Outboard CT: the connection to the transfer bus is between the circuit breaker and the CT (*Figure 1.26*).
- Inboard CT: the connection to the transfer bus is not between the circuit breaker and the CT (*Figure 1.27*).

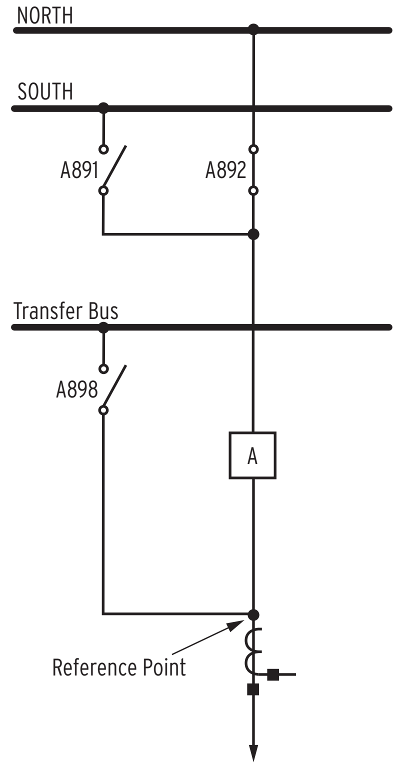


Figure 1.26 Outboard CT

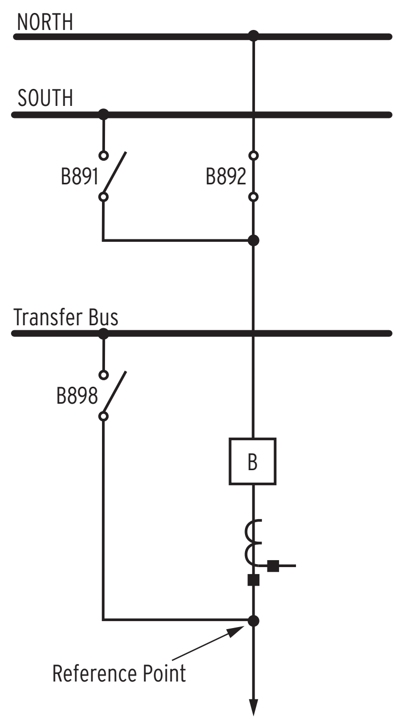


Figure 1.27 Inboard CT

Bushing CTs (typically the source of inboard CTs) present two difficulties to bus protection when a terminal is on transfer:

- A transfer differential zone cannot be formed because of a lack of CT inputs.

➤ The check zone is unbalanced.

Not having a transfer differential zone is not a major problem if it is understood that the transfer busbar becomes part of the line and forms part of the line protection when a terminal is on transfer. However, the unbalanced check zone usually necessitates blocking busbar protection when a terminal is on transfer.

Terminal Configurations

In essence, busbar protection is assigning the correct CT currents to the appropriate differential elements. Disconnect auxiliary contacts provide the information necessary for busbar protection, and breaker auxiliary contacts provide the breaker status for refining the protection. SELOGIC control equations provide the mechanism for declaring the conditions when the currents are assigned to the appropriate differential elements. Entering data in the relay requires two steps. The first identifies the terminal and attributes, the second involves creation of the SELOGIC control equation stating the conditions for the CTs to be considered in the differential calculation. Buscouplers (tie breakers) require more condition information when two or more bus-zones are combined.

Step 1. Identify the terminal, the bus-zone to which the terminal can connect, and the CT polarity when this connection is made.

The following is the relay prompt for the *Step 1* entry:

```
Terminal, Bus-Zone, Polarity (P,N)
?
```

Step 2. State the conditions when **Terminal** will be connected to the **Bus-Zone**:

I01BZ2V :=

Think of **Terminal** as the CT of that particular terminal and **Bus-Zone** as the busbar to which the CT will be connected for differential and restraint current calculations. In other words, assign the CT (**Terminal**) to busbar (**Bus-Zone**) under the following conditions: **I01BZ2V := <conditions>**.

Figure 1.28 shows Terminal NEW_YRK. The differential calculations consider the CT when disconnect NEW891 closes to complete the connection to Bus-Zone NORTH.

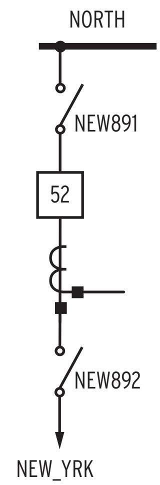


Figure 1.28 Terminal NEW_YRK Disconnects NEW892 and NEW891 and Bus-Zone NORTH

Step 3. Enter the data as follows:

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH,P <Enter>
```

Entering incorrect information may result in relay misoperation. To reduce potential entry of incorrect information, the relay provides a double check to verify that terminal and bus-zone connections are indeed as intended. The next prompt has two parts:

➢ The relay states terminal and bus-zone alias names just entered.

➢ The relay generates a prompt with the primitive terminal and bus-zone names.

Thus, the prompt now appears as follows:

```
NEW_YRK to NORTH Connection (SELogic Equation)
I01BZ1V :=
```

Step 4. Enter the conditions under which Terminal NEW_YRK is to be assigned to Busbar NORTH by specifying the particular disconnect (89) auxiliary contact that will connect the terminal to the busbar.

For example, when Disconnect NEW891 is closed, Terminal NEW_YRK is connected to Busbar NORTH. A Terminal, Bus-Zone, Polarity (P,N), and I01BZ1V setting is required for each 89 contact that results in a terminal-to-busbar connection. Consider a terminal that can be connected to Busbar 1, Busbar 2, and the transfer bus. Because the terminal connects to three busbars, provide terminal-to-bus-zone (Terminal, Bus-Zone, Polarity) and conditions for consideration in the differential calculations [I01BZ*n*V (*n* = 3)] for each of the three busbars.

Step 5. Enter the following settings for Terminal NEW_YRK:

```
NEW_YORK to NORTH Connection (SELogic Equation)
I01BZ1V := NEW891 <Enter>
```

Entries here assign CT currents to differential elements. Take care to first investigate the position of the CT for each entry. For example, refer to *Figure 1.26*, and observe that regardless of which disconnect closes (A891, A892 or A898), current always flows through the CT. This is not the case with inboard CTs; closing B898 in *Figure 1.27* bypasses the CT, and no current flows in the inboard CT.

Step 6. Follow the guidelines for establishing CT polarity (*Guideline for Establishing CT Polarity on page A.1.14*) to determine the CT polarity. Following the steps (shown in *Figure 1.29*), we determine that the CT polarity is positive.

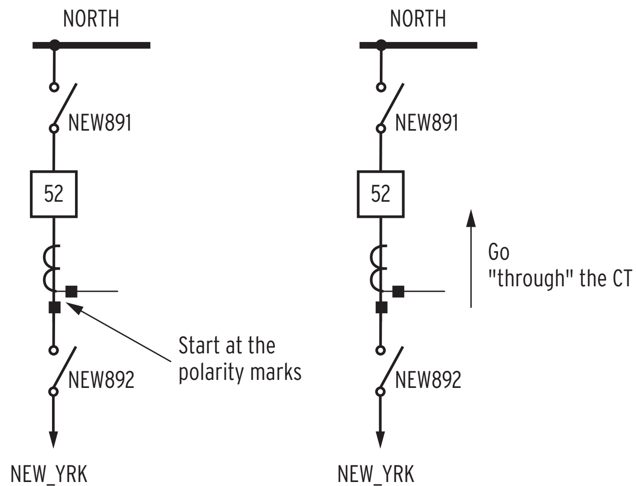


Figure 1.29 Determine the CT Polarity to Select P or N for the Polarity Setting

Step 7. Omit the final argument if the CT polarity is positive.

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH,P <Enter>
```

It has the same meaning as

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH <Enter>
```

Buscoupler (Tie Breaker) Configurations

In general, buscouplers are usually configured according to one of the three cases shown in *Figure 1.30*:

- ➤ Case 1: Single CT, single or two cores (two cores shown) with overlap
- ➤ Case 2: CT either side of the breaker, configured in overlap
- ➤ Case 3: CT either side of the breaker with breaker differential

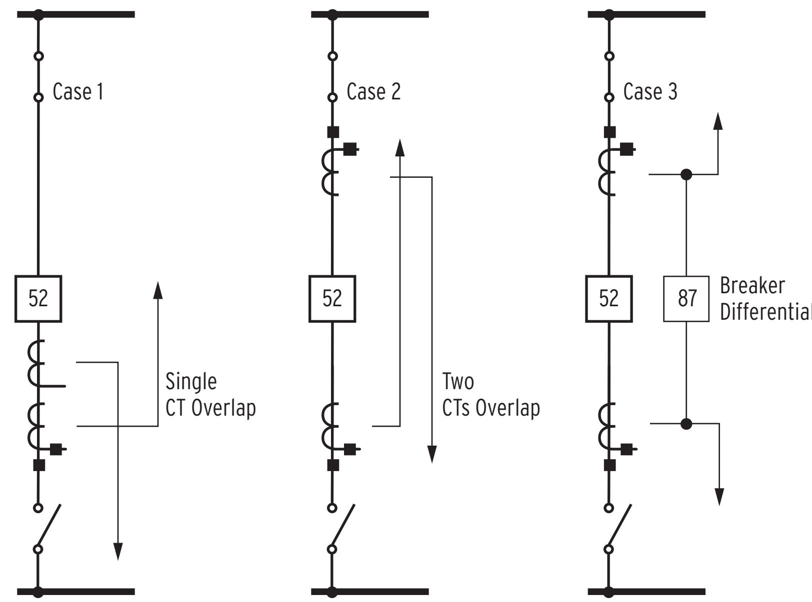


Figure 1.30 Three Typical Cases of Buscoupler Configurations

A discussion on how to set the three configurations follows.

Label all CTs as indicated in *Figure 1.31* (i.e., CPL1 and CPL2) with the understanding that CPL1 is wired to Terminal I01, and CPL2 to Terminal I02 of the SEL-487B.

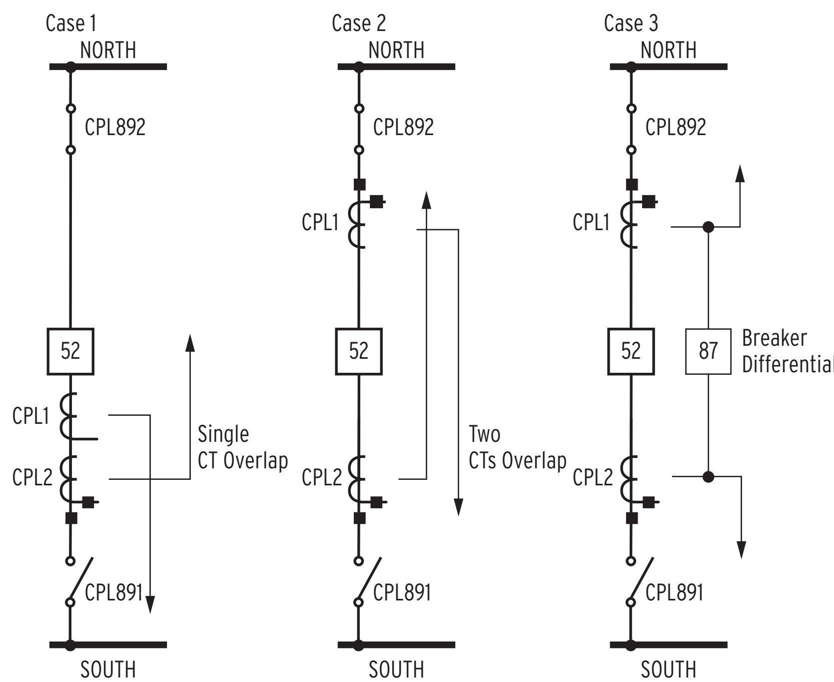


Figure 1.31 General Information Regarding the Three Typical Buscoupler Configurations

Case 1: Single CT, Single or Two Cores (Two Cores Shown) With Overlap

Step 1. For an overlap, establish the following relationships:

- ➢ CPL1 and SOUTH when CPL891 is closed
- ➢ CPL2 and NORTH when CPL892 is closed

Step 2. After applying guidelines for establishing CT polarity (see *Guideline for Establishing CT Polarity on page A.1.14*), we determine that the polarity of Terminal CPL1 is negative, as shown in *Figure 1.32*:

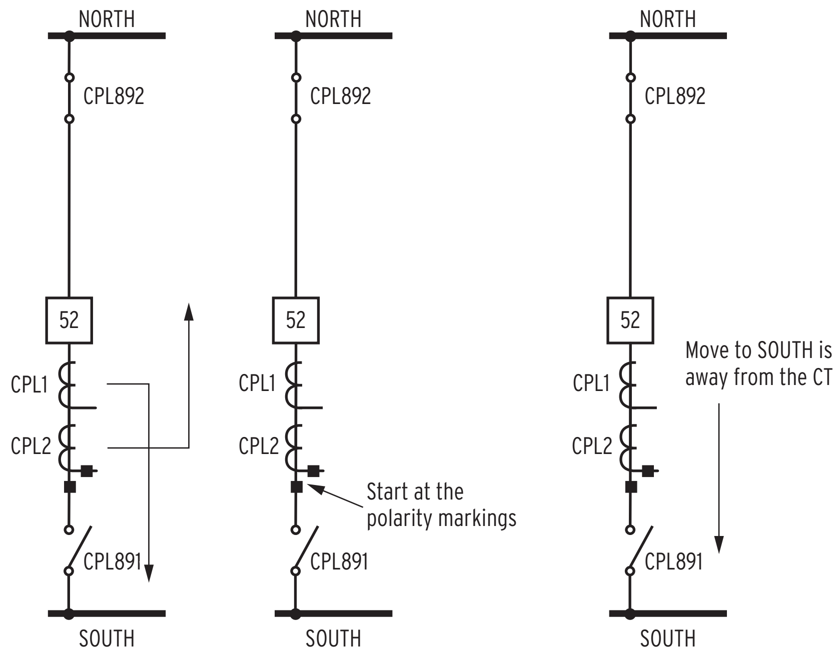


Figure 1.32 Steps in Establishing Negative CT Polarity for Terminal CPL1

Step 3. Similarly, after applying guidelines for establishing CT polarity, we determine that the polarity of Terminal CPL2 is positive, as shown in *Figure 1.33*.

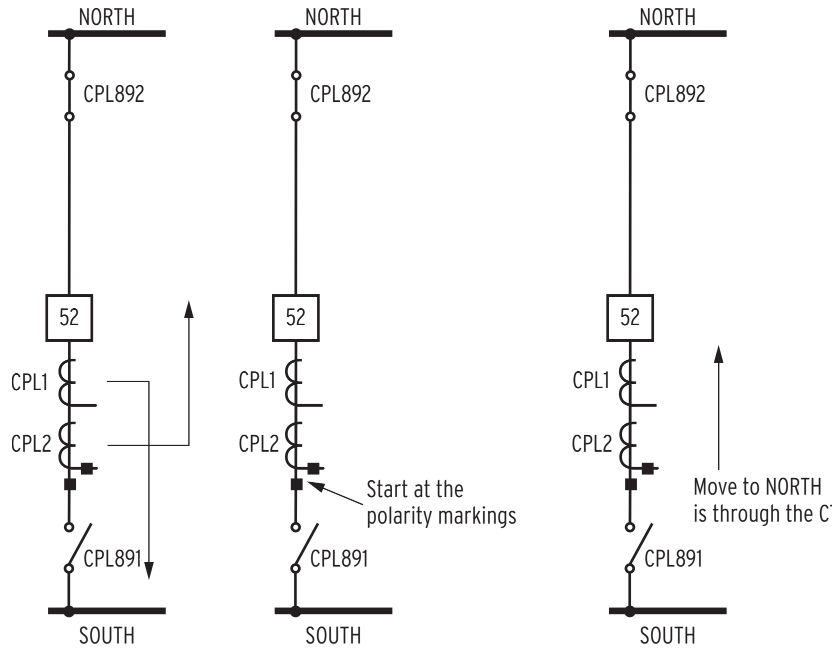


Figure 1.33 Steps in Establishing Positive CT Polarity for Terminal CPL2

Step 4. *Figure 1.34* shows an extract from the **SET Z 1** ASCII command in determining the terminal-to-bus-zone settings in the relay.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,SOUTH,N <Enter>
CPL1 to SOUTH Connection (SELogic Equation)
I01BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,NORTH,P <Enter>
CPL2 to NORTH Connection (SELogic Equation)
I02BZ1V := CPL892 <Enter>
```

Figure 1.34 Using the SET Z 1 Command to Determine Terminal-to-Bus-Zone Settings

This concludes the Case 1 configuration.

Case 2: CT Either Side of the Breaker, Configured in Overlap

Step 1. As we did before for an overlap, establish the following relationships:

- ➢ CPL1 and SOUTH when CPL891 is closed
- ➢ CPL2 and NORTH when CPL892 is closed

Step 2. After applying the guidelines for establishing CT polarity (see *Guideline for Establishing CT Polarity on page A.1.14*), we determine the polarities of both Terminals CPL1 and CPL2 to be positive, as shown in *Figure 1.35*.

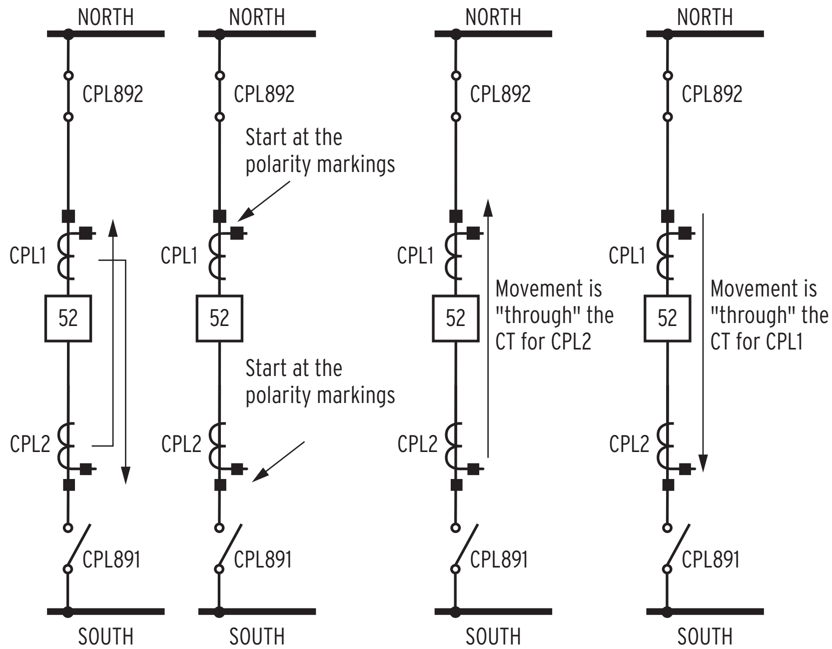


Figure 1.35 Steps in Establishing Positive CT Polarity for Both Terminals CPL1 and CPL2

Figure 1.36 shows an extract from use of the **SET Z 1** ASCII command to set the terminal-to-bus-zone settings in the relay.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,SOUTH,P <Enter>
CPL1 to SOUTH Connection (SELogic Equation)
I01BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,NORTH,P <Enter>
CPL21 to NORTH Connection (SELogic Equation)
I02BZ1V := CPL892 <Enter>
```

Figure 1.36 Using the SET Z 1 Command to Set the Terminal-to-Bus-Zone Settings

This concludes the configuration for Case 2.

Case 3: CT Either Side of the Breaker With Breaker Differential

Step 1. Use one of the six available differential elements to configure the breaker differential.

For the buscoupler in the example, three differential elements are required; the third differential element covers only the common area between the two CTs.

In addition to the breaker differential, configure the same CTs (CPL1 and CPL2) to balance SOUTH and NORTH. For the breaker differential, establish the following relationships:

For balancing SOUTH and NORTH:

- ➢ CPL1 and NORTH when CPL892 is closed
- ➢ CPL2 and SOUTH when CPL891 is closed

For the breaker differential:

- ➢ CPL1 and ZONE3 when CPL891 or CPL892 is closed
- ➢ CPL2 and ZONE3 when CPL891 or CPL892 is closed

Considering both Terminals CPL1 and CPL2, and after we apply the guidelines for establishing CT polarity (see *Guideline for Establishing CT Polarity on page A.1.14*), we determine that both polarities are negative, when we balance SOUTH and NORTH, as shown in *Figure 1.37*.

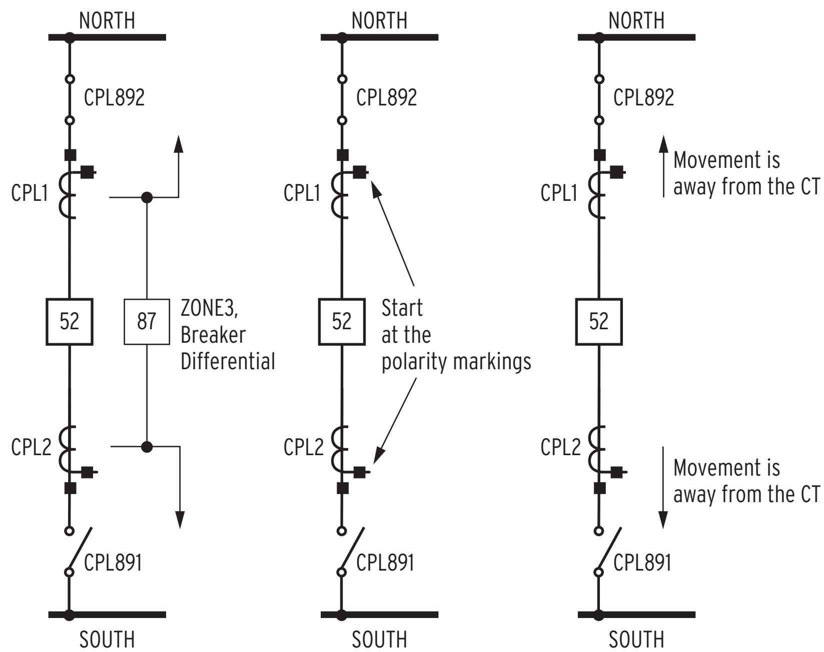


Figure 1.37 Steps in Establishing Negative CT Polarities for Both Terminals CPL1 and CPL2 When Balancing SOUTH and NORTH

Step 2. After applying guidelines for establishing CT polarity (see *Polarity on page A.1.13*), we determine the polarities of both Terminals CPL1 and CPL2 to be positive for the breaker differential (ZONE3), as shown in *Figure 1.38*.

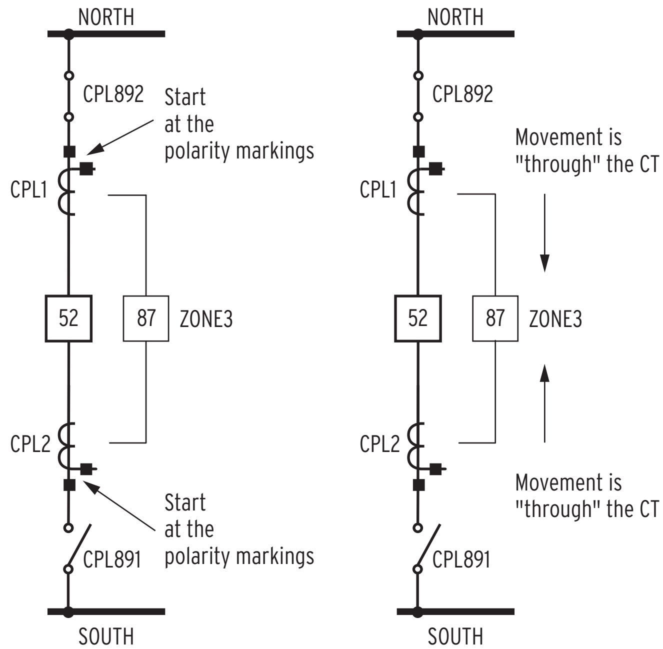


Figure 1.38 Steps in Establishing Positive CT Polarities for Both Terminals CPL1 and CPL2 for the Breaker Differential

Figure 1.39 shows the entries for Terminals CPL1 and CPL2.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,NORTH,N <Enter>
CPL1 to NORTH Connection (SELogic Equation)
I01BZ1V := CPL892 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,ZONE3,P <Enter>
CPL1 to ZONE3 Connection (SELogic Equation)
I01BZ3V := CPL891 OR CPL892 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,SOUTH,N <Enter>
CPL2 to SOUTH Connection (SELogic Equation)
I02BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,ZONE3,P <Enter>
CPL2 to ZONE3 Connection (SELogic Equation)
I02BZ3V := CPL891 OR CPL892 <Enter>
```

Figure 1.39 Entries for Terminals CPL1 and CPL2

Bus-Zone-to-Bus-Zone Connections

Bus-zone-to-bus-zone settings are used only when bus-zone-to-bus-zone connections are formed between two or more busbars, particularly when the connection is formed without a circuit breaker between the busbars. For example, closing disconnects D891 and D892 in *Figure 1.40* forms a solid connection between NORTH and SOUTH, and there is no circuit breaker between the busbars.

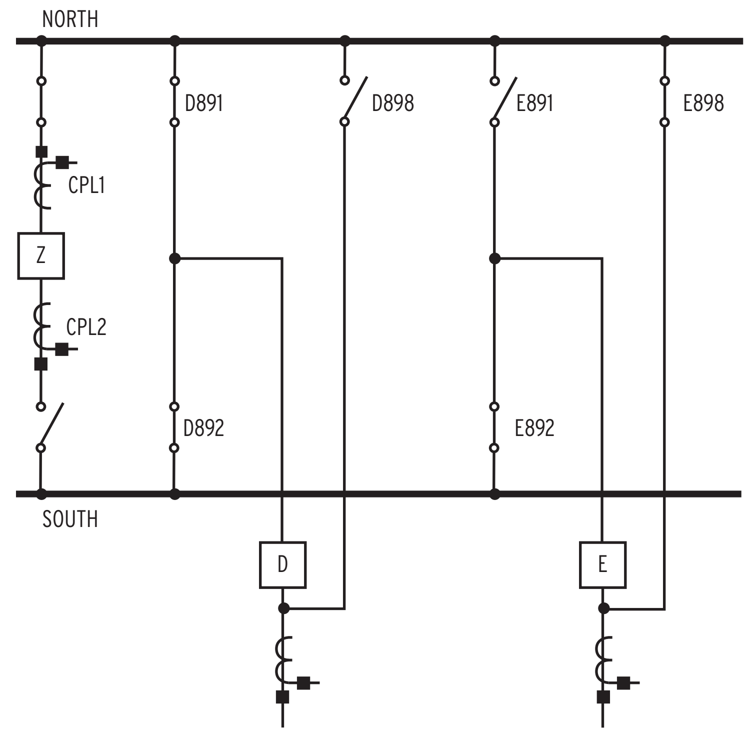


Figure 1.40 Forming Bus-Zone-to-Bus-Zone Connections With and Without a Circuit Breaker

By contrast, closing E892 and E898 or E891, E892, and E898 also forms a connection between Busbar 1 and Busbar 2, but now there exists a circuit breaker between the busbars, namely the Terminal E circuit breaker. The significance of the bus-zone-to-bus-zone connection is twofold.

- Both differential zones (SOUTH and NORTH) must operate when a fault develops on either zone during the time when the two differential zones are connected via disconnects D891 and D892 (or similar connections).
- Parallel paths are formed, and both differential zones may be unbalanced see *Figure 1.25*.

When two bus-zones are combined, buscoupler CTs are redundant and are removed from the differential calculations.

One protection philosophy requires the tripping of only those circuit breakers that can contribute fault current to optimize breaker maintenance. However, there is also the protection philosophy that requires all breakers in the faulted differential zone to be tripped. To satisfy both protection philosophies, the SEL-487B offers the choice of leaving the buscoupler closed or issuing a trip signal. The first prompt in this group asks you for the two busbars that will be combined.

Step 1. From *Figure 1.40*, we see that we would enter SOUTH and NORTH at the prompt (without spaces between the differential zone names or the comma).

```
Bus-Zone,Bus-Zone?
SOUTH,NORTH <Enter>
```

Step 2. Next, the SELOGIC control equation that declares the digital input conditions which must be a logical 1 for the relay to recognize the combination of SOUTH and NORTH. Again, the relay states the names you enter and then generates a prompt with the primitive names as a double check.

List all of the several possible combinations, separating each combination with the OR function. From *Figure 1.40*, NORTH and SOUTH are combined when D891 and D892 are closed, or when E891 and E892 are closed:

```
SOUTH to NORTH Connection (SELogic Equation)
BZ1BZ2V := (D891 AND D892) OR (E891 AND E892) <Enter>
```

NOTE: When the bus-zone-to-bus-zone SELOGIC control equation includes the circuit breaker, be sure to also include the breaker auxiliary contact status (not only the disconnect status) to ensure separate bus-zones when the circuit breaker is open.

This setting identifies the particular differential zones that can be combined and the conditions under which this combination can take place.

Step 3. The next setting allows you to select a subset of the conditions stated in the previous setting. In the present example, there is no subset, and the setting is a repeat of the previous setting.

```
Remove Terminals when NORTH and SOUTH Bus-Zones merge (SELogic Equation)
BZ1BZ2R := NA
?  (D891 AND D892) OR (E891 AND E892) <Enter>
```

Step 4. Next, state the terminals to be removed when the two differential zones are combined. In most cases, these terminals are the buscoupler CTs, as is the case in *Figure 1.40*. You would, therefore, enter the buscoupler terminal names at the prompt.

```
Terminals Removed when NORTH and SOUTH Bus-Zone merge (Ter k,...,Ter n)
BZ1BZ2M :=
?CPL1,CPL2 <Enter>
```

Step 5. To end this group, select whether the buscoupler must be tripped (**Y**) when a fault occurs in the combined protection zone during the time when the two bus-zones are merged, or whether the buscoupler must not be issued a trip signal (**N**). Again, as a double check, the relay states the primitive names of the terminals that must be removed:

```
Trip Terminals CPL1, CPL2 (Y,N)
BZ1BZ2T := N
?  Y <Enter>
```

Zone Supervision

This is the final check before a bus-zone trip (87Z1) is issued for each of the six differential zones. *Figure 1.41* shows the relay logic for this function, where the output from the differential calculations (87R1) is ANDed with the zone supervision conditions. See *Section 1: Protection Functions in the Reference Manual* for more information.

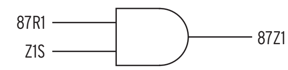


Figure 1.41 Zone Supervision Logic

This is a good place to include the overall check zone differential element output, if one was configured.

Assume Check Zone 1 was configured. Enter the following to include the check zone.

```
Z1S:= 87CZ1 <Enter>
```

Trip Logic

Figure 1.42 shows the steps necessary for assigning protection functions to the trip logic.

Make sure all selected protection functions appear in the trip equation.

For example, having selected the breaker failure protection, assign the output from this logic to the output contact, or the contact will not assert when the breaker failure protection operates. For Terminal I06 wired to OUT201, the following includes differential protection, internal breaker failure protection, and time-overcurrent protection.

```
=>>SET TR06 <Enter>
Group 1

Trip Logic

Trip 06 (SELogic Equation)
TR06 := NA
? 87BTR06 OR SBFTR06 OR 51P01T <Enter>
Unlatch Trip 06 (SELogic Equation)
ULTR06 := NA
?  END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.42 Assign the Protection Functions to the Trip Logic

Output Assignments

Figure 1.43 shows the steps necessary for assigning the output from the trip logic (TRIP06) to output contact OUT201.

```
=>>SET O OUT201 <Enter>
Output

Interface Board #1

OUT201 := NA
?   TRIP06 <Enter>

OUT202 := NA
?   END <Enter>
Output

Main Board

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.43 Assigning the Output From the Trip Logic to an Output Contact

Summary

In general, system configuration can be summarized in the four-step approach shown in *Figure 1.44*. Use the worksheets provided on the SEL-487B *Relay Product Literature CD* to collect and organize the data before configuring and setting the relay.

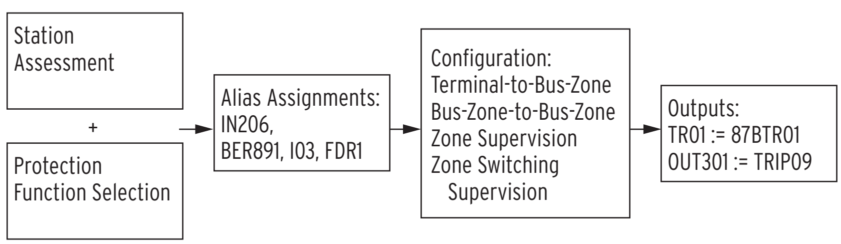


Figure 1.44 Information Flow Diagram

Step 1. Assess your station and select appropriate protection functions.

Inspect the substation layout to make the appropriate selection in terms of number of bus-zones, number of terminals, CT ratio mismatch, I/O count, etc.

As for protection functions, decide whether to use internal or external breaker failure protection, breaker differential, or an overlap coupler CT application (if two sets of CTs are available), etc.

Step 2. Assign alias names.

Because configuration settings use terminal names, assign alias names at this point.

Step 3. Configure your system.

Entries here determine the CT/differential element assignment with the terminal-to-bus-zone and bus-zone-to-bus-zone settings, while zone supervision and zone-switching supervision provide for additional control and information.

Step 4. Assign outputs.

For each terminal, select the relay functions for which the terminal will be issued a trip signal.

Use *Table 1.4* through *Table 1.9* to assist with *Step 1* of the configuration process.

Table 1.4 Primary Plant Data

Items	Requirement for Your Plant
Number of terminals (maximum 18)	
Number of busbars (maximum 6)	
Number of main zones (maximum 6)	
Number of check zones (maximum 1)	
Number of buscouplers or tie breakers (maximum 4)[a]	
Inboard CTs (Y,N)	
Maximum/minimum CT ratio	

[a] Mutually exclusive; sum of buscouplers and bus sections cannot exceed four.

Table 1.5 Data for Buscoupler 1 and Buscoupler 2

Buscoupler 1 Data		Buscoupler 2 Data	
Number of CTs		Number of CTs	
Overlap or differential		Overlap or differential	
Coupler security logic? Y, N[a]		Coupler security logic? Y, N[a]	
Breaker status logic? Y, N[b]		Breaker status logic? Y, N[b]	

[a] Allocate independent optoisolated inputs to the selected logic.
[b] Allocate one grouped optoisolated input to the selected logic for each logic.

Table 1.6 Data for Buscoupler 3 and Buscoupler 4

Buscoupler 3 Data		Buscoupler 4 Data	
Number of CTs		Number of CTs	
Overlap or differential		Overlap or differential	
Coupler security logic? Y, N[a]		Coupler security logic? Y, N[a]	
Breaker status logic? Y, N[b]		Breaker status logic? Y, N[b]	

[a] Allocate independent optoisolated inputs to the selected logic.
[b] Allocate one grouped optoisolated input to the selected logic for each logic.

Table 1.7 Disconnect, Breaker, and Input Data

Items	Requirement for Your Plant
Number of 89A (N/O) contacts?[a]	
Number of 89B (N/C) contacts?[b]	
Disconnect Monitoring Logic? (maximum 48)	
Zone-Switching Supervision Logic?	
Number of 52A contacts	

[a] There are on average (for 18 terminals) three optoisolated inputs available per terminal.
[b] Allocate independent optoisolated inputs to the selected logic.

Table 1.8 Breaker Failure Data

Items	Requirement for Your Plant
Number of internal breaker failure circuits	
Number of external breaker failure circuits	
Additional security?[a]	

[a] Allocate independent optoisolated inputs to the selected logic.

Table 1.9 End-Zone Protection

Items	Requirement for Your Plant
Number of 52A (N/O) contacts?[a]	
Number of communication outputs required?[b]	

[a] Allocate this number of common optoisolated input contacts.
[b] Allocate this number of independent output contacts.

Application 1: Single Bus and Tie Breaker (Three Relays)

This application describes the busbar arrangement shown in *Figure 1.45*, a single bus with bus sectionalizer (tie breaker), three-relay application. The busbar arrangement consists of two busbar sections, four feeders, and a tie breaker. Consider the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection functions selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation and alias name assignment
- ➤ Station layout update
- ➤ Relay setting and configuration

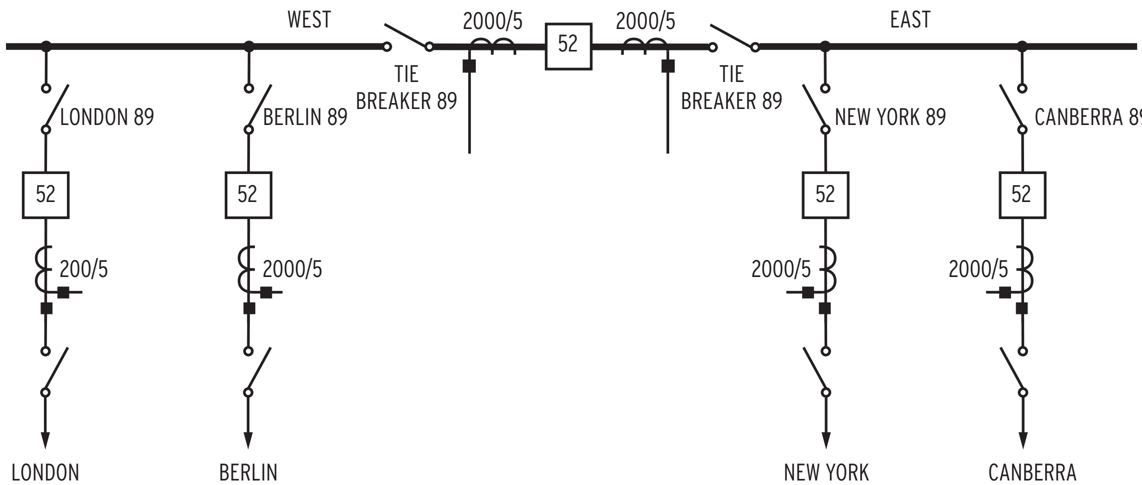


Figure 1.45 Single Bus With Bus Sectionalizer (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information and declares the tie-breaker (buscoupler or sectionalizing breaker) configuration. The classification for this application is as follows:

- Description
  - Single bus with tie breaker
- Current Transformers
  - Outboard (free standing)
- Disconnects
  - Both 89A and 89B disconnect auxiliary contacts are available
- Sectionalizing breaker (tie-breaker) configuration
  - Overlap
- Future expansion
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the 89 disconnect auxiliary contacts to dynamically configure the station.
2. Use the Disconnect Monitoring Logic.
3. Block the busbar protection for an open-circuit CT.
4. Configure check-zone protection.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process, because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for a check zone, but not for breaker failure protection.

The SEL-487B offers a number of protection functions as standard features, but also includes the capability through SELOGIC control equations to create user-configurable functions. Breaker failure protection is a standard function but check-zone protection is not. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created using SELOGIC control equations)

Standard Functions

Refer to *Protection Philosophy* and select the standard functions required for the application. *Table 1.10* shows the selection of the standard functions.

Table 1.10 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection, Check-zone protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Enter the check zone and zone-specific conditions to supervise the zone-specific differential elements
Zone-switching supervision logic	No	89A and 89B disconnect contacts available; therefore, this logic is not required
Coupler security logic	No	Two CTs with overlap configuration do not require the coupler security logic
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Because the SEL-487B includes all protection functions necessary for this application as standard protection functions, we do not need any user-defined functions.

Check-Zone Protection

Figure 1.46 shows a station with check-zone protection. Check-zone protection stems from the philosophy of providing an additional trip criterion before issuing a busbar protection trip signal. This philosophy encompasses additional trip criteria such as directional elements and overcurrent elements.

When using check-zone protection as an additional criterion, the practice is to provide a measurement from a second differential element that is independent of the disconnect auxiliary contact status. Using a measurement independent of the disconnect auxiliary contact status prevents differential element misoperation resulting from disconnect auxiliary contact failure.

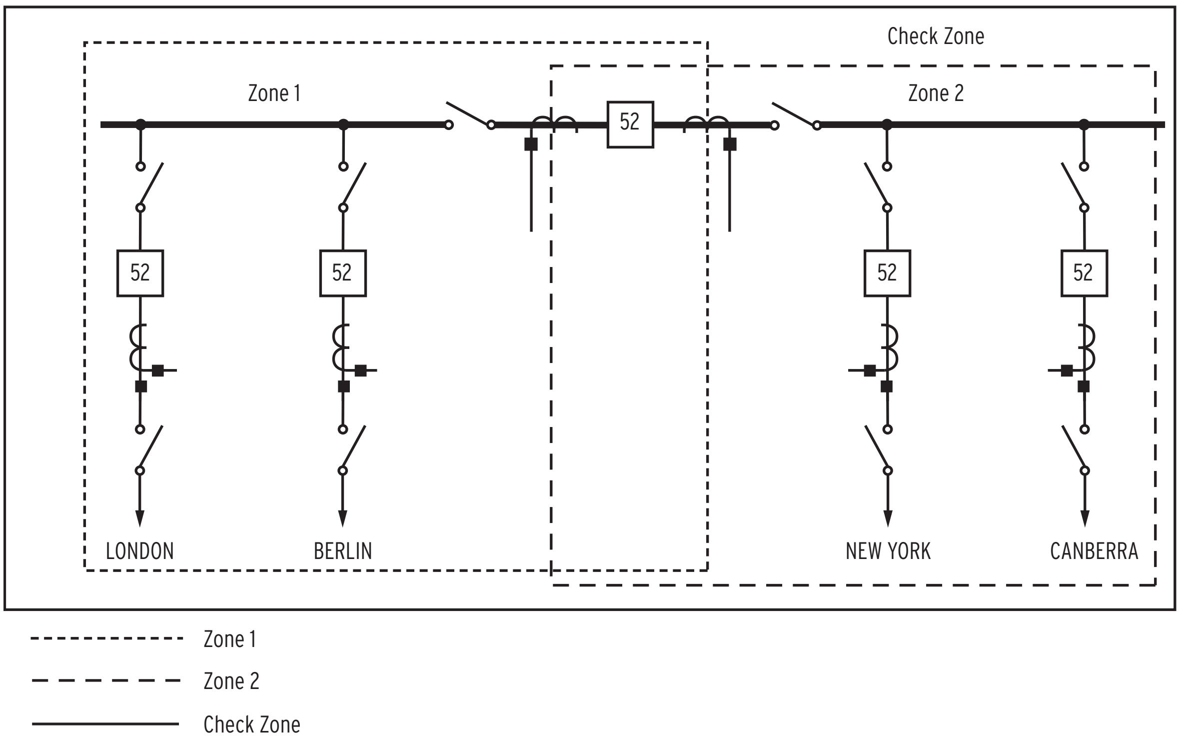


Figure 1.46 Station With Two Zone-Specific Bus-Zones and an Overall Check Zone

Both the Check Zone and either Zone 1 or Zone 2 differential elements must assert before a busbar protection trip output asserts. Use the Differential Element Zone Supervision setting to comply with the requirement for both check zone and zone-specific differential elements to assert. *Figure 1.47* shows the zone supervision logic. Relay Word bit 87R1 is the output from the Zone 1 differential element and Z1S is the SELOGIC control equation where we enter conditions for supervising the Zone 1 differential element. (See *Zone Configuration Group Settings on page A.1.55* for more detail.)

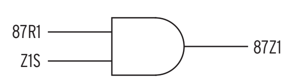


Figure 1.47 Zone Supervision Logic

Create the check-zone protection by configuring the available check zone when entering the zone configuration settings (ECHKZN := Y).

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with as many as 18 CTs (seven 3-phase terminals), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.2* to calculate the number of current channels at the station, and use *Equation 1.3* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.2**

# of bus-zones required = # of per-phase station bus sections **Equation 1.3**

The number of per-phase CTs at the station is 18 and the number of bus-zones required is 2 (Zone 1 and Zone 2). The number of check zones required is 1 (Check Zone 1). One SEL-487B suffices for these requirements, but the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wiring) the input and output contacts to the other two relays. This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (LOND_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding LOND_A setting is LOND_B in the B-phase relay and LOND_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires one disconnect monitoring logic and the tie breaker requires two; therefore, the number of disconnect logics required is six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.4* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.4**

Table 1.11 summarizes the input contact required for this application.

Table 1.11 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	6 • 2 = 12
Total number of inputs	12

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs. From the input contact perspective, we need one interface board. It is not necessary to include I/O for future expansion with the initial order; install additional I/O if and when required.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all breakers are part of the busbar differential protection, we want to trip each breaker upon differential protection operation. *Table 1.12* shows the breakdown and the total number of relay output contacts required.

Table 1.12 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts.

The interface boards may have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can be ordered with an option that provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name
- Check-Zone name

Alias names are valid when they consist of a maximum of seven characters and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

Table 1.13 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT1 to relay channel I01, and assign to this CT the alias name SEC1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.13* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left to right from *Figure 1.45*.

Table 1.13 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	SEC1_A
TIE-BREAKER CT2, A-Phase	I02	SEC2_A
LONDON, A-phase	I03	LOND_A
BERLIN, A-phase	I04	BERL_A
NEW YORK, A-phase	I05	NEWY_A
CANBERRA, A-phase	I06	CANB_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.14*.

Table 1.14 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	WEST_A
BZ2	Bus-Zone 2	EAST_A

Check-Zone Alias Assignment

Each SEL-487B provides one check zone. For the A-phase relay, we use the check zone with the alias name as shown in *Table 1.15*.

Table 1.15 Alias Name for the Check Zone

Check-Zone Name	Description	Alias
CZ1	Check Zone	CHECK_A

Input to Logic Allocation and Alias Assignment

Table 1.11 shows that we require 12 digital inputs. We now assign the 12 digital input contacts to the selected logic and assign alias names to the input contacts and logic elements. Because of the functional requirement of this application, we do not need to use any digital inputs on the main board.

Input Contact to Logic Allocation and Alias Assignment, Interface Board 1 (200)

Table 1.16 shows the disconnect auxiliary contact input allocations and the alias names. Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs for breaker failure initiate inputs; these inputs are not used in the present application.

Table 1.16 Alias Names for the Breaker Status Logic Output Relay Word Bits

Input	Description	Alias
IN204	TIE-BREAKER disconnect (WEST) NO contact	ISE891A
IN205	TIE-BREAKER disconnect (WEST) NC contact	ISE891B
IN206	TIE-BREAKER disconnect (EAST) NO contact	ISE892A
IN207	TIE-BREAKER disconnect (EAST) NC contact	ISE892B
IN208	LONDON disconnect N/O contact	ILON89A
IN209	LONDON disconnect N/C contact	ILON89B
IN210	BERLIN disconnect N/O contact	IBER89A
IN211	BERLIN disconnect N/C contact	IBER89B
IN212	NEW YORK disconnect NO contact	INEW89A
IN216	NEW YORK disconnect NC contact	INEW89B
IN217	CANBERRA disconnect NO contact	ICAN89A
IN218	CANBERRA disconnect NC contact	ICAN89B

Assign Alias Names to the Selected Standard Logic

Referring to *Table 1.10*, the following is a discussion on each selected function. Alias name assignments are also included.

Disconnect Monitoring Logic and Disconnect Alias Assignment

Figure 1.48 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Disconnect Requirements on page A.1.15* for more information on the disconnect auxiliary contact requirements).

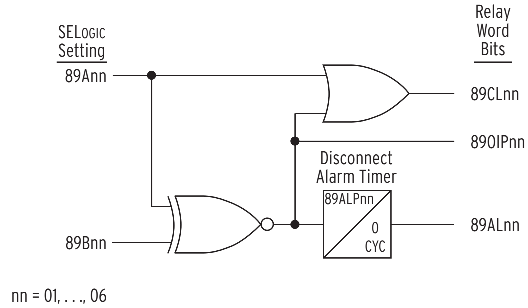


Figure 1.48 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.17 shows the alias names for the disconnect auxiliary contact Relay Word bits.

Table 1.17 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits

Input	Description	Alias
89A01	TIE-BREAKER disconnect (WEST) NO contact	SEC891A
89B01	TIE-BREAKER disconnect (WEST) NC contact	SEC891B
89A02	TIE-BREAKER disconnect (EAST) NO contact	SEC892A
89B02	TIE-BREAKER disconnect (EAST) NC contact	SEC892B
89A03	LONDON disconnect NO contact	LON89A
89B03	LONDON disconnect NC contact	LON89B
89A04	BERLIN disconnect NO contact	BER89A
89B04	BERLIN disconnect NC contact	BER89B
89A05	NEW YORK disconnect NO contact	NEW89A
89B05	NEW YORK disconnect NC contact	NEW89B
89A06	CANBERRA disconnect NO contact	CAN89A
89B06	CANBERRA disconnect NC contact	CAN89B

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets that the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations. We also assign alias names to the alarm Relay Word bits (89AL*nn*). *Table 1.18* shows the alias names.

Table 1.18 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits (Sheet 1 of 2)

Primitive Name	Description	Alias
89CL01	TIE-BREAKER disconnect (WEST) is closed	SEC189C
89CL02	TIE-BREAKER disconnect (EAST) is closed	SEC289C
89CL03	LONDON disconnect is closed	LOND89C
89CL04	BERLIN disconnect is closed	BERL89C
89CL05	NEW YORK disconnect is closed	NEWY89C
89CL06	CANBERRA disconnect is closed	CANB89C
89AL01	TIE-BREAKER disconnect (WEST) alarm	SEC189A

Table 1.18 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits (Sheet 2 of 2)

Primitive Name	Description	Alias
89AL02	TIE-BREAKER disconnect (EAST) alarm	SEC289A
89AL03	LONDON disconnect alarm	LOND89A
89AL04	BERLIN disconnect alarm	BERL89A
89AL05	NEW YORK disconnect alarm	NEWY89A
89AL06	CANBERRA disconnect alarm	CANB89A

Differential Trip Logic and Differential Element Alias Assignment

Figure 1.49 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information). *Table 1.19* shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 1.19 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	WESTA_T
87Z2	Zone 2 differential element trip	EASTA_T
87CZ1	Check Zone differential element trip	CHECA_T

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information).

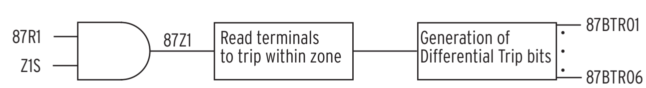


Figure 1.49 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.54* for more information). *Table 1.20* shows the primitive differential trip bit names, the alias names for the differential trip bits, and the terminal with which the relay associates each differential trip bit.

Table 1.20 Primitive Differential Trip Bit Names, Alias Names for the Differential Trip Bits, and Associated Terminals

Differential Trip Bit	Alias	Comments
87BTR01	87SEC1A	Associated with Terminal 01
87BTR02	87SEC2A	Associated with Terminal 02
87BTR03	87LON_A	Associated with Terminal 03
87BTR04	87BER_A	Associated with Terminal 04
87BTR05	87NEW_A	Associated with Terminal 05
87BTR06	87CAN_A	Associated with Terminal 06

Breaker Trip Logic and Trip Alias Assignment

Figure 1.50 shows the general tripping logic in the SEL-487B. (See *Section 1: Protection Functions in the Reference Manual* for more information).

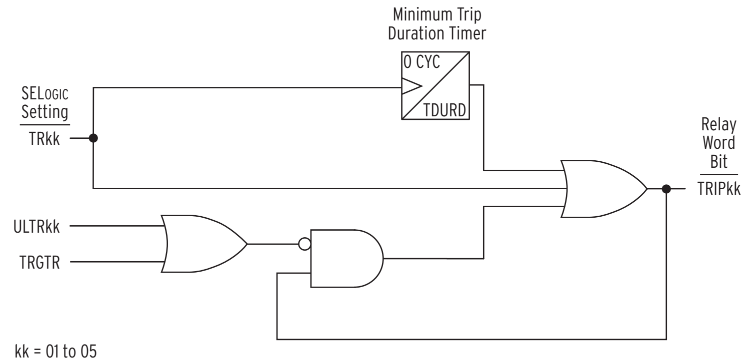


Figure 1.50 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers setting (NUMBK) and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK) setting. *Table 1.21* shows the five primitive and alias names for the trip logic of each terminal.

Table 1.21 Primitive and Alias Names for the Trip Logic of Each Terminal

Primitive Name	Description	Alias Name
TRIP01	Trip output of the sectionalizing breaker asserted	TRSEC_A
TRIP02	Trip output of the LONDON Terminal asserted	TRLON_A
TRIP03	Trip output of the BERLIN Terminal asserted	TRBER_A
TRIP04	Trip output of the NEW YORK Terminal asserted	TRNEW_A
TRIP05	Trip output of the CANBERRA Terminal asserted	TRCAN_A

Assign Alias Names to the User-Defined Logic

This application requires no user-defined logic.

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 1.12* shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts and assign alias names to the relay output contacts. *Table 1.22* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.23* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1 and the alias names of the of the interface board output contacts.

Output Alias Assignment, Main Board

This application requires no output contacts from the main board.

Table 1.22 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can be ordered to include six high-speed, high-interrupting output contacts. *Table 1.23* shows the alias assignment for the five terminals of the A-phase relay.

Table 1.23 Alias Assignment for the Five Terminals in Our Example

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	TIE-BREAKER trip logic output	SECTR_A
OUT202[a]	LONDON trip logic output	LONTR_A
OUT203[a]	BERLIN trip logic output	BERTR_A
OUT204[a]	NEW YORK trip logic output	NEWTR_A
OUT205[a]	CANBERRA trip logic output	CANTR_A

a High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.51*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the auxiliary terminal contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals

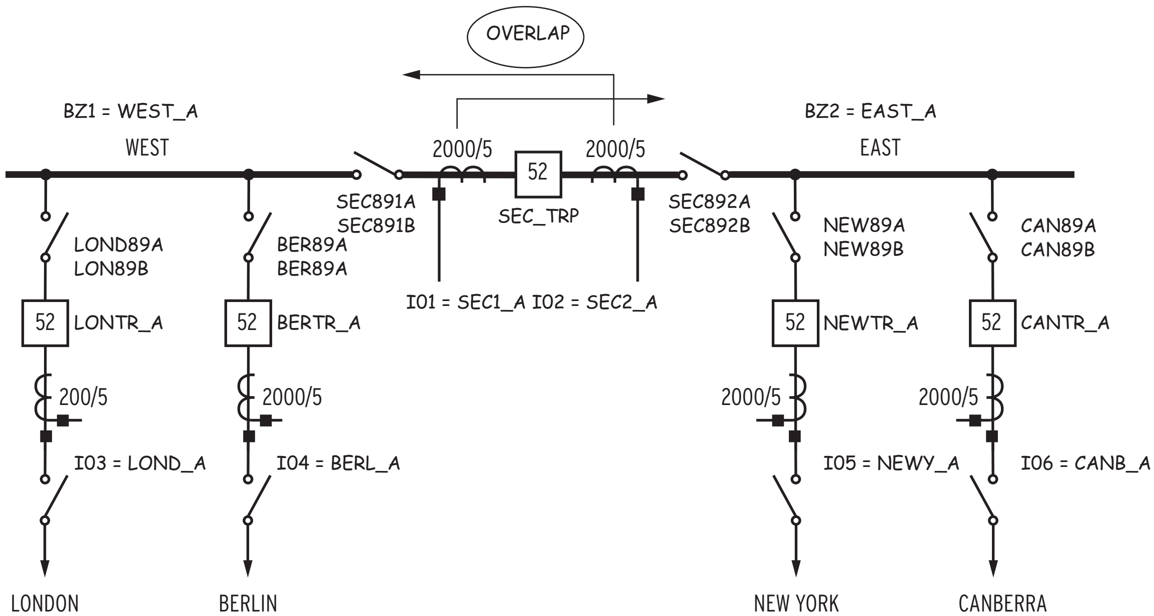


Figure 1.51 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. We set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias settings class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.52*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"

1: I01,"FDR_1"
?
```

Figure 1.52 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.53*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.53 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.54*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  IO1,SEC1_A <Enter>
20:
?  IO2,SEC2_A <Enter>
21:
?  IO3,LOND_A <Enter>
22:
?  IO4,BERL_A <Enter>
23:
?  IO5,NEWY_A <Enter>
24:
?  IO6,CANB_A <Enter>
25:
?  BZ1,WEST_A <Enter>
26:
?  BZ2,EAST_A <Enter>
27:
?  CZ1,CHECK_A <Enter>
28:
?  IN204,ISE891A <Enter>
29:
?  IN205,ISE891B <Enter>
30:
.
.
.
?  OUT204,NEWTR_A <Enter>
92:
?  OUT205,CANTR_A <Enter>
93:
?  END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.54 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from protection setting Group 1 to protection setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.55* shows the setting changes we need for our example. Because we declared the alias names in the alias settings class, use either alias names or primitive names when entering settings.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01–52A05) and five corresponding trip equations (TR01–TR05) available for setting. Because we do not need circuit breaker auxiliary contacts for this application, set 52A01–52A05 to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need six disconnect logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01 through 06). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                          NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-48)                       NUMDS   := N      ?6 <Enter>
Nominal System Frequency (50,60 Hz)                  NFREQ   := 60     ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                     EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                      GINPU   := 0.17   ?> < Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
Breaker Inputs
N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  ISE891A <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  ISE891B <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)                89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  ISE892A <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  ISE892B <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)                89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  ILON89A <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
.
.
.

89ALP06 := 300 <Enter>
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.55 Global Settings for Application 1

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information). In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the LONDON feeder, all three phases (LOND_A, LOND_B, and LOND_C) operate together. Because the relay measures the three phases in three separate relays (phase LOND_A in the A-phase relay, phase LOND_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

Because the check zone performs a supervising function, enter the check zone zone configuration settings ahead of the Zone 1 and Zone 2 settings. To configure the Check Zone, declare all terminals, except the tie-breaker (bus sectionalizer) CTs in the Check Zone terminal-to-check-zone SELOGIC control equations. Never include the tie-breaker CTs in the check zone. *Figure 1.59* shows the zone configuration group settings. Use the Differential Element Zone Supervision setting to comply with the requirement for both check zone and zone-specific differential elements to assert before a busbar protection trip output asserts. For this application, we allocated BZ1 for Zone 1, BZ2 for Zone 2, and CZ1 for the overall check zone (see *Table 1.14*). Because the check zone is independent from any other zone, the relay does not follow the differential trip logic shown in *Figure 1.56* when the check zone asserts.

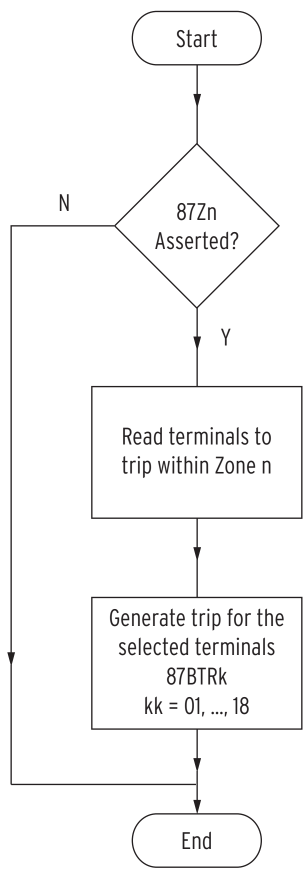


Figure 1.56 Bus Differential Trip Logic

The implication of this independence is that the Check Zone Supervision Logic can be left to its default value of 1 as seen in *Figure 1.57*. The same effect is achieved by setting E87CZSP = N.

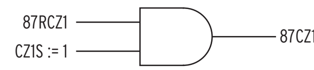


Figure 1.57 Check-Zone Supervision Logic

For the zone-specific elements, enter the Check Zone differential element trip output 87CZ1 as a supervisory condition for each zone, as shown in *Figure 1.58*.

Figure 1.58 Zone Supervision for Zone 1 (a) and Zone 2 (b)

Be sure to include Relay Word bit 87CZ1 as the supervisory condition for all zones encompassed by the Check Zone. Set E87ZSUP = Y to enable the Differential Element Zone Supervision settings, then enter the supervision settings.

For the ease of setting the zone configuration settings for the new substation, delete the existing zone configuration group default settings. With the zone configuration group default settings deleted, the setting prompts no longer reference the default settings. The zone configuration group default settings are for a specific substation with arbitrarily selected alias names, serving only as an example.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?400 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?400 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?40 <Enter>
Current Transformer Ratio -I04 (1-50000)            CTR04   := 600    ?400 <Enter>
Current Transformer Ratio -I05 (1-50000)            CTR05   := 600    ?400 <Enter>
Current Transformer Ratio -I06 (1-50000)            CTR06   := 600    ?400 <Enter>
Current Transformer Ratio -I07 (1-50000)            CTR07   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := SEC1_A, WEST_A, P
?  DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,BZ2,P <Enter>
SEC1_A to EAST_A Connection (SELogic Equation)
I01BZ2V := NA
?  SEC189C AND SEC289C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,BZ1,P <Enter>
SEC2_A to WEST_A Connection (SELogic Equation)
I02BZ1V := NA
?  SEC189C AND SEC289C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,BZ1,P <Enter>
LOND_A to WEST_A Connection (SELogic Equation)
I03BZ1V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,BZ1,P <Enter>
BERL_A to WEST_A Connection (SELogic Equation)
I04BZ1V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,BZ2,P <Enter>
```

```
NEWY_A to EAST_A Connection (SELogic Equation)
I05BZ2V := NA
?  NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I06,BZ2,P <Enter>
CANB_A to EAST_A Connection (SELogic Equation)
I06BZ2V := NA
?  CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N       ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  87CZ1 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  87CZ1 <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N       ?<Enter>

Reset Zone 1 Open CT Detector (SELogic Equation)
ROCTZ1 := RSTOCT1
?<Enter>
Reset Zone 2 Open CT Detector (SELogic Equation)
ROCTZ2 := RSTOCT2
?<Enter>

Check Zone Configuration

Enable Check Zones at Station (Y,N)                  ECHKZN  := N       ?Y <Enter>

Check Zone Configuration: Terminal to Check Zone Connections

Terminal, Check-Zone, Polarity (P,N)
?  I03,CZ1,P <Enter>
LOND_A to CHECK_A Connection (SELogic Equation)
I03CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  I04,CZ1,P <Enter>
BERL_A to CHECK_A Connection (SELogic Equation)
I04CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  I05,CZ1,P <Enter>
NEWY_A to CHECK_A Connection (SELogic Equation)
I05CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  I06,CZ1,P <Enter>
CANB_A to CHECK_A Connection (SELogic Equation)
I06CZ1V := NA
?  1 <Enter>
Terminal, Check-Zone, Polarity (P,N)
?<Enter>

Check Zone Supervision

Differential Element Check Zone Supervision (Y,N)    E87CZSP := N       ?<Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.59 Zone Configuration Group Settings for Application 1

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y.

With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information). Set ECSL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, and EVOLT := N because we do not use the coupler security logic, terminal out of service, breaker failure protection, overcurrent elements, or voltage elements in this application.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01 through 52A05) and five corresponding trip equations (TR01 through TR05) available for setting. There are five trip equations available, but there are six analog channels (I01 though I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.20*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip. Because the tie breaker has two analog channels but only one circuit breaker, include both differential trip bits (87SEC1A and 87SEC2A) in trip equation TR01.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting. Set the timer TDURD longer than the clearing time of the slowest circuit breaker at the station. For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element, the Directional Element, and the Trip Duration Timer. *Figure 1.60* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N       ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y       ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N       ?> <Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Check Zone Sensitive Differential Element

CZ Sensitive Differential Element Pickup (0.05-1 pu) CZS87P := 0.10     ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Check Zone Restrained Differential Element

CZ Restrained Diff Element Pickup (0.10-4 pu)        CZO87P := 1.00     ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87SEC1A
?  87SEC1A OR 87SEC2A <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
? <Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87SEC2A
?  87LON_A <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
? <Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87LON_A
?  87BER_A <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BER_A
?  87NEW_A <Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87NEW_A OR SBFTR06 OR 87CAN_A
?  87CAN_A <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?> <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.60 Protection Group Settings for Application 1

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the {RELAY TEST MODE} pushbutton disables all output contacts. Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 1.61* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRSEC_A AND NOT PLT03
?   NA <Enter>

OUT102 := TRLON_A AND NOT PLT03
?   NA <Enter>

OUT103 := TRBER_A AND NOT PLT03
?   NA <Enter>

OUT104 := TRNEW_A AND NOT PLT03
?   NA <Enter>

OUT105 := TRCAN_A AND NOT PLT03
?   NA <Enter>

OUT106 := NA
? > <Enter>

Interface Board #1

OUT201 := NA
?   TRSEC_A AND NOT PLT03 <Enter>

OUT202 := NA
?   TRLON_A AND NOT PLT03 <Enter>

OUT203 := NA
?   TRBER_A AND NOT PLT03 <Enter>

OUT204 := NA
?   TRNEW_A AND NOT PLT03 <Enter>

OUT205 := NA
?   TRCAN_A AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.61 Control Output Settings for Application 1

This concludes the settings for Application 1.

Application 2: Single Bus and Tie Breaker (Single Relay)

This application describes the busbar arrangement shown in *Figure 1.62*, a single bus with bus sectionalizer (tie breaker), single-relay application. The busbar arrangement consists of two busbar sections, four feeders, and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

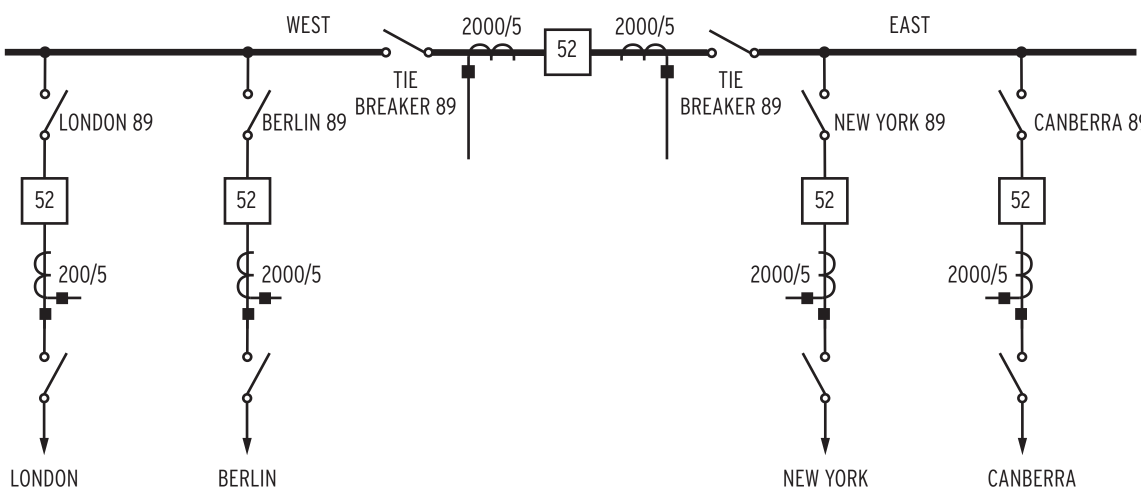


Figure 1.62 Single Bus With Bus Sectionalizer (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie breaker (buscoupler or sectionalizing breaker) configuration.

- Description:
  - Single bus with tie breaker
- Current Transformers:
  - Outboard
- Disconnect:
  - Both 89A and 89B disconnect auxiliary contacts are available
- Sectionalizing breaker (tie-breaker) configuration:
  - Overlap

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the 89 disconnect auxiliary contacts to dynamically configure the station.
2. Block the busbar protection for an open-circuit CT.
3. Use the Disconnect Monitoring Logic.
4. Include end-zone protection with direct transfer tripping for the four feeders.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for end-zone protection, but not for breaker failure protection.

The SEL-487B offers a number of protection functions as standard features, but also includes the capability through SELOGIC control equations to create user-configurable functions. Breaker failure protection is a standard function but end-zone protection is not. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created using SELOGIC control equations)

Standard Functions

Refer to the *Protection Philosophy* and select the standard functions required for the application. *Table 1.24* shows the selection of the standard functions.

Table 1.24 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch.
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available.
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions
Sensitive differential protection	Yes	CT open circuit detection.
Zone supervision logic	No	Not required
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.

Table 1.24 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Function	Selection	Comment
Coupler security logic	No	Two CTs configured in overlap configuration do not require the coupler security logic.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need for the application that are not part of the standard logic in the relay. For this application, end-zone protection for the four feeders is not a standard function; we use SELOGIC control equations to create this logic.

End-Zone Protection

Figure 1.63 shows end-zone fault F1, which is a fault between the feeder CT and circuit breaker. The busbar protection at Busbar S operates for this fault and trips Circuit Breaker 1, but the line still feeds the fault from the source at Busbar R.

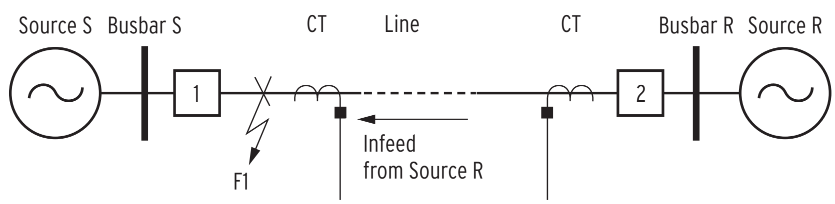


Figure 1.63 Fault Between Circuit Breaker 1 and the CT at Busbar S

Fault F1 is only cleared when Circuit Breaker 2 at Busbar R trips. In step-distance protection schemes, Circuit Breaker 2 trips after a time delay, typically on the order of 400 ms. Using end-zone protection, we can shorten this time by sending a direct transfer trip (DTT) from Station S to Circuit Breaker 2 at Station R to trip Circuit Breaker 2.

This logic detects faults under the following three conditions:

- ➤ The differential protection has issued a trip signal to the circuit breaker.
- ➤ There is still current flowing in the feeder CT after Circuit Breaker 1 has been open for 5 cycles.
- ➤ The busbar disconnect of the feeder is closed.

Create the above-mentioned end-zone logic by programming four protection SELOGIC control variables (PSV01–PSV04) when setting the protection logic, and assign the alias names as described in *Assign Alias Names to the User-Defined Logic on page A.1.74*.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and 3 voltage channels. For stations with as many as 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install 3 SEL-487B relays. Use *Equation 1.5* to calculate the number of current channels at the station, and use *Equation 1.6* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs} \qquad \textbf{Equation 1.5}$$

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections} \qquad \textbf{Equation 1.6}$$

The number of per-phase CTs at the station is 18 and the number of bus-zones required is 6. Because each SEL-487B has 18 analog input channels and 6 zones, we need only one SEL-487B. This is known as a single-relay application.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires one disconnect monitoring logic and the tie breaker requires two; the number of disconnect logics required is therefore six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.7* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics} \qquad \textbf{Equation 1.7}$$

The protection philosophy calls for end-zone protection. Because there are four feeder circuit breakers at the station the number of circuit breaker auxiliary inputs we need is four. *Table 1.25* summarizes the input contact required for this application.

Table 1.25 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 6 = 12
Number of relay inputs required for end-zone protection	4
Total number of inputs	16

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs; the six independent input contacts are available for breaker failure initiate inputs. Because this application has no circuit breaker failure protection, the independent input contacts are available for circuit breaker auxiliary contact inputs. However, in anticipation of future circuit breaker failure protection installation, instead use the grouped input contacts on the interface board for the circuit breaker auxiliary contact inputs and disconnect contact inputs. From the input contact perspective, we need one interface board.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all breakers are part of the busbar differential protection, we want to trip each breaker upon differential protection operation. We also need direct transfer trip output contacts for the end-zone protection for each of the four feeders. *Table 1.26* shows the breakdown and the total number of relay output contacts required.

Table 1.26 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping	5
Number of relay output contacts required for direct transfer tripping	4
Total number of relay output contacts	9

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). *Table 1.26* shows that we need nine output contacts; the eight main board output contacts are insufficient for our application. Also, the main board contacts are all standard output contacts.

The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign the circuit breaker trip outputs to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. Although the standard output contacts are slightly slower (6 ms for resistive loads) than the high-speed, high-interrupting output contacts, we use the main board output contact for direct transfer tripping. From the output contact perspective, we need one interface board. If you require fast output contacts for direct transfer tripping, add another interface board to the relay.

The conclusion from the preceding analysis is that we need one SEL-487B, equipped with a single interface board, for this application.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- the selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- ➤ link specific CT inputs to specific relay analog channels
- ➤ link specific disconnect and circuit breaker inputs to specific relay input contacts
- ➤ link relay element/logic outputs to specific relay output contacts
- ➤ assign alias names where appropriate

NOTE: Alias names cannot exceed seven characters.

Assign a valid seven-character alias name to any of the following:

- ➤ Relay Word bit
- ➤ Analog quantity
- ➤ Terminal name
- ➤ Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

Table 1.27 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie breaker CT1 to relay channel I01, and assign to this CT the alias name SEC1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.27* shows the assignment taken from *Figure 1.62*.

Table 1.27 CTs to Analog Channel Allocations and Alias Assignments (Sheet 1 of 2)

CTs	Analog Channel	Alias
LONDON, A-phase	I01	LOND_A
LONDON, B-phase	I02	LOND_B
LONDON, C-phase	I03	LOND_C
BERLIN, A-phase	I04	BERL_A
BERLIN, B-phase	I05	BERL_B
BERLIN, C-phase	I06	BERL_C
NEW YORK, A-phase	I07	NEWY_A
NEW YORK, B-phase	I08	NEWY_B
NEW YORK, C-phase	I09	NEWY_C
CANBERRA, A-phase	I10	CANB_A
CANBERRA, B-phase	I11	CANB_B
CANBERRA, C-phase	I12	CANB_C

Table 1.27 CTs to Analog Channel Allocations and Alias Assignments (Sheet 2 of 2)

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I13	SEC1_A
TIE-BREAKER CT1, B-phase	I14	SEC1_B
TIE-BREAKER CT1, C-phase	I15	SEC1_C
TIE-BREAKER CT2, A-phase	I16	SEC2_A
TIE-BREAKER CT2, B-phase	I17	SEC2_B
TIE-BREAKER CT2, C-phase	I18	SEC2_C

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. In this application, we use all six zones with alias names as shown in *Table 1.28*.

Table 1.28 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	WEST_A
BZ2	Bus-Zone 2	WEST_B
BZ3	Bus-Zone 3	WEST_C
BZ4	Bus-Zone 4	EAST_A
BZ5	Bus-Zone 5	EAST_B
BZ6	Bus-Zone 6	EAST_C

Input-to-Logic Allocation and Alias Assignment

Table 1.25 shows that we require 16 digital inputs. We now assign the digital inputs to the selected logic, and apply alias names to the inputs and logic elements. Because of the functional requirement of this application, we do not need to use any digital inputs on the main board.

Input-to-Logic-Allocation and Alias Assignment, Interface Board 1 (200)

Table 1.29 shows the circuit breaker auxiliary contact input allocations, the disconnect auxiliary contact input allocations, and the alias names. Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs for breaker failure initiate inputs; these inputs are not used in this application.

Table 1.29 Alias Names and Assignment for the Digital Inputs (Sheet 1 of 2)

Input	Description	Alias
IN204	LONDON circuit breaker	ILON52A
IN205	BERLIN circuit breaker	IBER52A
IN206	NEW YORK circuit breaker	INEW52A
IN207	CANBERRA circuit breaker	ICAN52A
IN208	LONDON disconnect NO contact	ILON89A
IN209	LONDON disconnect NC contact	ILON89B
IN210	BERLIN disconnect NO contact	IBER89A

Table 1.29 Alias Names and Assignment for the Digital Inputs (Sheet 2 of 2)

Input	Description	Alias
IN211	BERLIN disconnect NC contact	IBER89B
IN212	NEW YORK disconnect NO contact	INEW89A
IN216	NEW YORK disconnect NC contact	INEW89B
IN217	CANBERRA disconnect NO contact	ICAN89A
IN218	CANBERRA disconnect NC contact	ICAN89B
IN219	TIE-BREAKER disconnect (WEST) NO contact	ISE891A
IN220	TIE-BREAKER disconnect (WEST) NC contact	ISE891B
IN221	TIE-BREAKER disconnect (EAST) NO contact	ISE892A
IN222	TIE-BREAKER disconnect (EAST) NC contact	ISE892B

Assign Alias Names to the Selected Standard Logic

Referring to *Table 1.24*, the following is a discussion on each selected function. Alias name assignments are also included.

Disconnect Monitoring Logic and Disconnect Alias Assignment

Figure 1.64 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Disconnect Requirements on page A.1.15* for more information on the disconnect auxiliary contact requirements.)

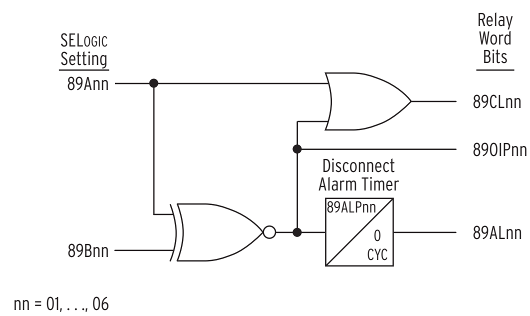


Figure 1.64 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.30 shows the alias names for the disconnect auxiliary contact Relay Word bits.

Table 1.30 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description	Alias
89A01	LONDON disconnect NO contact	LON89A
89B01	LONDON disconnect NC contact	LON89B
89A02	BERLIN disconnect NO contact	BER89A
89B02	BERLIN disconnect NC contact	BER89B
89A03	NEW YORK disconnect NO contact	NEW89A
89B03	NEW YORK disconnect NC contact	NEW89B
89A04	CANBERRA disconnect NO contact	CAN89A
89B04	CANBERRA disconnect NC contact	CAN89B

Table 1.30 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description	Alias
89A05	TIE-BREAKER disconnect (WEST) NO contact	SEC891A
89B05	TIE-BREAKER disconnect (WEST) NC contact	SEC891B
89A06	TIE-BREAKER disconnect (EAST) NO contact	SEC892A
89B06	TIE-BREAKER disconnect (EAST) NC contact	SEC892B

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations. We also assign alias names to the alarm Relay Word bits (89AL*nn*). *Table 1.31* shows the alias names.

Table 1.31 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits

Primitive Name	Description	Alias
89CL01	LONDON disconnect is closed	LOND89C
89CL02	BERLIN disconnect is closed	BERL89C
89CL03	NEW YORK disconnect is closed	NEWY89C
89CL04	CANBERRA disconnect is closed	CANB89C
89CL05	TIE-BREAKER disconnect (WEST) is closed	SEC189C
89CL06	TIE-BREAKER disconnect (EAST) is closed	SEC289C
89AL01	LONDON disconnect alarm	LON89AL
89AL02	BERLIN disconnect alarm	BER89AL
89AL03	NEW YORK disconnect alarm	NEW89AL
89AL04	CANBERRA disconnect alarm	CAN89AL
89AL05	TIE-BREAKER disconnect (WEST) alarm	SE189AL
89AL06	TIE-BREAKER disconnect (EAST) alarm	SE289AL

Breaker Status Logic

Figure 1.65 shows the breaker status logic circuit associated with current channel I01. This logic includes an OPH01 input from the open phase detection logic. Open phase detection logic asserts the OPH01 Relay Word bit when the logic measures no current in that specific phase. Alarm output 52AL01 asserts when the 52A01 and OPH01 inputs are both deasserted for longer than 5 cycles. For example, when the circuit breaker is open (52A01 is logical 0), Relay Word bit OPH01 asserts (changes to logical 1) when current stops flowing. AND Gate 2 in *Figure 1.65* outputs a logical 0 and the timer does not run. However, if current still flows through the CT when the circuit breaker is open (end-zone fault, for example), Relay Word bit OPH01 does not assert (remains at logical 0) and the timer starts.

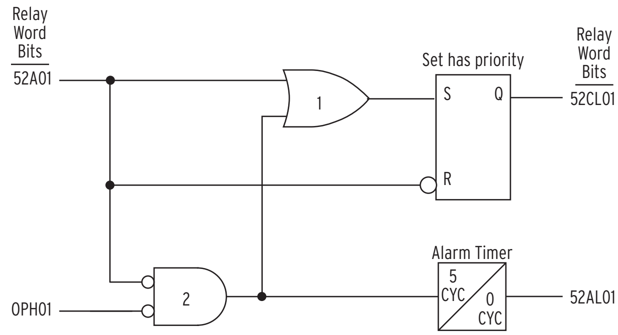


Figure 1.65 Breaker Status Logic

Wire a single, normally open circuit breaker auxiliary contact from each of the four feeder circuit breakers to an individual relay input (IN204, IN205, IN206, and IN207). In this example, we do not assign alias names to the Relay Word bits; we use the primitive names instead. Because this is a single-relay application, the three phases of each terminal are in the same relay. *Table 1.32* shows the breaker status logic input and output Relay Word bits.

Table 1.32 Breaker Status Logic Input and Output Relay Word Bits

Primitive Name	Description
52A01	LONDON A-phase NO contact
52AL01	LONDON A-phase discrepancy alarm
52A02	LONDON B-phase NO contact
52AL02	LONDON B-phase discrepancy alarm
52A03	LONDON C-phase NO contact
52AL03	LONDON C-phase discrepancy alarm
52A04	BERLIN A-phase NO contact
52AL04	BERLIN A-phase discrepancy alarm
52A05	BERLIN B-phase NO contact
52AL05	BERLIN B-phase discrepancy alarm
52A06	BERLIN C-phase NO contact
52AL06	BERLIN C-phase discrepancy alarm
52A07	NEW YORK A-phase NO contact
52AL07	NEW YORK A-phase discrepancy alarm
52A08	NEW YORK B-phase NO contact
52AL08	NEW YORK B-phase discrepancy alarm
52A09	NEW YORK C-phase NO contact
52AL09	NEW YORK C-phase discrepancy alarm
52A10	CANBERRA A-phase NO contact
52AL10	CANBERRA A-phase discrepancy alarm
52A11	CANBERRA B-phase NO contact
52AL11	CANBERRA B-phase discrepancy alarm
52A12	CANBERRA C-phase NO contact
52AL12	CANBERRA C-phase discrepancy alarm

Differential Trip Logic and Differential Element Alias Assignment

Figure 1.66 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information). *Table 1.33* shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 1.33 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	WESTA_T
87Z2	Zone 2 differential element trip	WESTB_T
87Z3	Zone 3 differential element trip	WESTC_T
87Z4	Zone 4 differential element trip	EASTA_T
87Z5	Zone 5 differential element trip	EASTB_T
87Z6	Zone 6 differential element trip	EASTC_T

Differential trip bits 87BTR01 through 87BTR18 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information).

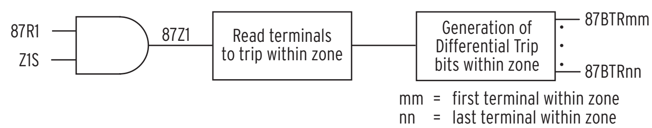


Figure 1.66 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate. In our example, we will use all the 87BTR*mm* (*mm* = 01 through 18) Relay Word bits. *Table 1.34* shows the primitive differential trip bit names, and the alias names for the differential trip bits.

Table 1.34 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits (Sheet 1 of 2)

Differential Trip Bit	Alias	Comments
87BTR01	87LON_A	Associated with Terminal 01
87BTR02	87LON_B	Associated with Terminal 02
87BTR03	87LON_C	Associated with Terminal 03
87BTR04	87BER_A	Associated with Terminal 04
87BTR05	87BER_B	Associated with Terminal 05
87BTR06	87BER_C	Associated with Terminal 06
87BTR07	87NEW_A	Associated with Terminal 07
87BTR08	87NEW_B	Associated with Terminal 08
87BTR09	87NEW_C	Associated with Terminal 09
87BTR10	87CAN_A	Associated with Terminal 10
87BTR11	87CAN_B	Associated with Terminal 11
87BTR12	87CAN_C	Associated with Terminal 12
87BTR13	87SEC1A	Associated with Terminal 13

Table 1.34 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits (Sheet 2 of 2)

Differential Trip Bit	Alias	Comments
87BTR14	87SEC1B	Associated with Terminal 14
87BTR15	87SEC1C	Associated with Terminal 15
87BTR16	87SEC2A	Associated with Terminal 16
87BTR17	87SEC2B	Associated with Terminal 17
87BTR18	87SEC2C	Associated with Terminal 18

Breaker Trip Logic and Trip Alias Assignment

Figure 1.67 shows the general tripping logic for the 15 trip outputs used in this application. (See *Section 1: Protection Functions in the Reference Manual* for more information).

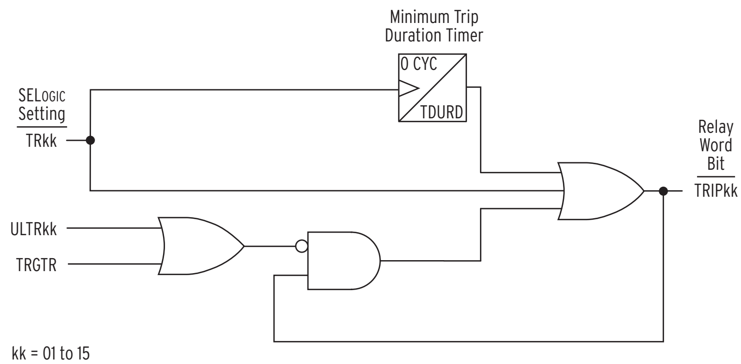


Figure 1.67 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK). Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals 15.

After setting the TR*nn* trip equations, the relay associates each TR*nn* trip equation with a particular circuit breaker pole; we must combine the trip equations in the output settings to form a single output for the tie breaker (see the *Protection Group Settings on page A.1.83*). For example, after setting TR01:= 87BTR01 and TR02:= 87BTR02, the relay associates Trip Equation TR01 with Terminal 01 (LOND_A), Trip Equation TR02 with Terminal 02 (LOND_B), and so on. *Table 1.35* shows the 15 primitive and alias names for the trip logic of each terminal.

Table 1.35 Primitive and Alias Names for the Trip Logic of Each Terminal (Sheet 1 of 2)

Primitive Name	Description	Alias
TRIP01	Trip output of the LONDON Terminal A phase asserted	TRLON_A
TRIP02	Trip output of the LONDON Terminal B phase asserted	TRLON_B
TRIP03	Trip output of the LONDON Terminal C phase asserted	TRLON_C
TRIP04	Trip output of the BERLIN Terminal A phase asserted	TRBER_A
TRIP05	Trip output of the BERLIN Terminal B phase asserted	TRBER_B
TRIP06	Trip output of the BERLIN Terminal C phase asserted	TRBER_C

Table 1.35 Primitive and Alias Names for the Trip Logic of Each Terminal (Sheet 2 of 2)

Primitive Name	Description	Alias
TRIP07	Trip output of the NEW YORK Terminal A phase asserted	TRNEW_A
TRIP08	Trip output of the NEW YORK Terminal B phase asserted	TRNEW_B
TRIP09	Trip output of the NEW YORK Terminal C phase asserted	TRNEW_C
TRIP10	Trip output of the CANBERRA Terminal A phase asserted	TRCAN_A
TRIP11	Trip output of the CANBERRA Terminal B phase asserted	TRCAN_B
TRIP12	Trip output of the CANBERRA Terminal C phase asserted	TRCAN_C
TRIP13	Trip output of the sectionalizing breaker A phase asserted	TRSEC_A
TRIP14	Trip output of the sectionalizing breaker B phase asserted	TRSEC_B
TRIP15	Trip output of the sectionalizing breaker C phase asserted	TRSEC_C

Assign Alias Names to the User-Defined Logic

We created the general end-zone protection logic under *User-Defined Functions on page A.1.64*. We now assign the application-specific alias names to all the appropriate Relay Word bits in the end-zone protection logic.

End-Zone Protection

Table 1.36 shows the alias names for the four protection SELOGIC control equation variables (PSV01–PSV04).

Table 1.36 Alias Names for the End-Zone Protection Logic

Primitive Name	Description	Alias
PSV01	End-zone element for LONDON terminal	LOND_EZ
PSV02	End-zone element for BERLIN terminal	BERL_EZ
PSV03	End-zone element for NEW YORK terminal	NEWY_EZ
PSV04	End-zone element for CANBERRA terminal	CANB_EZ

Figure 1.68 shows the end-zone logic with the alias names instead of the primitive names. The logic declares an end-zone fault when the following three conditions are met:

- ➤ A differential trip signal has been issued to the circuit breaker
- ➤ Current continues to flow through the feeder CT after a 5-cycle delay
- ➤ The busbar disconnect of the feeder is closed.

Notice that the second condition is met by using the built-in 5-cycle delay of 52AL*nn*, which is the alarm timer output of the circuit breaker status logic. Create similar logic for the other three feeders with the protection logic settings.

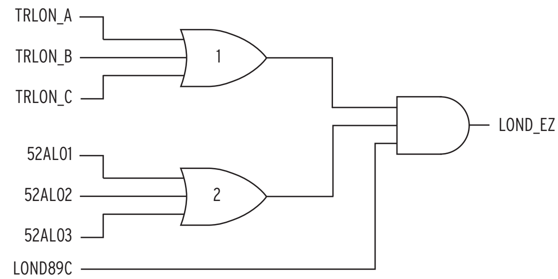


Figure 1.68 End-Zone Logic With the Alias Names for the London Feeder

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 1.26* shows the breakdown of the nine relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts and assign alias names to the relay output contacts. *Table 1.37* shows the linking of the end-zone protection logic to the output contacts of the main board and the alias names of the relay main board output contacts. *Table 1.38* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1 and the alias names of the of the interface board output contacts.

Output Alias Assignment–Main Board

We assign the outputs from the end-zone protection logics as direct transfer trip (DTT) functions to the output contacts of the main board. Wire the direct transfer trip outputs to the communications equipment or terminal panel to transmit the signal to the remote busbar.

Table 1.37 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT101	DTT for an end zone fault on LONDON Feeder	LON_DTT
OUT102	DTT for an end zone fault on BERLIN Feeder	BER_DTT
OUT103	DTT for an end zone fault on NEW YORK Feeder	NEW_DTT
OUT104	DTT for an end zone fault on CANBERRA Feeder	CAN_DTT
OUT105	NA	NA
OUT106	NA	NA
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment–Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.38* shows the alias assignment for the five terminals in our example.

Table 1.38 Alias Assignment for the Five Terminals in Our Example

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	LONDON trip logic output	LON_TRP
OUT202[a]	BERLIN trip logic output	BER_TRP
OUT203[a]	NEW YORK trip logic output	NEW_TRP
OUT204[a]	CANBERRA trip logic output	CAN_TRP
OUT205[a]	TIE-BREAKER trip logic output	SEC_TRP

[a] High-speed, high-interrupting outputs.

Station Layout Update

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.69*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminals CTs to the relay input current channels.
4. Allocate the auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

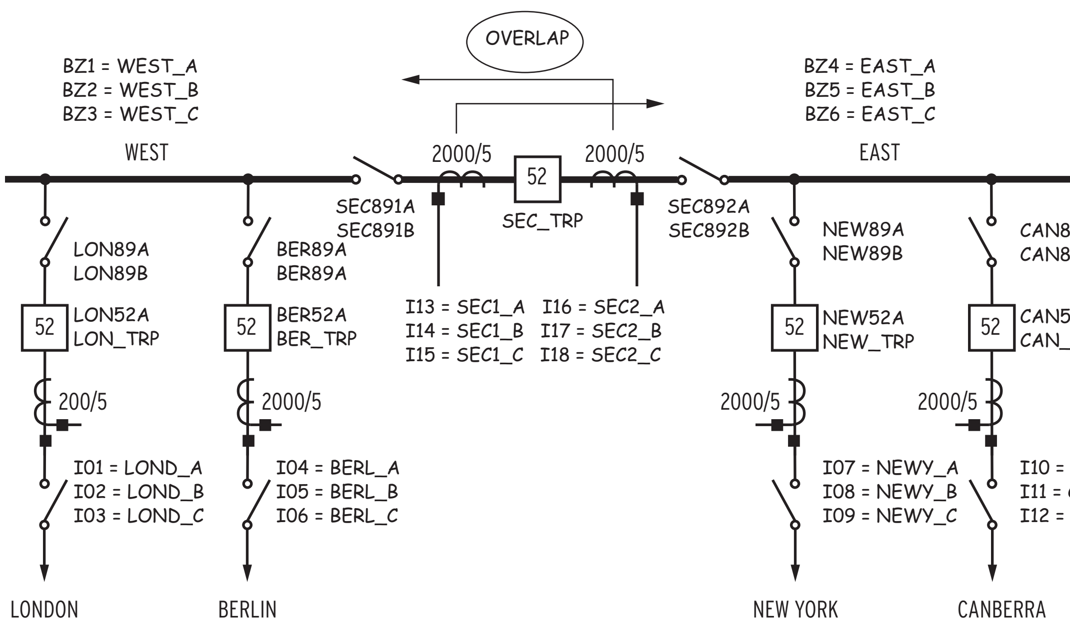


Figure 1.69 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following settings classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings
- ➤ Protection Group Settings
- ➤ Protection Logic Settings
- ➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.70*.

After inspecting the list, we decide that the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>
1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.70 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.71*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.71 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the 18 analog channels and Relay Word bits, as shown in *Figure 1.72*.

```
1:OUT107,"TEST"
?  <Enter>
19:
?  I01,LOND_A <Enter>
20:
?  I02,LOND_B <Enter>
21:
?  I03,LOND_C <Enter>
22:
?  I04,BERL_A <Enter>
23:
?  I05,BERL_B <Enter>
24:
?  I06,BERL_C <Enter>
.
.
.

133:
?  OUT204,CAN_TRP <Enter>
134:
?  OUT205,SEC_TRP <Enter>
135:
?  END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.72 Analog Quantities and Relay Word Bit Alias Names for Application 2

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Settings Group 1 to Protection Settings Group 2, global settings such as station name and relay name still apply. *Figure 1.73* shows the setting changes we need for our example. Because we declared the alias names in the alias setting class, use either alias names or primitive names when entering settings.

Carefully consider circuit breaker related settings when applying the relay in a single-relay application. The relay considers all applications to be three-relay applications; there is no setting distinguishing a single-relay application from a three-relay application. In particular, the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, not as the number of circuit breakers.

In this single-relay application example, there are 15 circuit breaker poles at the substation, and the value of NUMBK is 15. However, wire only one circuit breaker auxiliary contact from each circuit breaker to the relay; see the TR*kk*, TRIP*kk,* and the output settings for information on how to set the relay for this application.

There exists a direct relationship between the number of circuit breakers and the number of breaker status logics, i.e., the number of breaker input equations (52A*kk*) equals the number of circuit breakers (NUMBK). Enter the number of poles at the station for the NUMBK setting. Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals 15.

Setting NUMBK equal to 15 makes 15 corresponding circuit breaker auxiliary input equations (52A01 through 52A15), and 15 corresponding trip equations (TR01 through TR15) available for setting. Although 15 circuit breaker auxiliary input equations are available, there are only four circuit breaker auxiliary contacts wired to the relay, one contact from each of the four feeder circuit breakers at the station. Group three circuit breaker auxiliary input equations to form an association with a circuit breaker, and enter the same contact name for the three circuit breaker auxiliary input equations. For example, group circuit breaker auxiliary input equations 52A01, 52A02, and 52A03 to form an association with the LONDON circuit breaker.

Table 1.29 shows the allocation of ILON52A, the circuit breaker auxiliary contact to relay input IN204. We use relay input IN204 to monitor the status of the LONDON circuit breaker. All three circuit breaker auxiliary input equations (52A01, 52A02, and 52A03) must assert when ILON52A asserts, so ILON52A must appear in all three circuit breaker auxiliary input equations. Because we do not need a circuit breaker auxiliary contact from the tie breaker, set 52A13–52A15 to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need six disconnect logics although there are 12 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*nn* setting (*nn* = 01 through 06). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                    NUMBK   := 5      ?15 <Enter>
Number of Disconnects (N,1-48)                 NUMDS   := N      ?6 <Enter>
Nominal System Frequency (50,60 Hz)            NFREQ   := 60     ?<Enter>
Date Format (MDY,YMD,DMY)                      DATE_F  := MDY    ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)               EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                GINPU   := 0.17   ?> <Enter>
Settings Group Selection
Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  ILON52A <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
?  ILON52A <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  ILON52A <Enter>
N/O Contact Input -BK04 (SELogic Equation)
52A04 := NA
?  IBER52A <Enter>
N/O Contact Input -BK05 (SELogic Equation)
52A05 := NA
?  IBER52A <Enter>
N/O Contact Input -BK06 (SELogic Equation)
52A06 := NA
?  IBER52A <Enter>
N/O Contact Input -BK07 (SELogic Equation)
.
.
.
52A13 := NA
?  <Enter>
N/O Contact Input -BK13 (SELogic Equation)
52A14 := NA
?  <Enter>
N/O Contact Input -BK14 (SELogic Equation)
52A15 := NA
?  <Enter>
N/O Contact Input -BK15 (SELogic Equation)

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  ILON89A <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  ILON89B <Enter>

DS01 Alarm Pickup Delay (0-99999 cyc)          89ALP01 := 300    ? <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IBER89A <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IBER89B <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)          89ALP02 := 300    ? <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.73 Global Settings for Application 2

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration, and to assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three phases. For example, when we close the busbar disconnect on the LONDON feeder, all three phases (LOND_A, LOND_B, and LOND_C) operate together. Because the relay measures the three phases in three separate differential elements (phase LOND_A in differential element WEST_A, phase LOND_B in differential element WEST_B, etc.), we need to convey the disconnect status to all three differential elements. *Table 1.31* shows the alias names of the disconnect status Relay Word bits; *Figure 1.74* shows the zone configuration group settings.

The zone configuration group default settings are for a specific substation with arbitrarily selected alias names, serving only as an example. For the ease of setting the zone configuration group settings for the new substation, delete the existing zone configuration default settings. With the zone configuration group default settings deleted, the setting prompts no longer reference the default settings.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>
Current Transformer Ratio
Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?40 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?40 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?40 <Enter>
Current Transformer Ratio -I04 (1-50000)            CTR04   := 600    ?400 <Enter>
Current Transformer Ratio -I05 (1-50000)            CTR05   := 600    ?400 <Enter>
Current Transformer Ratio -I06 (1-50000)            CTR06   := 600    ?400 <Enter>
Current Transformer Ratio -I07 (1-50000)            CTR07   := 600    ?400 <Enter>
Current Transformer Ratio -I08 (1-50000)            CTR08   := 600    ?400 <Enter>
Current Transformer Ratio -I09 (1-50000)            CTR09   := 600    ?400 <Enter>
Current Transformer Ratio -I10 (1-50000)            CTR10   := 600    ?400 <Enter>
Current Transformer Ratio -I11 (1-50000)            CTR11   := 600    ?400 <Enter>
.
.
.
Current Transformer Ratio -I18 (1-50000)            CTR18   := 600    ?400 <Enter>
Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := SEC1_A, WEST_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,BZ1,P <Enter>
LOND_A to WEST_A Connection (SELogic Equation)
I01BZ1V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,BZ2,P <Enter>
```

```
LOND_B to WEST_B Connection (SELogic Equation)
I02BZ2V := NA
?   LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,BZ3,P <Enter>
LOND_C to WEST_C Connection (SELogic Equation)
I03BZ3V := NA
?   LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,BZ1,P <Enter>
BERL_A to WEST_A Connection (SELogic Equation)
I04BZ1V := NA
?   BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,BZ2,P <Enter>
BERL_B to WEST_B Connection (SELogic Equation)
I05BZ2V := NA
?   BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,BZ3,P <Enter>
BERL_C to WEST_C Connection (SELogic Equation)
I06BZ3V := NA
?   BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I07,BZ4,P <Enter>
NEWY_A to EAST_A Connection (SELogic Equation)
I07BZ4V := NA
?   NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I08,BZ5,P <Enter>
NEWY_B to EAST_B Connection (SELogic Equation)
I08BZ5V := NA
?   NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I09,BZ6,P <Enter>
NEWY_C to EAST_C Connection (SELogic Equation)
I09BZ6V := NA
?   NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I10,BZ4,P <Enter>
CANB_A to EAST_A Connection (SELogic Equation)
I10BZ4V := NA
?   CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I11,BZ5,P <Enter>
CANB_B to EAST_B Connection (SELogic Equation)
I11BZ5V := NA
?   CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I12,BZ6,P <Enter>
CANB_C to EAST_C Connection (SELogic Equation)
I12BZ6V := NA
?   CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I13,BZ4,P <Enter>
SEC1_A to EAST_A Connection (SELogic Equation)
I13BZ4V := NA
?   SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I14,BZ5,P <Enter>
SEC1_B to EAST_B Connection (SELogic Equation)
I14BZ5V := NA
?   SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I15,BZ6,P <Enter>
SEC1_C to EAST_C Connection (SELogic Equation)
I15BZ6V := NA
?   SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I16,BZ1,P <Enter>
SEC2_A to WEST_A Connection (SELogic Equation)
I16BZ1V := NA
?   SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I17,BZ2,P <Enter>
SEC2_B to WEST_B Connection (SELogic Equation)
I17BZ2V := NA
?   SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I18,BZ3,P <Enter>
SEC2_C to WEST_C Connection (SELogic Equation)
I18BZ3V := NA
?   SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
```

```
Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?<Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.74 Zone Configuration Group Settings for Application 2

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set ECSL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, and EVOLT := N because we do not use the Coupler Security Logic, terminal out of service, breaker failure protection, overcurrent elements, or voltage elements in this application. Pay close attention to the trip logic (TR01 through TR15) settings.

Because we use one SEL-487B, CTs from the three phases (A-phase, B-phase, and C-phase) from each terminal are assigned to three different differential elements (see *Single-Relay Application on page A.1.3*).

Setting NUMBK (Global Settings) equal to 15 also makes 15 corresponding trip equations (TR01 through TR15) available for setting. *Table 1.34* shows the 18 differential trip bits that assert when the differential protection operates. Setting the trip equations involves assigning the 18 differential trip bits to the correct 15 trip equations. There are six differential elements in the relay, and because there are six bus-zones at the station, we use all six differential elements.

For the per-phase differential calculations, the relay assigns the individual phases of each terminal to three separate differential elements. (Strictly speaking, the relay assigns the phases according to the zone configuration group settings. However, correct zone configuration group settings cause the relay to assign the individual phases of each terminal to three separate differential elements.) The tie breaker has six CTs; one CT assigned to each of the six differential elements. Because the tie breaker has only one circuit breaker, operation of any one of the six differential elements must trip the tie-breaker circuit breaker. For this reason, we include the two A-phase differential trip bits (87SEC1A and 87SEC2A) in the same trip equation, the two B-phase differential trip bits (87SEC1B and 87SEC2B) in the same trip equation, and so on.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. Press the **{TARGET RESET}** pushbutton on the front panel to deassert the trip outputs. Alternatively, enter specific reset conditions at the ULTR*kk* settings.

Although the SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting. Set the timer TDURD longer than the clearing time of the slowest circuit breaker at the station.

For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element, the Directional Element, and the Trip Duration Timer. *Figure 1.75* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>
Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87LON_A
?  87LON_A <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87LON_B
?  87LON_B <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87LON_C
?  87LON_C <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.
Trip 12 (SELogic Equation)
TR12 := NA
?  87CAN_C <Enter>
Unlatch Trip 12 (SELogic Equation)
ULTR12 := NA
?<Enter>
Trip 13 (SELogic Equation)
TR13 := NA
?  87SEC1A OR 87SEC2A <Enter>
Unlatch Trip 13 (SELogic Equation)
ULTR13 := NA
?<Enter>
Trip 14 (SELogic Equation)
TR14 := NA
?  87SEC1B OR 87SEC2B <Enter>
Unlatch Trip 14 (SELogic Equation)
ULTR14 := NA
?<Enter>
Trip 15 (SELogic Equation)
TR15 := NA
?  87SEC1C AND 87SEC2C <Enter>
```

```
Unlatch Trip 15 (SELogic Equation)
ULTR15 := NA
?  <Enter>

Trip Logic
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?> <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.75 Protection Group Settings for Application 2

This concludes the protection group settings. The next settings class is the protection logic settings.

Protection Logic Settings

Use the protection logic settings to create logics in the relay. *Figure 1.76* shows the settings in our example. Protection Latch Bit PLT01 constitutes the differential enable function on the front-panel pushbutton labeled **{87(DIFF) ENABLED}**. Because we do not require breaker failure protection or voltage elements for this application, we remove the settings associated with these functions. Lines 5 through 9 show the programming for the end-zone protection. *Figure 1.76* shows the protection logic settings.

```
=>>SET L <Enter>
Protection 1

1: PLT01S := PCT02Q AND NOT PLT01 # DIFFERENTIAL ENABLED
?<Enter>
2: PLT01R := PB1_PUL AND PLT01
?<Enter>
3: PLT02S := PCT03Q AND NOT PLT02 # BREAKER FAILURE ENABLED
?  DELETE <Enter>
3: PLT02R := PB2_PUL AND PLT02
?  DELETE <Enter>
3: PLT03S := PCT04Q AND NOT PLT03 # RELAY TEST MODE
?<Enter>
4: PLT03R := PB4_PUL AND PLT03
?<Enter>
5: PCT01PU := 240.000000
?  DELETE 12 <Enter>
5:
?  # END-ZONE PROTECTION FOR THE LONDON FEEDER <Enter>
6:
?  LOND_EZ:=(TRLON_A OR TRLON_B OR TRLON_C) AND (52AL01 OR 52AL02 OR 52AL03) AND LOND89C <Enter>
7:
?  # END-ZONE PROTECTION FOR THE BERLIN FEEDER <Enter>
8:
?  BERL_EZ:=(TRBER_A OR TRBER_B OR TRBER_C) AND (52AL04 OR 52AL05 or 52AL06) AND BERL89C <Enter>
9:
?  # END-ZONE PROTECTION FOR THE NEW YORK FEEDER <Enter>
10:
?  NEWY_EZ:=(TRNEW_A OR TRNEW_B OR TRNEW_C) AND (52AL07 or 52AL08 or 52AL09)\
AND NEWY89C <Enter>
11:
?  # END-ZONE PROTECTION FOR THE CANBERRA FEEDER <Enter>
12:
?  CANB_EZ:=(TRCAN_A OR TRCAN_B OR TRCAN_C) AND (52AL10 OR 52AL11 OR 52AL12)\
AND CANB89C <Enter>
13:
?  END <Enter>

Protection 1
.
.
.
```

```
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.76 Protection Logic Settings for Application 2

This concludes the protection logic settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need nine output contacts for our example:

- four for the direct transfer trip outputs
- five for the bus-bar protection trip outputs

Although not specifically called for in the protection philosophy, it is good practice to also include the TEST and ALARM outputs in the relay settings.

Because the relay interprets the NUMBK setting as the number of poles, there are 15 trip equations for this application. There is, of course, only one circuit breaker for each terminal. We, therefore, combine the appropriate trip outputs from the breaker trip logic (TRIP01 through TRIP15, see *Figure 1.67*) to provide a single trip output for each circuit breaker. For example, we set the trip equations (*Protection Group Settings on page A.1.83*) for the London terminal to TR01:= 87LON_A, TR02:= 87LON_B, and TR03:= 87LON_C, with the corresponding breaker trip logic output alias names of TRLON_A, TRLON_B, and TRLON_C. Because Terminal LONDON has only one circuit breaker, we assign only one trip output contact (OUT201) to trip the circuit breaker. Therefore, assertion of any one of the three breaker trip logic outputs (TRLON_A, TRLON_B, or TRLON_C) must trip the circuit breaker of the London terminal. To achieve this tripping, set Output OUT201 equal to the OR combination of the three breaker trip logic outputs.

NOTE: The tie-breaker trip equations (TR13 through TR15) already include the combination of two differential elements (87SEC1A OR 87SEC2A, etc.).

Figure 1.77 shows the settings. We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts. We assign the direct transfer trip outputs to the main board contacts and the bus-zone protection to the trip outputs of the interface board. *Figure 1.77* shows the output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRSEC_A AND NOT PLT03
?   LOND_EZ AND NOT PLT03 <Enter>

OUT102 := TRSEC_B AND NOT PLT03
?   BERL_EZ AND NOT PLT03 <Enter>

OUT103 := TRSEC_C AND NOT PLT03
?   NEWY_EZ AND NOT PLT03 <Enter>

OUT104 := TRLON_A AND NOT PLT03
?   CANB_EZ AND NOT PLT03 <Enter>

OUT105 := TRLON_B AND NOT PLT03
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   (TRLON_A OR TRLON_B OR TRLON_C) AND NOT PLT03 <Enter>
```

```
OUT202 := NA
?   (TRBER_A OR TRBER_B OR TRBER_C) AND NOT PLT03 <Enter>

OUT203 := NA
?   (TRNEW_A OR TRNEW_B OR TRNEW_C) AND NOT PLT03 <Enter>

OUT204 := NA
?   (TRCAN_A OR TRCAN_B OR TRCAN_C) AND NOT PLT03 <Enter>

OUT205 := NA
?   (TRSEC_A OR TRSEC_B OR TRSEC_C) AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 1.77 Control Output Settings for Application 2

This concludes the settings for Application 2.

Application 3: Breaker-and-a-Half

This application describes the breaker-and-a-half busbar arrangement shown in *Figure 1.78*. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

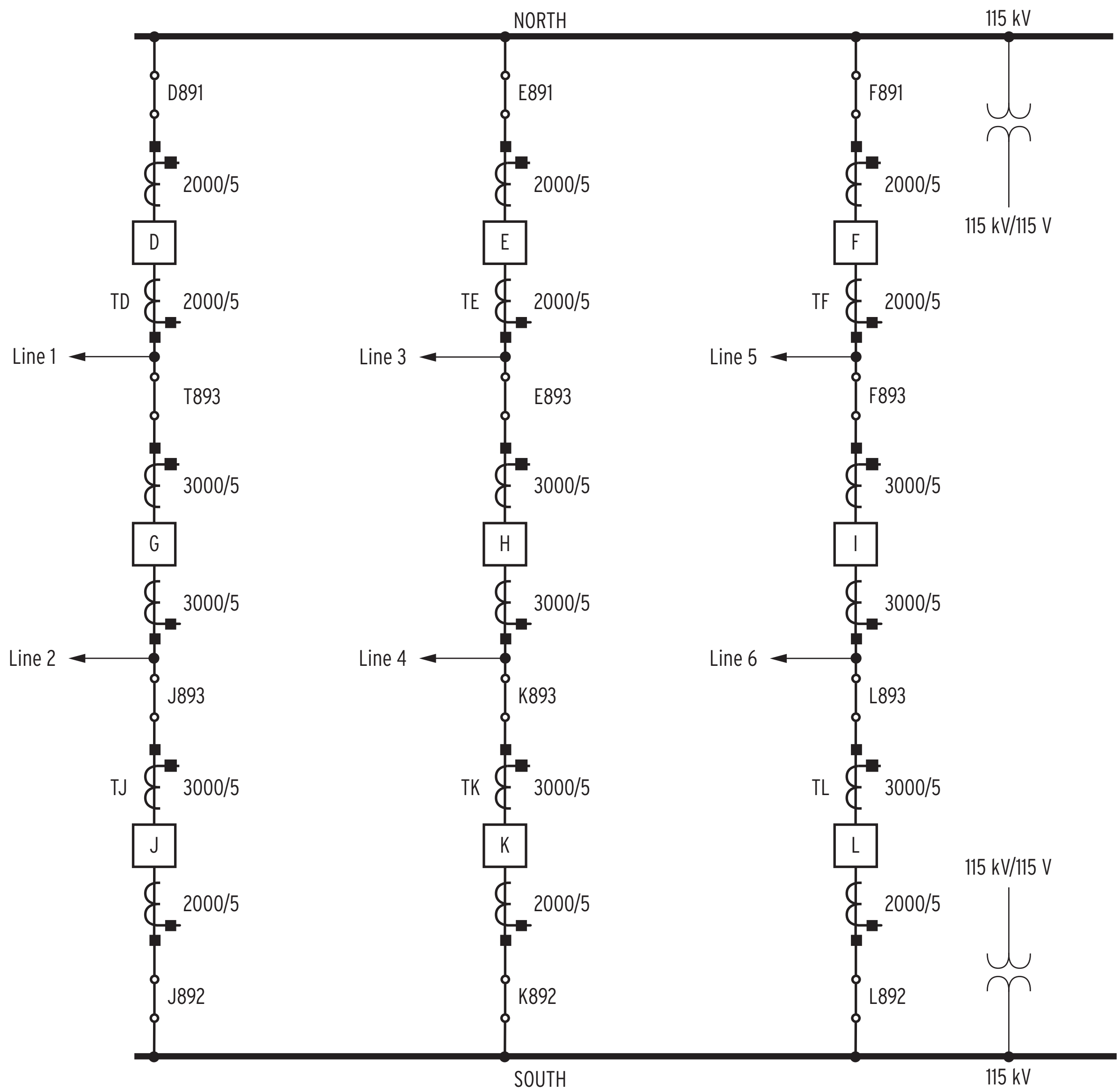


Figure 1.78 Breaker-and-a-Half Busbar Layout

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information.

- Description:
  - Breaker-and-a-half
- Current Transformers:
  - Outboard (free standing)
- Disconnects:
  - No disconnect auxiliary contacts are available
- Future expansion:
  - One feeder

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every substation uses all of these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the terminal-out-of service function.
2. Use the voltage elements as an additional trip criterion, and generate an event report when the voltage elements assert.
3. Block the busbar protection for an open-circuit CT.
4. Use the internal breaker failure protection in the relay for Terminals TD, TE, and TF and include retrip for each terminal.
5. Protect the two busbars with separate relays.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. The SEL-487B offers a number of protection functions as standard features, but it also includes the capability through SELOGIC control equations to create user-configurable functions. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created with SELOGIC control equations)

Standard Functions

Refer to the protection philosophy and select the standard functions necessary for the application. *Table 1.39* shows the selection of the standard functions.

Table 1.39 Section of Standard Protection Functions (Sheet 1 of 2)

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	No	No disconnect auxiliary contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	No	No disconnect auxiliary contacts available
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Supervise tripping with the under-voltage elements as well as the negative- and zero-sequence over-voltage elements
Zone-switching supervision logic	No	No disconnect auxiliary contacts available
Coupler security logic	No	Breaker-and-a-half busbar layout does not require this function
Circuit breaker failure protection	Yes	Use the internal circuit breaker failure protection

Table 1.39 Section of Standard Protection Functions (Sheet 2 of 2)

Protection Function	Selection	Comment
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	Yes	Use these elements as an additional trip criterion
Zero- or negative-sequence voltage elements	Yes	Use these elements as an additional trip criterion

User-Defined Functions

Because the SEL-487B includes all protection functions necessary for this application as standard protection functions, we do not need any user-defined functions.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with as many as 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.8* to calculate the number of current channels at the station, and use *Equation 1.9* to calculate the number of zones at the station.

# of current channels required # of per-phase station CTs **Equation 1.8**

# of bus-zones required = # of per-phase station bus sections **Equation 1.9**

The protection philosophy calls for a separate relay for each busbar. There are three terminals in each zone, for a total of nine analog channels. Because of future expansion, however, add 3 more channels for a total of 12. Each SEL-487B has 18 analog channels, so that one relay has enough analog inputs to protect one of the busbars; we need 2 relays to protect both busbars.

Therefore, an SEL-487B protects busbar NORTH, and a separate SEL-487B protects the SOUTH busbar. This is known as a single-relay application. The following discussion describes setting the relay that protects the NORTH busbar. Configuration settings for the relay protecting the SOUTH busbar are the same, except for the alias names. System settings such as CT ratios may be different.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application. The protection philosophy calls for breaker failure protection. We, therefore, need a breaker failure initiate input contact for each of the three terminals. *Table 1.40* summarizes the input contact requirement for this application.

Table 1.40 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for circuit breaker failure protection	3
Total number of inputs	3

The relay main board has seven input contacts, sufficient for our application. From the input contact perspective, we only need the main board; we do not need an interface board.

Number of Relay Output Contacts

Circuit breakers TD, TE, and TF each need a trip output contact as well as a direct transfer trip (DTT). *Table 1.41* shows the breakdown and the total number of relay output contacts required.

Table 1.41 Breakdown and the Total Number of Relay Outputs Required

Output description	Outputs
Number of relay output contacts required for differential, breaker failure tripping, and direct transfer trip	3
Number of relay output contacts required for direct transfer tripping	3
Total number of relay output contacts	6

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). There are enough output contacts on the main board, but these contacts are all standard output contacts. The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need one SEL-487B per busbar, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays necessary for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation, and CT Alias Assignment

Table 1.42 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase CT from Terminal TD to relay channel I01, and assign to this CT the alias name TD_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.42* shows the assignment starting with Terminal TD, followed by Terminal TE, and Terminal TF, taken left-to-right from *Figure 1.78*.

Table 1.42 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
Terminal TD, A-phase	I01	TD_A
Terminal TD, B-phase	I02	TD_B
Terminal TD, C-phase	I03	TD_C
Terminal TE, A-phase	I04	TE_A
Terminal TE, B-phase	I05	TE_B
Terminal TE, C-phase	I06	TE_C
Terminal TF, A-phase	I07	TF_A
Terminal TF, B-phase	I08	TF_B
Terminal TF, C-phase	I09	TF_C

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. In this application, we use three of the six zones with alias names as shown in *Table 1.43*.

Table 1.43 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	NORTH_A
BZ2	Bus-Zone 2	NORTH_B
BZ3	Bus-Zone 3	NORTH_C

Input-to-Logic Allocation and Alias Assignment

Table 1.40 shows that we require three digital inputs. We now assign the digital inputs to the selected logic and apply alias names to the inputs and logic elements. Because we installed an interface board, we use the independent inputs on the interface board for the breaker failure initiate inputs, instead of the inputs on the main board.

Input-to-Logic Allocation and Alias Assignment, Interface Board 1 (200)

Table 1.44 shows the breaker failure initiate input allocations.

Table 1.44 Alias Names for the Breaker Failure Input Contacts

Input	Description	Alias
IN201	Terminal TD breaker failure initiate	ITD_BFI
IN202	Terminal TE breaker failure initiate	ITE_BFI
IN203	Terminal TF breaker failure initiate	ITF_BFI

Assign Alias Names to the Selected Standard Logic

The following explains each selected function in reference to *Table 1.39*. Alias name assignments are also included.

Breaker Failure

This application is a breaker-and-a-half busbar layout. For such busbar layouts, two circuit breakers must operate to clear a fault. *Figure 1.79* shows fault F1, for which both Circuit Breaker TD and Circuit Breaker TG must operate to clear the fault. For certain faults, the current distribution may be such that Circuit Breaker TD carries the bulk of the fault current, as shown in *Figure 1.79*.

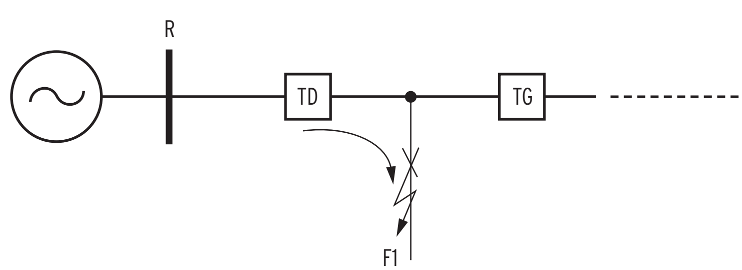


Figure 1.79 Current Distribution for Fault F1 With Circuit Breaker TD and Circuit Breaker TG Closed

Because of the current distribution, Terminal TG may only have enough current to assert the breaker failure current element threshold (50F*nn*) when Circuit Breaker TD opens, as shown in *Figure 1.80*.

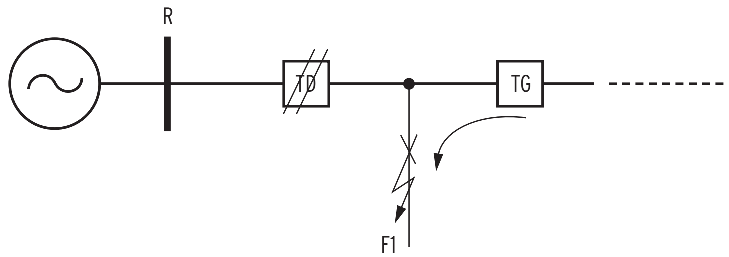


Figure 1.80 Current Flow for Fault F1 After Circuit Breaker TD Opened

This situation delays initiation of the breaker failure protection of Terminal TG until Circuit Breaker TD interrupts the current. However, both circuit breakers receive the trip signal at the same time and are expected to operate at the same time. Use breaker failure protection Scheme 2 to prevent this delay. See *Circuit Breaker Failure Protection on page R.1.37* for more information.

Because the protection philosophy calls for use of the internal breaker failure protection, wire a breaker failure initiate contact from each feeder panel to an independent relay input contact. *Table 1.45* shows the primitive names and the alias names of the breaker failure initiate Relay Word bits (see the *Protection Group Settings on page A.1.104* for more information).

Table 1.45 Alias Names for the Breaker Failure Initiate Relay Word Bits

Logic Name	Description	Alias
ATBFI01	Terminal TD A-phase breaker failure protection initiate input	TDA_BFI
ATBFI02	Terminal TD B-phase breaker failure protection initiate input	TDB_BFI
ATBFI03	Terminal TD C-phase breaker failure protection initiate input	TDC_BFI
ATBFI04	Terminal TE A-phase breaker failure protection initiate input	TEA_BFI
ATBFI05	Terminal TE B-phase breaker failure protection initiate input	TEB_BFI
ATBFI06	Terminal TE C-phase breaker failure protection initiate input	TEC_BFI
ATBFI07	Terminal TF A-phase breaker failure protection initiate input	TFA_BFI
ATBFI08	Terminal TF B-phase breaker failure protection initiate input	TFB_BFI
ATBFI09	Terminal TF C-phase breaker failure protection initiate input	TFC_BFI

We also assign alias names to breaker failure logic output Relay Word bits. *Table 1.46* shows the primitive names and the alias names.

Table 1.46 Alias Names for the Breaker Failure Logic Output Relay Word Bits

Logic Name	Description	Alias
FBF01	Terminal TD A-phase breaker failure protection asserted	TDA_BF
FBF02	Terminal TD B-phase breaker failure protection asserted	TDB_BF
FBF03	Terminal TD C-phase breaker failure protection asserted	TDC_BF
FBF04	Terminal TE A-phase breaker failure protection asserted	TEA_BF
FBF05	Terminal TE B-phase breaker failure protection asserted	TEB_BF
FBF06	Terminal TE C-phase breaker failure protection asserted	TEC_BF
FBF07	Terminal TF A-phase breaker failure protection asserted	TFA_BF

Table 1.46 Alias Names for the Breaker Failure Logic Output Relay Word Bits

Logic Name	Description	Alias
FBF08	Terminal TF B-phase breaker failure protection asserted	TFB_BF
FBF09	Terminal TF C-phase breaker failure protection asserted	TFC_BF

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Alias Assignment

Figure 1.81 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF09 are the inputs to the station breaker failure trip logic; Relay Word bits SBFTR01–SBFTR09 are the outputs from the station breaker failure trip logic. Relay Breaker failure trip bits SBFTR01–SBFTR09 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

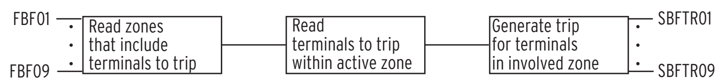


Figure 1.81 Station Breaker Failure Trip Logic

Table 1.47 shows the station breaker failure Relay Word bits and the alias names for the breaker failure protection outputs.

Table 1.47 Primitive Terminal and Station Breaker Failure Trip Relay Word Bit Names and the Alias Names for the Breaker Failure Trip Bits

Primitive Name	Description	Alias Names
SBFTR01	Terminal TD A-phase station breaker failure protection asserted	TDA_SBF
SBFTR02	Terminal TD B-phase station breaker failure protection asserted	TDB_SBF
SBFTR03	Terminal TD C-phase station breaker failure protection asserted	TDC_SBF
SBFTR04	Terminal TE A-phase station breaker failure protection asserted	TEA_SBF
SBFTR05	Terminal TE B-phase station breaker failure protection asserted	TEB_SBF
SBFTR06	Terminal TE C-phase station breaker failure protection asserted	TEC_SBF
SBFTR07	Terminal TF A-phase station breaker failure protection asserted	TFA_SBF
SBFTR08	Terminal TF B-phase station breaker failure protection asserted	TFB_SBF
SBFTR09	Terminal TF C-phase station breaker failure protection asserted	TFC_SBF

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection (see the *Control Output Settings on page A.1.115* for more information).

Differential Trip Logic and Differential Element Alias Assignment

Figure 1.82 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

Differential trip bits 87BTR01 through 87BTR09 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

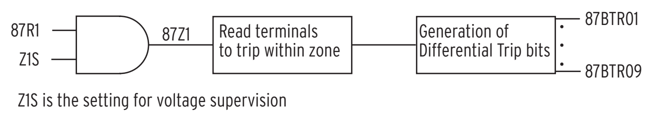


Figure 1.82 Differential Trip Logic for Differential Element 1

Table 1.48 shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 1.48 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	NORTA_T
87Z2	Zone 2 differential element trip	NORTB_T
87Z3	Zone 3 differential element trip	NORTC_T

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate. In our example, we want to trip three terminals. *Table 1.49* shows the primitive terminal names, the differential trip bit names, and the alias names for the differential trip bits.

Table 1.49 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits

Primitive Name	Description	Alias
87BTR01	Terminal TD A-phase differential protection trip asserted	TD_TA
87BTR02	Terminal TD B-phase differential protection trip asserted	TD_TB
87BTR03	Terminal TD C-phase differential protection trip asserted	TD_TC
87BTR04	Terminal TE A-phase differential protection trip asserted	TE_TA
87BTR05	Terminal TE B-phase differential protection trip asserted	TE_TB
87BTR06	Terminal TE C-phase differential protection trip asserted	TE_TC
87BTR07	Terminal TF A-phase differential protection trip asserted	TF_TA
87BTR08	Terminal TF B-phase differential protection trip asserted	TF_TB
87BTR09	Terminal TF C-phase differential protection trip asserted	TF_TC

Breaker Trip Logic and Trip Alias Assignment

Figure 1.83 shows the general tripping logic in the SEL-487B. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

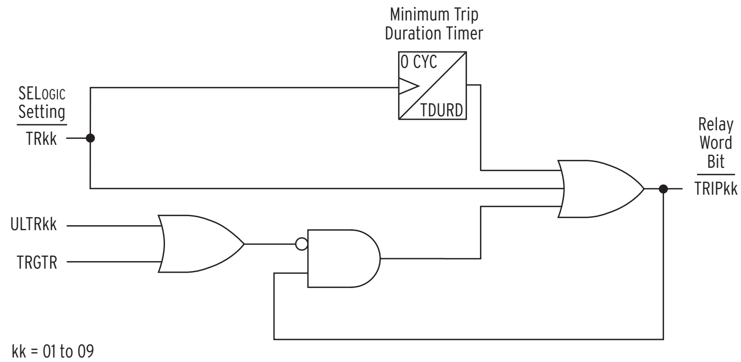


Figure 1.83 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK). Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals nine. After setting the TR*kk* trip equations, the relay associates each TR*kk* trip equation with a particular circuit breaker pole; we must combine the trip equations in the output settings to form a single output for the circuit breaker (see *Control Output Settings on page A.1.115* for more information). For example, after setting TR01:= 87BTR01 OR SBFTR01 and TR02:= 87BTR02 OR SBFTR02, the relay associates Trip Equation TR01 with Terminal 01 (TD_A), Trip Equation TR02 with Terminal 02 (TD_B), and so on. *Table 1.50* shows the primitive and alias names for the trip logic of each terminal.

Table 1.50 Primitive and Alias Names for the Trip Logic of Each Terminal

Primitive Name	Description	Alias Name
TRIP01	Terminal TD A-phase trip output asserted	TRTD_A
TRIP02	Terminal TD B-phase trip output asserted	TRTD_B
TRIP03	Terminal TD C-phase trip output asserted	TRTD_C
TRIP04	Terminal TE A-phase trip output asserted	TRTE_A
TRIP05	Terminal TE B-phase trip output asserted	TRTE_B
TRIP06	Terminal TE C-phase trip output asserted	TRTE_C
TRIP07	Terminal TF A-phase trip output asserted	TRTF_A
TRIP08	Terminal TF B-phase trip output asserted	TRTF_B
TRIP09	Terminal TF C-phase trip output asserted	TRTF_C

Assign Alias Names to the User-Defined Logic

This application requires no user-defined logic.

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 1.41* shows the breakdown of the relay outputs that we need for this application. We now assign specific relay output contacts to the relay functions and assign alias names to the relay output contacts. *Table 1.51* shows the main board assignments and alias names.

Output Alias Assignment, Main Board

This application requires no main board output contacts.

Table 1.51 Alias Assignment for the Trip Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.52* shows the assignments and alias names for Interface Board 1.

Table 1.52 Alias Assignments for the Output Contacts of Interface Board 1

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	Terminal TD trip output	TD_TRIP
OUT202[a]	Terminal TE trip output	TE_TRIP
OUT203[a]	Terminal TF trip output	TF_TRIP
OUT204[a]	Terminal TD direct transfer trip output	TD_DTT
OUT205[a]	Terminal TE direct transfer trip output	TE_DTT
OUT206[a]	Terminal TF direct transfer trip output	TF_DTT

[a] High-speed, high-interrupting outputs.

Station Layout Update

We are now ready to set and configure the relay. Write down all the relevant information onto the station diagram, as shown in *Figure 1.84*. *Figure 1.84* shows the updated station layout for both relays.

1. Write down the bus-zone, terminal, and disconnect names.
2. Allocate the terminals CTs to the relay input current channels.
3. Allocate the auxiliary contacts to the relay digital inputs.
4. Allocate the digital outputs from the relay to the station terminals.

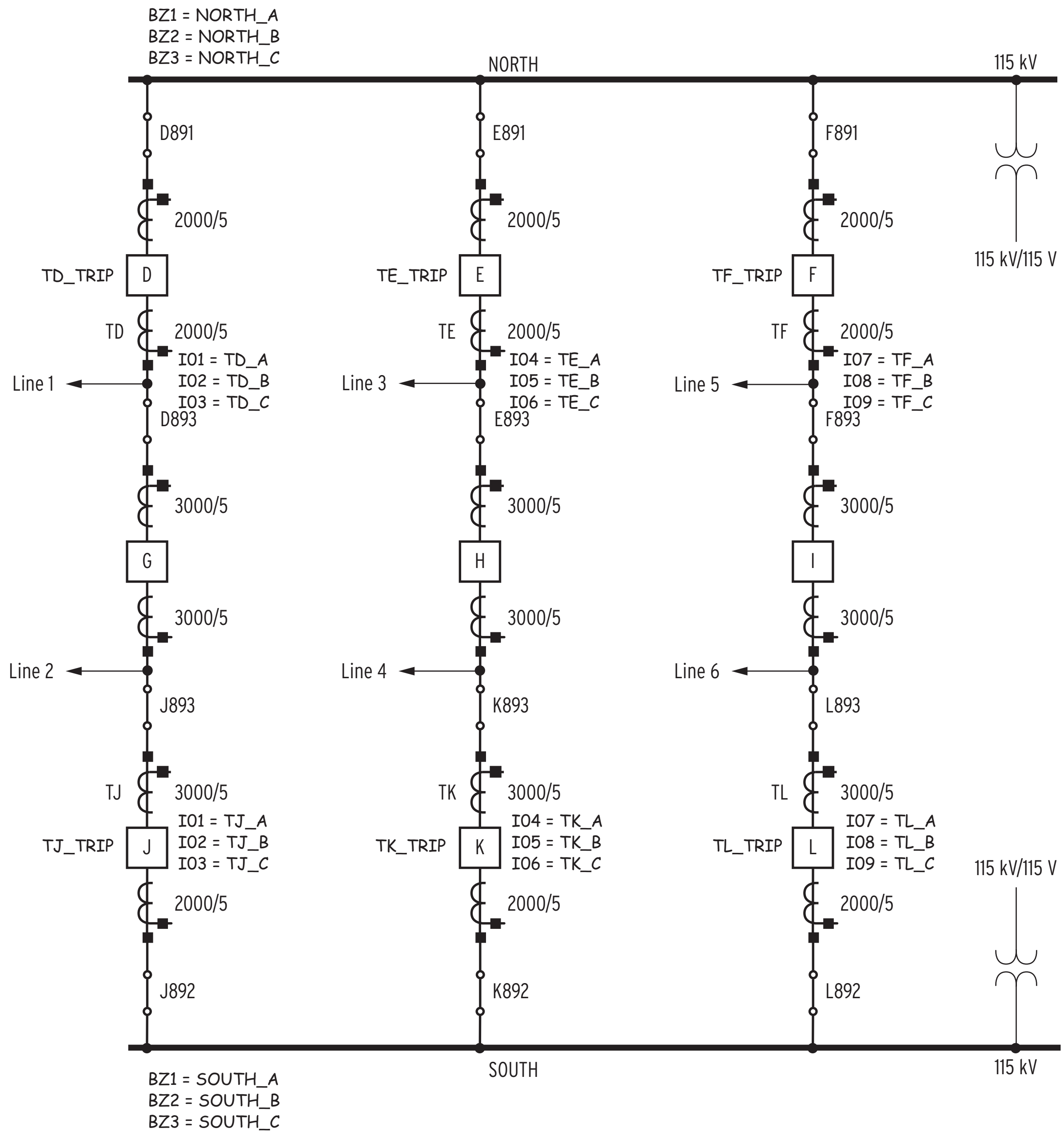


Figure 1.84 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Front Panel Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.85*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.85 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.86*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.86 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the analog channels and Relay Word bits, as shown in *Figure 1.87*.

We include the alias names for the three protection latch bits (PLT01, PLT02, and PLT03). We use these protection latch bits for local control of the differential elements (PLT01), the breaker fail protection (PLT02), and the relay test mode (PLT03). Because the protection logic default settings include these three protection latch bits as default settings, we did not select these protection latch bits as user-defined logic.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  IO1,TD_A <Enter>
20:
?  IO2,TD_B <Enter>
21:
?  IO3,TD_C <Enter>
22:
?  IO4,TE_A <Enter>
23:
?  IO5,TE_B <Enter>
24:
?  IO6,TE_C <Enter>
.
.
.
136:
?  PLT01,DIFF_EN <Enter>
137:
?  PLT02,BF_EN <Enter>
138:
?  PLT03,TNS_SW <Enter>
139:
?  END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.87 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.88* shows the setting changes we need for our example. Because we declared the alias names in the alias settings class, use either the alias names or the primitive names when entering settings.

Enter the number of poles at the station for the NUMBK settings. There are three terminals in the differential equation, each with three poles. The total number of poles, therefore, equals nine poles, and we set NUMBK to 9.

Setting NUMBK to 9 makes 9 corresponding circuit breaker auxiliary input equations (52A01 through 52A09) and nine corresponding trip equations (TR01 through TR09) available for setting. Because we do not need circuit breaker auxiliary inputs for this example, we need not enter values for the circuit breaker auxiliary input equations. For this example, the only Global setting change is the number of circuit breakers; all other settings remain at default settings.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                    NUMBK   := 5      ?9 <Enter>
Number of Disconnects (N,1-48)                 NUMDS   := N      ?END <Enter>
Global
.
.
.
52A08 := NA
52A09 := NA

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.88 Global Settings for Application 3

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. In this application, there are no disconnect auxiliary contacts available, and we permanently assign analog channels to the appropriate differential elements. All 18 channels are available for setting, but only the first 9 are part of the differential protection. We, therefore, assign only the first nine analog channels to the differential elements. The protection philosophy calls for the use of the voltage elements as an additional trip criterion.

Calculate the ratio settings as follows:

$$\begin{aligned} \text{PTR} &= \frac{\text{Primary Nominal Voltage}}{\text{Secondary Nominal Voltage}} \\ &= \frac{115000}{115} \\ &= 1000 \end{aligned}$$

Equation 1.10

Figure 1.89 shows the zone configuration settings.

Because there are no disconnects available at this station, we cannot use the dynamic zone selection logic. Because we cannot use the dynamic zone selection logic, the CTs are always considered in the differential equations.

When we consider only the disconnect auxiliary contacts as conditions in the terminal-to-bus-zone connection settings, we would have entered a 1 for each of the terminal-to-bus-zone connection settings.

This example, however, also includes two other conditions that must be a logical 1 before the relay considers the CTs in the differential equations. The two conditions are

- ➤ the differential enable switch (Alias DIFF_EN)
- ➤ and the terminal-out-of-service switch (TOS*nn*, where *nn* is the terminal number)

Front-panel pushbutton {PB1} controls DIFF_EN. The function of DIFF_EN is to remove all the terminals from the differential equations with a single command. Enter **DIFF_EN** at every terminal-to-bus-zone variable.

The terminal out-of-service switch, which removes individual terminals from the differential calculations, is part of the front panel local controls. Include an individual terminal out-of-service (TOS*nn*) for each terminal.

The zone configuration default settings are for a specific substation with arbitrarily selected alias names, serving only as an example. Delete the terminal-to-bus-zone default settings for ease of setting zone configuration settings for the new substation. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone settings. *Figure 1.89* shows the Zone configuration settings for this application. Instead of entering **1 AND DIFF_EN AND NOT TOS*nn***, we omit the 1, and enter only **DIFF_EN AND NOT TOS*nn*** for each setting.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000    ?1000 <Enter>
Potential Transformer Ratio -V02 (1-10000)          PTR2    := 2000    ?1000 <Enter>
Potential Transformer Ratio -V03 (1-10000)          PTR3    := 2000    ?1000 <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600     ?400 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600     ?400 <Enter>
.
.
.

Current Transformer Ratio -I09 (1-50000)            CTR09   := 600     ?400 <Enter>
Current Transformer Ratio -I10 (1-50000)            CTR10   := 600     ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TD_A, NORTH_A, P
?  DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,BZ1,P <Enter>
TD_A to NORTH_A Connection (SELogic Equation)
I01BZ1V := NA
?  PLT01 AND NOT TOS01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,BZ2,P <Enter>
TD_B to NORTH_B Connection (SELogic Equation)
I02BZ2V := NA
?  PLT01 AND NOT TOS01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,BZ3,P <Enter>
TD_C to NORTH_C Connection (SELogic Equation)
I03BZ3V := NA
?  PLT01 AND NOT TOS01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,BZ1,P <Enter>
TE_A to NORTH_A Connection (SELogic Equation)
I04BZ1V := NA
?  PLT01 AND NOT TOS02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,BZ2,P <Enter>
```

```
TE_B to NORTH_B Connection (SELogic Equation)
I05BZ2V := NA
?   PLT01 AND NOT TOS02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,BZ3,P <Enter>
TE_C to NORTH_C Connection (SELogic Equation)
I06BZ3V := NA
?   PLT01 AND NOT TOS02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I07,BZ1,P <Enter>
TF_A to NORTH_A Connection (SELogic Equation)
I07BZ1V := NA
?   PLT01 AND NOT TOS03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I08,BZ2,P <Enter>
TF_B to NORTH_B Connection (SELogic Equation)
I08BZ2V := NA
?   PLT01 AND NOT TOS03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I09,BZ3,P <Enter>
TF_C to NORTH_C Connection (SELogic Equation)
I09BZ3V := NA
?   PLT01 AND NOT TOS03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
? DELETE 100 <Enter>
Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?   59Q1 OR 59N1 OR 27P11 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?   59Q1 OR 59N1 OR 27P21 <Enter>
Zone 3 Supervision (SELogic Equation)
Z3S := 1
?   59Q1 OR 59N1 OR 27P31 <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.89 Zone Configuration Group Settings for Application 3

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, beginning with the function enable settings.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set ECSL := N because we do not use the Coupler Security Logic.

Terminal out of service is a local bit (local bits provide programming capabilities for functions available on the front-panel screen under LOCAL CONTROL). Include the terminal out of service in the trip equations to disable the outputs from individual terminals.

This local control selectively takes a terminal out of service, whereas the **{87(DIFF) ENABLED}** pushbutton disables all the trip outputs. Set ETOS := 3 because there are three breakers in the bus-zone differential protection.

There are nine breaker poles (NUMBK := 9), all of which need relay breaker failure protection. Set EBFL := 9 to enable nine breaker failure logics. Set E50 := N and E51 := N because we do not need overcurrent protection for this application.

The protection philosophy calls for undervoltage as an additional trip criterion. Because the voltage elements are enabled in the default settings, leave EVOLT := Y.

Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. Enable the advance settings by setting EADVS := Y to change the slope setting.

With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the sensitive differential element, the restrained differential element, and the directional element.

The protection philosophy calls for breaker failure protection. This application shows an example of how to calculate breaker failure settings for the Terminal TD circuit breaker. In this example, we apply the settings calculated for Terminal TD to all the terminals at the station. Because network parameters are different, be sure to calculate values for the other terminals; do not assume that settings for one terminal apply to all other terminals at the same station.

EBFL, Enable Breaker Fail Setting

Enter the number of per-pole breaker fail logics you want to enable.

In this single-relay application, we need nine per-pole breaker fail logics, because we must provide breaker failure protection for three breakers.

EBFL := **9** Enable breaker fail

Figure 1.90 shows the components of breaker failure protection for line protection. Do not consider remote terminal information when considering breaker failure protection for equipment such as capacitor banks, transformers, etc.

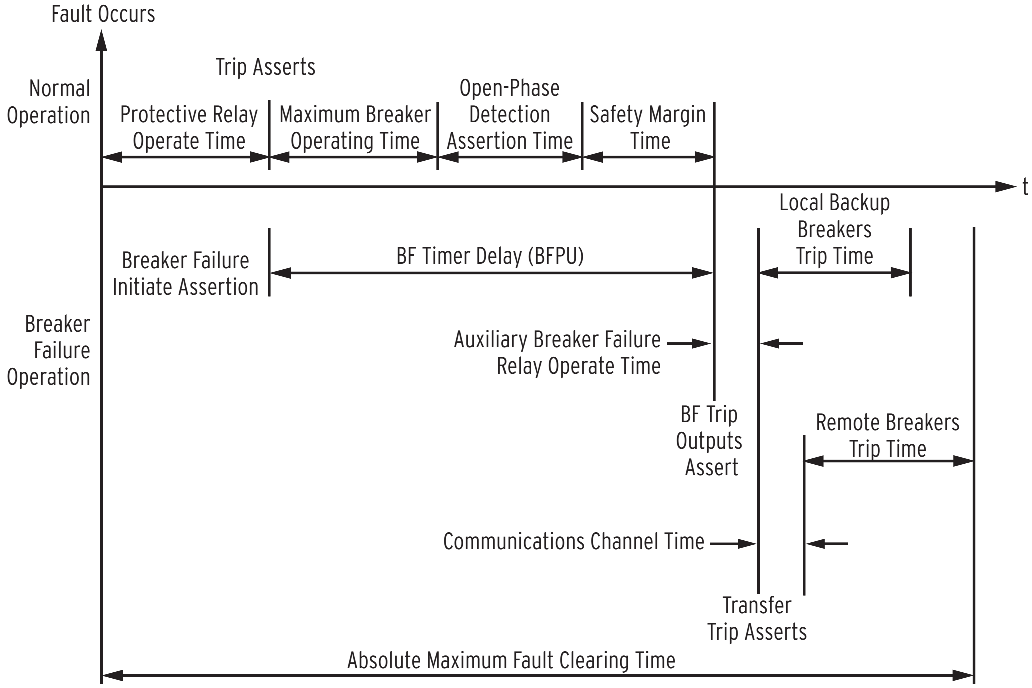


Figure 1.90 Breaker Failure Timing Diagram

Use the SEL-487B to provide circuit breaker failure protection for Circuit Breaker TD in *Figure 1.91*.

Figure 1.91 shows the power system for this example. Line 1 and Line 2 connect Station S and Station R. We set the breaker failure protection in the SEL-487B to detect circuit breaker failures for Terminal TD at Station S. This example uses a line with three-pole tripping, but the relay provides the flexibility to also apply circuit breaker failure for single-pole trip circuit breakers. This flexibility is possible because the current measurement and timers are available on a per-phase basis.

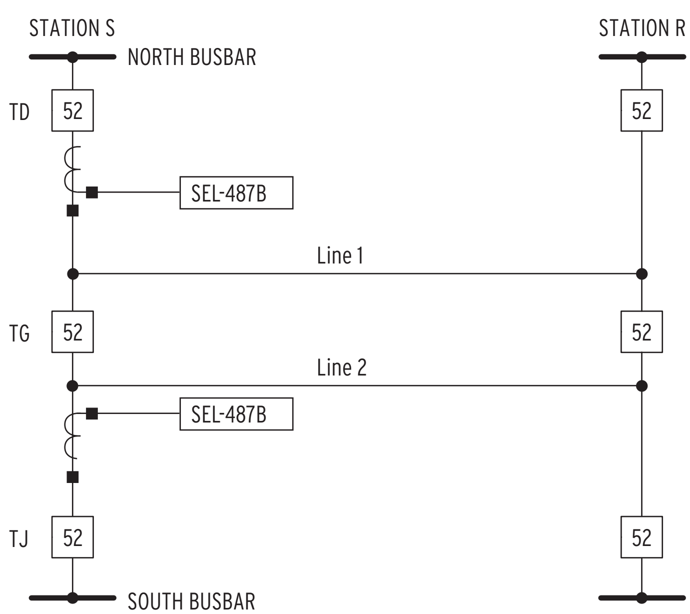


Figure 1.91 Power System for Circuit Breaker Failure Scheme 2

50FP01, Phase Current Level Detector Setting

NOTE: This is one method for calculating setting 50FP01. Use your company's practices and policies for determining the pickup setting for your particular application.

Set the current pickup (50FP01) greater than maximum load and less than the fault current that flows through Terminal TD. Assume that the total load current (I_S) is 3.25 A secondary, supplied from Substation S. Calculate setting 50FP01 with all the load current I_S through Terminal TD.

$$\begin{aligned} 50FP01 &= 120\%(\text{Percent Current} \bullet I_S) \\ &= 120\%(100\%\ \text{Current} \bullet 3.25\ \text{A}) \\ &= 3.91\ \text{A secondary} \end{aligned}$$

Equation 1.11

A fault study shows that the minimum ground fault current, $I_{fault\ minimum}$, is 4.2 A secondary when the parallel line is in service at minimum generation. Calculate the 50FP01 setting for dependability at half the minimum fault current.

$$\begin{aligned} 50FP01 &= 0.5(\text{Percent Current} \bullet I_{fault\ minimum}) \\ &= 0.5(100\%\ \text{Current} \bullet 4.20\text{A}) \\ &= 2.10\ \text{A secondary} \end{aligned}$$

Equation 1.12

Although the result of this setting calculation is less than maximum load, obtain greater dependability by using this calculation to set the 50FP01 element to 2.10 A.

BFPU01, Circuit Breaker Failure Time Delay Setting

BFPU01 (Breaker Failure Time Delay-Terminal TD) is the time for which the input (BFI01) to Timer BFPU01 must be continuously present to result in a circuit breaker failure trip operation. The recommended setting for BFPU1 is the sum of the following:

- ➤ Maximum circuit breaker operating time
- ➤ OPH01 maximum dropout time
- ➤ Safety margin

Figure 1.92 shows the timing diagram for setting Timer BFPU01.

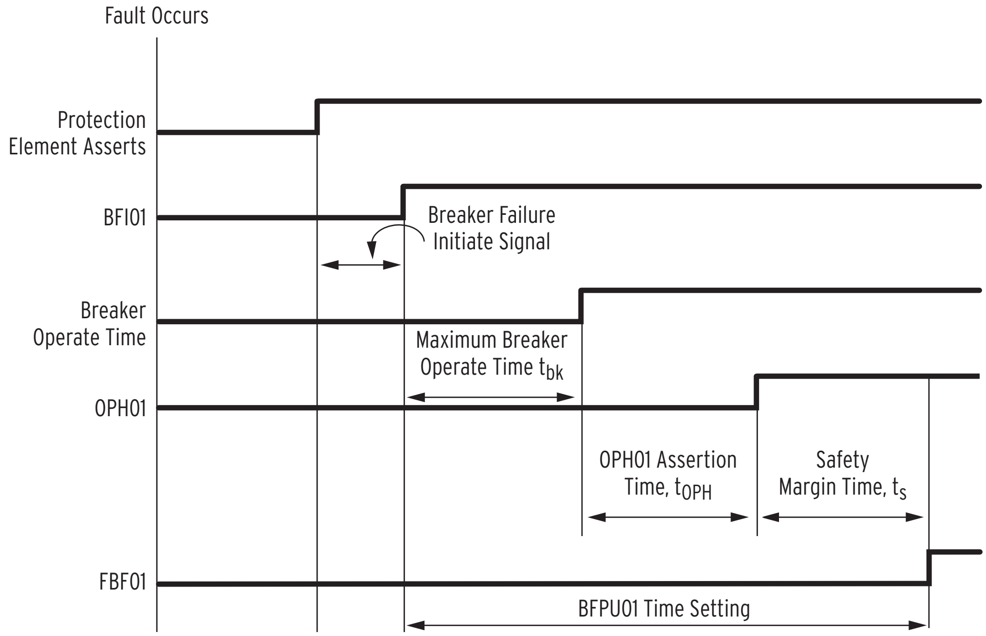


Figure 1.92 Timing Diagram for Setting BFPU01-Scheme 2

To maintain system stability, you must clear the fault within the total clearing time, assumed to be 17 cycles for this example. Use the maximum operating time of the local and remote circuit breakers. The maximum circuit breaker operating time, t_{bk}, is 3 cycles for this example.

Use 0.75 cycle for t_{OPH}, the maximum assertion time of the open-phase detector, OPH01. You must also include the communications channel time, t_{ch}, for remote circuit breaker tripping. To determine setting BFPU1, you must find the safety margin, t_s. Use *Equation 1.13* to calculate the safety margin:

$$\begin{aligned} t_s &= tt - (t_{1r} + t_{1bk} + t_{OPH} + t_{86} + t_{ch} + t_{rbk}) \\ &= 17 - (2 + 3 + 0.75 + 1 + 1 + 3) \\ &= 5.75 \text{ cycles} \end{aligned}$$ **Equation 1.13**

where:

t_s = safety margin
tt = total clearing time (17 cycles)
t_{1r} = line protection maximum operating time (2 cycles)
t_{1bk} = local circuit breaker maximum operating time (3 cycles)
t_{OPH} = open-phase detection OPH01 maximum assertion time (0.75 cycle)
t_{86} = auxiliary breaker failure relay operating time (1 cycle)
t_{ch} = communications channel maximum operating time (1 cycle)
t_{rbk} = remote circuit breaker maximum operating time (3 cycles)

Use the safety margin result from *Equation 1.13* to calculate BFPU01:

$$\begin{aligned} \text{BFPU01} &= t_{1bk} + t_{OPH} + t_s \\ &= 3 + 0.75 + 5.75 \\ &= 9.5 \text{ cycles} \end{aligned}$$ **Equation 1.14**

BFPU01 := **9.50** cycles Breaker Failure Time Delay

RTPU01, Retrip Time Delay Setting

If the circuit breaker is equipped with two trip coils, the relay should attempt to retrip the protected circuit breaker before a circuit breaker failure trip asserts. In this example, local circuit breaker maximum operating time is 3 cycles, and the open phase detection assertion is 0.75 cycle. Wait 4 cycles for the retrip.

RTPU01 := **4.00** Retrip Time Delay

BFI01 and ABFI01, Circuit Breaker Initiation Settings

Figure 1.93 shows the breaker failure initiate contact for Terminal TD. Wire similar contacts for Terminal TE and Terminal TF into the SEL-487B.

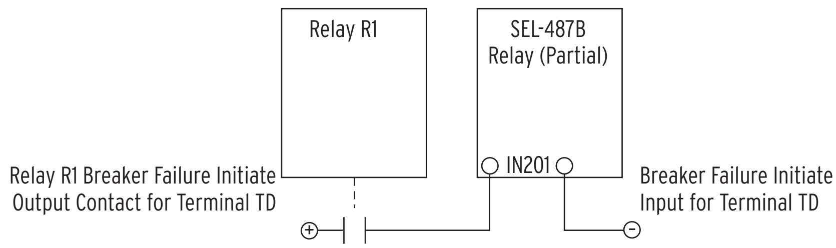


Figure 1.93 Breaker Failure Protection Wiring for Terminal TD

For this example, assume the breaker failure initiate signal is continuous. Because this is a breaker-and-a-half busbar layout, use the input extension option of *Alternate Breaker Failure Initiating Input With Extension and/or Seal In Logic on page R.1.38* (see *Circuit Breaker Failure Protection on page R.1.37* for more information).

Figure 1.94 shows the circuit breaker failure initiation extension and seal-in logic, and *Figure 1.95* shows the circuit breaker failure logic.

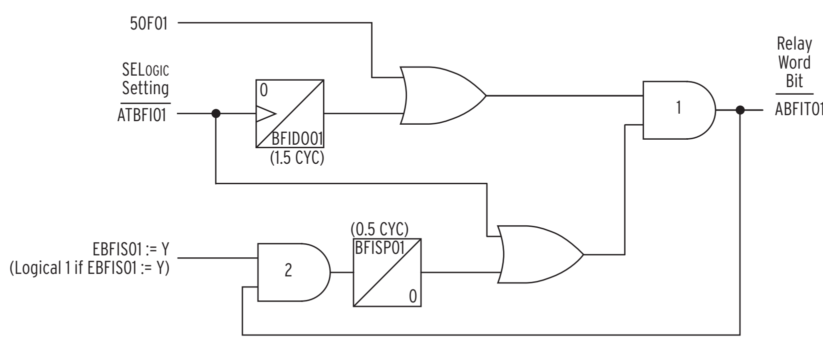


Figure 1.94 Circuit Breaker Failure Initiation Extension and Seal-In Logic

Scheme 2 uses a combination of the logic in *Figure 1.94* and *Figure 1.95* by setting the output from the circuit breaker failure initiation extension and seal-in logic (ABFIT01, *Figure 1.94*) as the breaker failure initiate input of the breaker failure logic (BFI01, *Figure 1.95*).

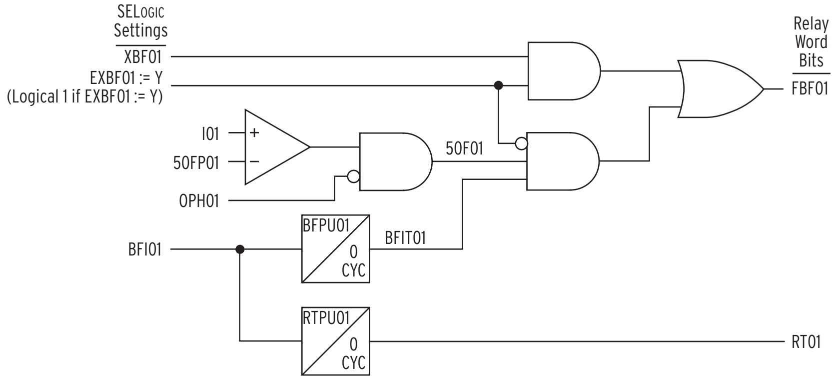


Figure 1.95 Circuit Breaker Failure Logic

Because this is an example of a three-pole circuit breaker, enter the same breaker failure initiate input (IN201) for all three phases (ATBFI01 through ATBFI03) for Terminal TD.

Table 1.53 shows the breaker failure initiate input (IN201) and the assignment and setting to combine the logic for Terminal TD, stating the alias names where applicable. Settings for the remaining terminals are similar.

Table 1.53 Input and Relay Word Bit Assignments and Settings for the Combined Logic

Assignment	Setting to Achieve the Assignment
IN201 to ATBFI01	TDA_BFI := ITD_BFI
IN201 to ATBFI02	TDB_BFI := ITD_BFI
IN201 to ATBFI03	TDC_BFI := ITD_BFI
ABFIT01 to BFI01	BFI01 := ABFIT01
ABFIT02 to BFI02	BFI02 := ABFIT02
ABFIT03 to BFI03	BFI03 := ABFIT03

BFIDO01, Circuit Breaker Failure Protection Initiation Dropout Delay Setting

Setting EBFIS01 applies to the case where the breaker failure initiate signal is not continuous. Because the breaker failure initiate signal is continuous in this example, leave EBFIS01 at the default value of N. Consider the case where the entire fault current initially flows through Terminal TG, and no current flows through Terminal TD. Timer BFIDO01 replaces the current input 50FI01 (*Figure 1.94*) for the period when the entire fault current flows through Circuit Breaker TG. During this period, not enough current is available to assert Relay Word bit 50FI01 to turn AND Gate 1 on (*Figure 1.94*). Timer BFIDO01 extends the breaker failure initiate signal, waiting for Terminal TD to interrupt the fault current. The maximum circuit breaker operating time for Terminal TG is 3 cycles; allow a short safety margin and set Timer BFIDO01 to 4 cycles.

BFID01 := **4.00** Breaker Failure Initiate Dropout Delay-BK1

59QP1 and 59NP1, Negative- and Zero-Sequence Overvoltage, Thresholds and Phase Undervoltage Settings

Conduct fault studies to obtain appropriate settings for the negative-sequence and zero-sequence overvoltage elements.

For this example, assume a setting of 15 V for both negative-sequence and zero-sequence overvoltage elements and 45 V for the undervoltage elements.

59Q1P := **15** Negative-sequence overvoltage element

59N1P := **15** Zero-sequence overvoltage element

27P11P := **45** undervoltage element

TR01–TR09, Trip Equations Settings

Pay close attention to the trip logic (TR01–TR09) settings. Because this is a single-relay application, CTs from the three phases (A-phase, B-phase, and C-phase) from each terminal are assigned to three different differential elements (see *Single-Relay Application on page A.1.3*). Setting NUMBK (Global settings) to 9 also makes 9 corresponding trip equations (TR01 through TR09) available for setting. All nine channels are part of the breaker failure protection, as well as part of the bus-zone protection. Therefore, we include the differential trip outputs as well as the station breaker fail trip outputs in the trip equation of each terminal. Setting the trip equations involves assigning the nine differential trip bits to the correct nine trip equations, and assigning the nine station breaker failure trip bits to the correct nine trip equations.

TDURD, Minimum Trip Duration Time Delay Setting

Although the SEL-487B includes nine trip logics, there is only one Minimum Trip Duration Time Delay setting. Set the timer TDURD longer than the operating time of the slowest circuit breaker at the station, using the default value of 12 cycles.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. Press the **{TARGET RESET}** pushbutton on the front panel to deassert the trip outputs. Alternatively, enter specific reset conditions at the ULTR*kk* settings.

The SEL-487B triggers an event report when any one of the following Relay Word bits asserts:

- 87BTR (any one of the nine differential trip bit)
- SBFTR (any one of the nine station breaker failure trip bit)
- TRIP (any one of the nine trip logic outputs)
- ER (user-defined functions)
- **TRIG** (ASCII command)

The protection philosophy calls for the relay to generate an event report when the negative-sequence and zero-sequence overvoltage elements assert. To achieve this, enter Relay Word bit 59Q1 and 59N1 at the ER prompt.

ER := **59Q1 OR 59N1 OR 87S1 OR 87S2 OR 87S3**

Protection Latch bit PLT02 enables/disables the breaker failure protection in the default settings. Include PLT02 in each breaker failure initiate setting for the **{BKR FAIL ENABLE}** pushbutton to control the breaker failure protection. *Figure 1.96* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y        ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N        ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5        ?3 <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6        ?9 <Enter>

Definite Time Overcurrent Elements (N,1-18)          E50     := N        ?> <Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10     ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00     ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05     ?> <Enter>

Terminal Out-of-Service

Terminal 01 Out-of-Service (SELogic Equation)
TOS01 := LB01
?  > <Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N        ?<Enter>
Fault Current Pickup -BK01 (0.50-50 amps,sec)        50FP01  := 3.00     ?2.1 <Enter>
Brkr Fail Init Pickup Delay -BK01 (0.00-6000 cyc)    BFPU01  := 6.00     ?9.5 <Enter>
Retrip Delay -BK01 (0.00-6000 cyc)                   RTPU01  := 3.00     ?4 <Enter>
Breaker Fail Initiate -BK01 (SELogic Equation)
BFI01 := IN101 AND BF_EN
?  ABFIT01 <Enter>
Alt Breaker Fail Initiate -BK01 (SELogic Equation)
ATBFI01 := NA
?  IN201 AND PLT02 <Enter>
Breaker Fail Initiate Seal-In -BK01 (Y,N)            EBFIS01 := N        ?<Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFIDO01 := 1.50     ?4 <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N        ?<Enter>
Fault Current Pickup -BK02 (0.50-50 amps,sec)        50FP02  := 3.00     ?2.1 <Enter>
Brkr Fail Init Pickup Delay -BK02 (0.00-6000 cyc)    BFPU02  := 6.00     ?9.5 <Enter>
Retrip Delay -BK02 (0.00-6000 cyc)                   RTPU02  := 3.00     ?4 <Enter>
Breaker Fail Initiate -BK02 (SELogic Equation)
BFI02 := IN102 AND BF_EN
?  ABFIT02 <Enter>
Alt Breaker Fail Initiate -BK02 (SELogic Equation)
ATBFI02 := NA
?  IN201 AND PLT02 <Enter>
Breaker Fail Initiate Seal-In -BK02 (Y,N)            EBFIS02 := N        ?<Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFIDO02 := 1.50     ?4 <Enter>
.
.
.
Phase Inst Under/Over Voltage Elements

Voltage 1 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P11P  := OFF      ?45 <Enter>
Voltage 1 Level 2 U/V Pickup (OFF, 1.0-200 volts)    27P12P  := OFF      ?
Voltage 1 Level 1 O/V Pickup (OFF, 1.0-200 volts)    59P11P  := OFF      ?
Voltage 1 Level 2 O/V Pickup (OFF, 1.0-200 volts)    59P12P  := OFF      ?
Voltage 2 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P21P  := OFF      ?45 <Enter>
Voltage 2 Level 2 U/V Pickup (OFF, 1.0-200 volts)    27P22P  := OFF      ?
Voltage 2 Level 1 O/V Pickup (OFF, 1.0-200 volts)    59P21P  := OFF      ?
Voltage 2 Level 2 O/V Pickup (OFF, 1.0-200 volts)    59P22P  := OFF      ?
Voltage 3 Level 1 U/V Pickup (OFF, 1.0-200 volts)    27P31P  := OFF      ?45 <Enter>
Voltage 3 Level 2 U/V Pickup (OFF, 1.0-200 volts)    27P32P  := OFF      ?
Voltage 3 Level 1 O/V Pickup (OFF, 1.0-200 volts)    59P31P  := OFF      ?
Voltage 3 Level 2 O/V Pickup (OFF, 1.0-200 volts)    59P32P  := OFF      ?

Sequence Over Voltage Elements

Neg.-Seq. Level 1 O/V Pickup (OFF, 1.0-200 volts)    59Q1P   := 20.0     ?15 <Enter>
Neg.-Seq. Level 2 O/V Pickup (OFF, 1.0-200 volts)    59Q2P   := 40.0     ?OFF <Enter>
Zero-Seq. Level 1 O/V Pickup (OFF, 1.0-200 volts)    59N1P   := 20.0     ?15 <Enter>
Zero-Seq. Level 2 O/V Pickup (OFF, 1.0-200 volts)    59N2P   := 40.0     ?OFF <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := TDA_SBF OR TD_TA
?<Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
```

```
Trip 02 (SELogic Equation)
TR02 := TDB_SBF OR TD_TB
?<Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := TDC_SBF OR TD_TC
?<Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := TEA_SBF OR TE_TA
?<Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
Trip 05 (SELogic Equation)
TR05 := TEB_SBF OR TE_TB OR TEC_SBF OR TE_TC
?  TEB_SBF OR TE_TB <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Trip 06 (SELogic Equation)
TR06 := NA
?  TEC_SBF OR TE_TC
Unlatch Trip 06 (SELogic Equation)
ULTR06 := NA
?<Enter>
.
.
.
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000  ? <Enter>
Event Report Trigger Equation (SELogic Equation)
ER := R_TRIG 87ST
?  59Q1 OR 59N1 OR 87S1 OR 87S2 OR 87S3 <Enter>
Group 1
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.96 Protection Group Settings for Application 3

This concludes the protection group settings. The next settings class is the front-panel settings.

Front-Panel Settings

The front-panel settings class is where we set functions visible and accessible from the front panel. Settings include LEDs, pushbuttons, front-panel screen selection, display point, and local control. All of these functions have default settings, except five pushbuttons and the display points.

Because not all functions are required in this application, change the settings according to the protection philosophy. Remove the following LED settings:

- ➤ ZONE 4 trip indication (LED 6)
- ➤ ZONE 5 trip indication (LED 7)
- ➤ ZONE 6 trip indication (LED 8)
- ➤ 50 indication (LED 9)
- ➤ 51 indication (LED 10)
- ➤ 89 IN PROG (LED 14)
- ➤ 89 ALARM (LED 15)

Also, change the number of Local bits for the TOS (Terminal Out of Service) function to the correct number, 3. *Figure 1.97* shows the settings.

```
=>>SET F <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF, 1-60 mins)       FP_TO   := 15      ?<Enter>
Pushbutton LED 1 (SELogic Equation)
PB1_LED := DIFF_EN # Differential Protection Enabled
?<Enter>
Pushbutton LED 2 (SELogic Equation)
PB2_LED := BF_EN # Breaker Failure Enabled
?<Enter>
Pushbutton LED 3 (SELogic Equation)
PB3_LED := NA
?<Enter>
Pushbutton LED 4 (SELogic Equation)
PB4_LED := TNS_SW # Test normal Switch Enabled
?<Enter>
Pushbutton LED 5 (SELogic Equation)
PB5_LED := NA
?<Enter>
Pushbutton LED 6 (SELogic Equation)
PB6_LED := NA
?<Enter>
Pushbutton LED 7 (SELogic Equation)
PB7_LED := NA
?<Enter>
Pushbutton LED 8 (SELogic Equation)
PB8_LED := NA
?<Enter>
Target LED 1 (SELogic Equation)
T1_LED := 87BTR
?<Enter>
Target LED 1 Latch (Y,N)                            T1LEDL  := Y       ?<Enter>
Target LED 2 (SELogic Equation)
T2_LED := SBFTR
?<Enter>
Target LED 2 Latch (Y,N)                            T2LEDL  := Y       ?<Enter>
Target LED 3 (SELogic Equation)
T3_LED := NORTA_T
?<Enter>
Target LED 3 Latch (Y,N)                            T3LEDL  := Y       ?<Enter>
Target LED 4 (SELogic Equation)
T4_LED := NORTB_T
?<Enter>
Target LED 4 Latch (Y,N)                            T4LEDL  := Y       ?<Enter>
Target LED 5 (SELogic Equation)
T5_LED := NORTC_T
?<Enter>
Target LED 5 Latch (Y,N)                            T5LEDL  := Y       ?<Enter>
Target LED 6 (SELogic Equation)
T6_LED := 87Z4
?  NA <Enter>
Target LED 6 Latch (Y,N)                            T6LEDL  := Y       ?N <Enter>
Target LED 7 (SELogic Equation)
T7_LED := 87Z5
?  NA <Enter>
Target LED 7 Latch (Y,N)                            T7LEDL  := Y       ?N <Enter>
Target LED 8 (SELogic Equation)
T8_LED := 87Z6
?  NA <Enter>
Target LED 8 Latch (Y,N)                            T8LEDL  := Y       ?N <Enter>
Target LED 9 (SELogic Equation)
T9_LED  := 50P01T OR 50P02T OR 50P03T OR 50P04T OR 50P05T OR 50P06T OR \
           50P07T OR 50P08T OR 50P09T OR 50P10T OR 50P11T OR 50P12T OR \
           50P13T OR 50P14T OR 50P15T OR 50P16T OR 50P17T OR 50P18T
?  NA <Enter>
Target LED 9 Latch (Y,N)                            T9LEDL  := Y       ?N <Enter>
Target LED 10 (SELogic Equation)
T10_LED := 51P01T OR 51P02T OR 51P03T OR 51P04T OR 51P05T OR 51P06T OR \
           51P07T OR 51P08T OR 51P09T OR 51P10T OR 51P11T OR 51P12T OR \
           51P13T OR 51P14T OR 51P15T OR 51P16T OR 51P17T OR 51P18T
?  NA <Enter>
Target LED 10 Latch (Y,N)                           T10LEDL := Y       ?N <Enter>
Target LED 11 (SELogic Equation)
T11_LED := 87ST
?<Enter>
Target LED 11 Latch (Y,N)                           T11LEDL := N       ?<Enter>
Target LED 12 (SELogic Equation)
T12_LED := NOT (Z1S AND Z2S AND Z3S AND Z4S AND Z5S AND Z6S)
?  NOT (Z1S AND Z2S AND Z3S) <Enter>
Target LED 12 Latch (Y,N)                           T12LEDL := Y       ?<Enter>
```

```
Target LED 13 (SELogic Equation)
T13_LED := TOS01 OR TOS02 OR TOS03 OR TOS04 OR TOS05 OR TOS06 OR \
           TOS07 OR TOS08 OR TOS09 OR TOS10 OR TOS11 OR TOS12 OR \
           TOS13 OR TOS14 OR TOS15 OR TOS16 OR TOS17 OR TOS18
?   TOS01 OR TOS02 OR TOS03 <Enter>
Target LED 13 Latch (Y,N)                          T13LEDL := N      ?<Enter>
Target LED 14 (SELogic Equation)
T14_LED := 89OIP
?   NA <Enter>
Target LED 14 Latch (Y,N)                          T14LEDL := N      ?<Enter>
Target LED 15 (SELogic Equation)
T15_LED := 89AL
?   NA <Enter>
Target LED 15 Latch (Y,N)                          T15LEDL := N      ?<Enter>
Target LED 16 (SELogic Equation)
T16_LED := PCT01Q
?<Enter>
Target LED 16 Latch (Y,N)                          T16LEDL := Y      ?<Enter>

Selectable Screens for the Front Panel

Station Battery Screen (Y,N)                       STA_BAT := N      ?<Enter>
Fundamental Voltage and Current Screen (Y,N)       FUND_VI := Y      ?<Enter>
Differential Metering (Y,N)                        DIFF    := Y      ?<Enter>
Terminals Associated with Zones (Y,N)              ZONECFG := Y      ?<Enter>

Display Points
(Relay Word Bit, Display Name, Display Set State, Display Clear State)

1:
? <Enter>

Local Control
(Local Bit, Local Name, Local Set State, Local Clear State, Pulse Enable)

1: LB01,"TB1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?   LB01,"Terminal TD","OUT OF SERVICE","IN SERVICE",N <Enter>
2: LB02,"F1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?   LB02,"Terminal TE","OUT OF SERVICE","IN SERVICE",N <Enter>
3: LB03,"F2 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?   LB03,"Terminal TF","OUT OF SERVICE","IN SERVICE",N <Enter>
4: LB04,"T1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?   DELETE <Enter>
4: LB05,"F3 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?   DELETE <Enter>
4:
?   END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.97 Front-Panel Settings for Application 3

This concludes the front-panel settings. The next settings class is the control output settings.

Control Output Settings

In this setting class, we assign the logic or Relay Word bits in the relay to output contacts. We need six output contacts for our example:

- three for the differential and breaker failure trip outputs
- three for direct transfer trip outputs

Although not specifically called for in the protection philosophy, it is good practice to also include the TEST and ALARM outputs in the relay settings.

Because the relay interprets the NUMBK setting as the number of poles, there are nine trip equations for this application. There is, of course, only one circuit breaker for each terminal. We therefore combine the appropriate trip outputs from the breaker trip logic (TRIP01–TRIP09, see *Figure 1.83*) to provide a single trip output for each circuit breaker. For example, we set (Group settings) the trip equations for Terminal TD to TR01 := TDA_SBF OR

TD_TA, TR02 := TDB_SBF OR TD_TB TR03 := TDC_SBF OR TD_TC, with the corresponding breaker trip logic output alias names of TRTD_A, TRTD_B, and TRTD_C. Because Terminal TD has only one circuit breaker, assertion of any one of the three breaker trip logic outputs (TRTD_A, TRTD_B, or TRTD_C) must trip the circuit breaker of Terminal TD. To achieve this combination, enter all three of the breaker trip logic output Relay Word bits in the output equation of the circuit breaker of Terminal TD. We assign the output Relay Word bits of the breaker failure logic to output contacts OUT204, OUT205, and OUT206 for direct transfer tripping.

Figure 1.98 shows the output settings. We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the {RELAY TEST MODE} pushbutton disables all output contacts.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRTD_A AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRTD_B AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRTD_C AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRTE_A AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRTE_B AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   (TRTD_A OR TRTD_B OR TRTD_C) AND NOT PLT03 <Enter>

OUT202 := NA
?   (TRTE_A OR TRTE_B OR TRTE_C) AND NOT PLT03 <Enter>

OUT203 := NA
?   (TRTF_A OR TRTF_B OR TRTF_C) AND NOT PLT03 <Enter>

OUT204 := NA
?   (TDA_SBF OR TDB_SBF OR TDC_SBF) AND NOT PLT03 <Enter>

OUT205 := NA
?   (TEA_SBF OR TEB_SBF OR TEC_SBF) AND NOT PLT03 <Enter>

OUT206 := NA
?   TFA_SBF OR TFB_SBF OR TFC_SBF AND NOT PLT03 <Enter>

OUT207 := NA
?   END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.98 Output Settings for Application 3

This concludes the settings for Application 3.

Application 4: Single Bus and Transfer Bus With Buscoupler

This application describes the busbar arrangement shown in *Figure 1.99*, single bus and transfer bus with tie breaker (buscoupler). The busbar arrangement consists of two busbars (main busbar and transfer busbar), four feeders and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

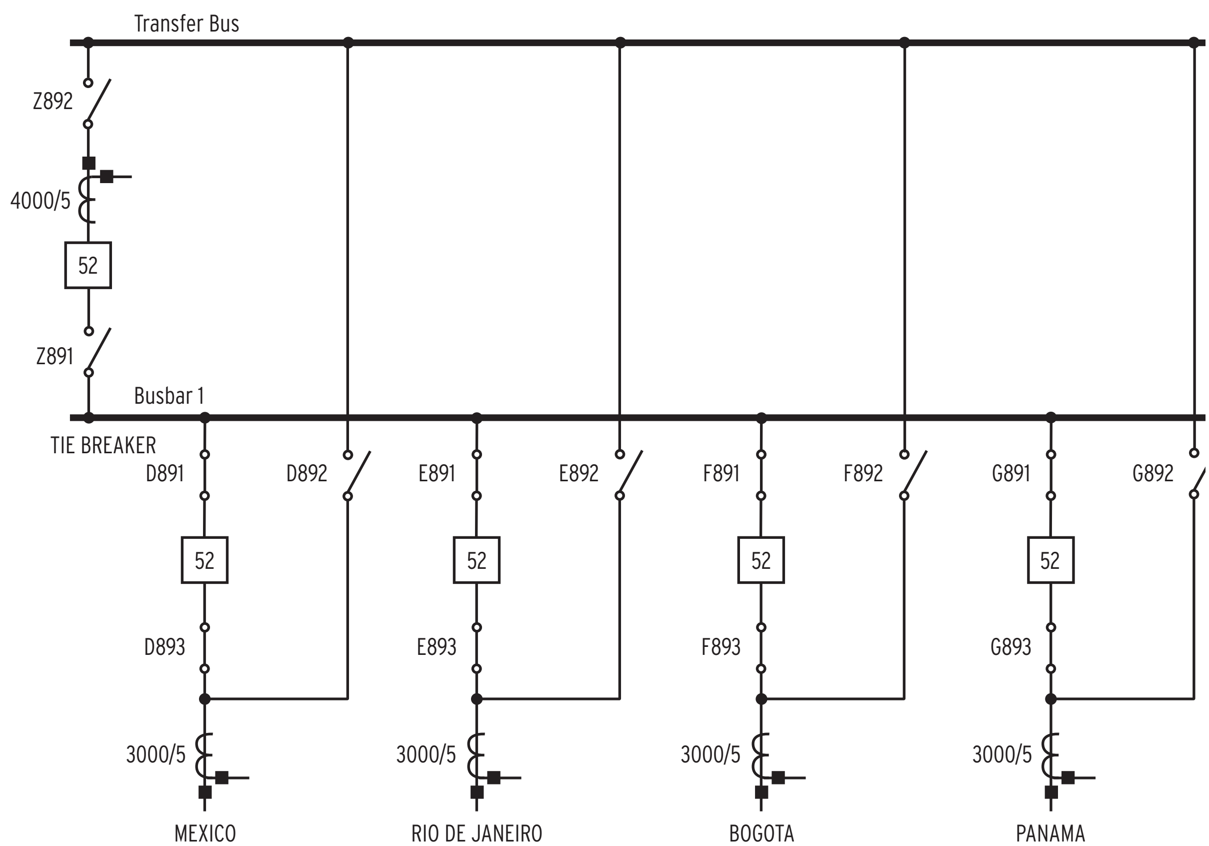


Figure 1.99 Single Bus and Transfer Bus With Buscoupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (buscoupler) configuration.

- Description:
  - Single bus and transfer bus with tie breaker
- Current transformers:
  - Outboard (free standing)
- Disconnects:
  - Only 89A disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Single CT with one CT core for busbar protection
- Future expansion:
  - Five feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every substation uses all of these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the 89B disconnect auxiliary contacts to dynamically configure the station.
4. Use the zone-switching supervision logic.
5. Prevent the loss of Busbar 1 for a fault between the tie breaker and tie-breaker CT.
6. Ensure bus-zone protection stability for all operating conditions.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for the use of the zone-switching supervision, but not for breaker failure protection. The SEL-487B offers a number of protection functions as standard features, but it also includes the capability through SELOGIC control equations to create user-configurable functions.

To prevent tripping of Busbar 1 when there is a fault between the tie breaker and tie-breaker CT, we can delay tripping of Busbar 1 and trip the tie breaker first (see *Protection Group Settings on page A.1.133*). We then remove the tie-breaker currents from the differential calculations. To remove the tie-breaker currents from the differential calculations, we use the breaker auxiliary contact from the tie breaker and a combination of the coupler security logic and zone supervision.

To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- ➤ standard protection functions (available in the relay)
- ➤ user-defined protection functions (created with SELOGIC control equations)

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 1.54* shows the selection of the standard functions.

Table 1.54 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	No	We need both 89A and 89B disconnect; only the 89A contact is available.
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Use the zone supervision logic as part of preventing the loss of Busbar 1 for a fault between the tie breaker and the tie-breaker CT.
Zone-switching supervision logic	Yes	Use this logic when only one (either 89A or 89B) disconnect contact is available.
Coupler security logic	Yes	Use the coupler security logic in a single CT application for enhanced protection for faults between the tie-breaker CT and circuit breaker.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

This application requires no user-defined functions.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ and the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with as many as 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.15* to calculate the number of current channels at the station, and use *Equation 1.16* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.15**

# of bus-zones required = # of per-phase station bus sections **Equation 1.16**

The number of per-phase CTs at the station is 15 (the tie breaker has three CT cores), and one SEL-487B suffices. However, the requirement for 5 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, identified with an appended letter A (MEXCO_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MEXCO_A setting is MEXCO_B in the B-phase relay, and MEXCO_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The protection philosophy calls for disconnect auxiliary contacts to dynamically configure the station. Because each terminal provides only one disconnect auxiliary contact, we cannot use the disconnect monitoring logic. Each feeder has two busbar disconnects (891 and 892), and the tie breaker also has two disconnects (891 and 892). Each feeder therefore requires 2 inputs, and the tie breaker requires 2 inputs, for a total number of 10 disconnect logics.

The protection philosophy also calls for zone-switching supervision logic, and we will use the coupler security logic to prevent tripping of Busbar 1 when there is a fault between the tie breaker and tie-breaker CT. For the zone-switching supervision logic, connect the close and open signals from each disconnect in parallel, and wire the parallel combination as a single input into the relay (see *Zone Configuration Group Settings on page A.1.128*).

The coupler security logic requires three inputs:

- a close signal
- a circuit breaker 52A auxiliary contact
- an input for the accelerated tripping function (see *Figure 1.108* for more information)

We need one input for the circuit breaker 52A auxiliary contact and one input for the closing signal. For the accelerated tripping input (ACTRP1), we use the output from the BZ1 differential element (87R1). *Table 1.55* summarizes the input contacts necessary for this application.

Table 1.55 Number of Required Relay Inputs

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	(4 • 2) + 2 = 10
Number of relay inputs required for disconnect open/close signal	1
Number of relay inputs required for the coupler security logic on the tie breaker	2 (one closing signal and one circuit breaker auxiliary contact)
Total number of inputs	13

The relay main board has seven inputs, insufficient inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs; the six independent inputs are available for breaker failure initiate inputs. Because this application has no circuit breaker failure protection, and the circuit breaker closing signals are best suited for independent inputs, use the independent inputs on the interface board for the circuit breaker closing signal. From the input perspective, we need one interface board. It is not necessary to include I/O for future expansion with the initial order; install additional I/O if and when required.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.56* shows the breakdown and the total number of relay output contacts required for tripping.

Table 1.56 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping the circuit breakers	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays necessary for the application
- the number of inputs
- the number of output contacts
- the selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation, and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.57* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.57* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.99*.

Table 1.57 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT, A-phase	I01	TIE_A
MEXICO terminal, A-phase	I02	MEXCO_A
RIO DE JANEIRO terminal, A-phase	I03	RIODJ_A
BOGOTA terminal, A-phase	I04	BOGOT_A
PANAMA terminal, A-phase	I05	PANAM_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.58*.

Table 1.58 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	BUS_A
BZ2	Bus-Zone 2	TRANS_A

Input-to-Logic Allocation

Table 1.55 shows that we require 13 digital inputs. We now assign the 13 digital input contacts to the selected logic. There are 18 grouped and 6 independent input contacts on the interface board. We assign the 10 disconnect inputs to the grouped terminals and the remaining 3 inputs to the independent relay inputs on the interface board.

Input Contact to Logic Allocation, Main Board

This application requires no main board inputs.

Input Contact-to-Logic Allocation, Interface Board 1 (200)

Table 1.59 shows the disconnect and circuit breaker auxiliary contact input allocations. Because inputs IN201–IN203 and IN213–IN215 are independent inputs, assign the inputs for the coupler security logic and the open/closing signals to these relay inputs.

Table 1.59 Relay Input-to-Relay Logic Assignment (Sheet 1 of 2)

Input	Description
IN201	TIE-BREAKER circuit breaker 52A auxiliary contact
IN202	TIE-BREAKER circuit breaker closing signal
IN203	Disconnect open/closing signal
IN204	TIE-BREAKER disconnect (BUS_A) NO contact
IN205	TIE-BREAKER disconnect (TRANS_A) NO contact
IN206	MEXICO terminal disconnect (BUS_A) NO contact
IN207	MEXICO terminal disconnect (TRANS_A) NO contact
IN208	RIO DE JANEIRO terminal disconnect (BUS_A) NO contact
IN209	RIO DE JANEIRO terminal disconnect (TRANS_A) NO contact
IN210	BOGOTA terminal disconnect (BUS_A) NO contact

Table 1.59 Relay Input-to-Relay Logic Assignment (Sheet 2 of 2)

Input	Description
IN211	BOGOTA terminal disconnect (TRANS_A) NO contact
IN212	PANAMA terminal disconnect (BUS_A) NO contact
IN216	PANAMA terminal disconnect (TRANS_A) NO contact

Identification of the Selected Standard Logic

The following explains each selected function in reference to *Table 1.54*. Alias name assignments are also included.

Differential Trip Logic Identification

Figure 1.100 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.60* shows the Relay Word bits and description for the zone differential protection outputs.

Table 1.60 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR05 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

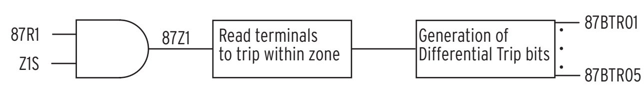


Figure 1.100 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.128* for more information). *Table 1.61* shows the differential trip bit and the associated terminals.

Table 1.61 Differential Trip Bit and Associated Terminals

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05

Relay Logic-to-Output Contact Allocation

Table 1.56 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.62* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.63* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Contact Allocation, Main Board

This application requires only the TEST and ALARM output contacts from the main board.

Table 1.62 Alias Names and Contact Allocation of the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Contact Allocation, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.63* shows the assignment for the five terminals of the A-phase relay.

Table 1.63 Allocation of the Interface Board Output Contacts

Output Contact Assignment	Description
OUT201[a]	Tie-breaker trip logic output
OUT202[a]	MEXICO trip logic output
OUT203[a]	RIO DE JANERO trip logic output
OUT204[a]	BOGOTA trip logic output
OUT205[a]	PANAMA trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.101*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the terminal digital inputs to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

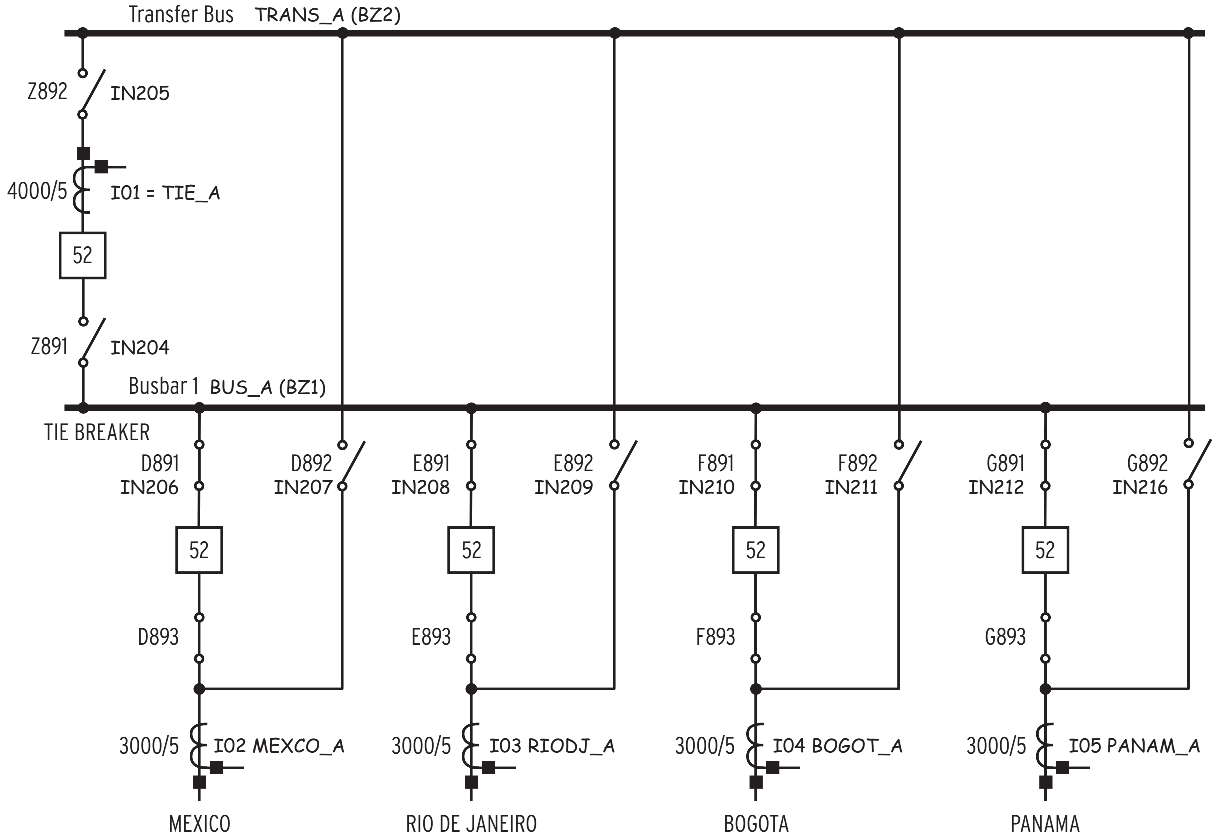


Figure 1.101 Substation Layout With Specific Information

Setting the Relay

The following describes the settings for this application. For this application example, we set the following setting classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings
- ➤ Protection Group Settings
- ➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay.

Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.102*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?   LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.102 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.103*.

```
1: I01,"FDR_1"
?   DELETE 43 <Enter>
```

Figure 1.103 Deletion of the First 43 Alias Names

Type > <Enter> to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.104*.

```
1: OUT107,"TEST"
?   > <Enter>
19:
?   I01,TIE_A <Enter>
20:
?   I02,MEXCO_A <Enter>
21:
?   I03,RIODJ_A <Enter>
22:
?   I04,BOGOT_A <Enter>
23:
?   I05,PANAM_A <Enter>
24:
?   BZ1,BUS_A <Enter>
25:
?   BZ2,TRANS_A <Enter>
26:
?   PLT01,DIFF_EN <Enter>
27:
? PLT03,TNS_SW <Enter>
28:
? END <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.104 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.105* shows the setting changes we need for our example.

Because there are five circuit breakers at the station, set NUMBK to 5. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01 through 52A05), and five corresponding trip equations (TR01 through TR05) available for setting.

Declare here the input contact for the tie-breaker auxiliary contact (52A01 := IN201). Set the remaining four circuit breaker auxiliary input equations (52A02–52A05) to NA.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                         NUMBK   := 5      ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                    EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                     GINPU   := 0.17   ?> <Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
? IN201 <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
? <Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.105 Global Settings for Application 4

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contact status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the Mexico feeder, all three phases (MEXCO_A, MEXCO_B, and MEXCO_C) operate together. Because the relay measures the three phases in three separate relays (phase MEXCO_A in the A-phase relay, phase MEXCO_B in B-phase relay, etc.), we must convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect that connects the terminal to the transfer busbar (disconnect G892 on the Panama Feeder)

Although the relay is flexible enough to accept settings for many disconnect combinations, we will configure the relay according to the following operating conditions:

- Only one feeder will be on transfer at any given time, i.e., the tie-breaker disconnects and the feeder transfer disconnect (*n*892, *n* = D, E, F, G) of only one of the four feeders can be closed simultaneously.
- Only Busbar 1 can be the source busbar.
- The operating sequence to put a feeder on transfer is fixed.

Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone settings for each step.

Table 1.64 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Refer to *Figure 1.101* and consider a case in which we put the PANAMA Feeder on transfer.

Assume the tie breaker is open and both tie-breaker disconnects are open.

Table 1.64 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Close tie-breaker disconnects Z892 and Z891. Close the tie-breaker circuit breaker.	Feeder Disconnects D891, E891, F891, and G891 as well as D893, E893, F893, and G893 are now closed. Feeder Disconnects D892, E892, F892, and G892 are open. Closing the tie breaker brings both busbars to the same potential.
2	Close the Panama G892 disconnect.	Closing Disconnect G892 forms a bus-zone-to-bus-zone connection, resulting in a parallel path between the tie breaker and the Panama Feeder. Merge the two zones to prevent possible relay misoperation.
3	Open the Panama circuit breaker.	Although the current distribution is known at this point, the feeder is still considered in the intermediate position and the two zones are still merged.
4	Open the line disconnect (G893) of the Panama feeder. Open the Busbar 1 (G891) disconnect.	Opening G891 removes the bus-zone-to-bus-zone connection, forming two independent zones. The Panama feeder is now on transfer.

Because the operating sequence prevents connections that could result in relay misoperation, we must merge the zones during the intermediate position (Step 2 in *Table 1.64*). We define this intermediate position as the time when disconnects *n*891 and *n*892 of any feeder are closed simultaneously.

Enter this state to merge the zones in the bus-zone-to-bus-zone connections:

BZ1BZ2V := **(IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN216)**

We use a combination of the zone supervision and coupler security logics to prevent tripping Busbar 1 for a fault between the tie-breaker circuit breaker and CT. For the zone supervision setting, we supervise the BZ1 differential element output by the negated coupler security output (ZS1 := NOT CSL1) (see *Protection Group Settings on page A.1.133* for more information).

I01BZ1V and I01BZ2V, the tie-breaker terminal-to-bus-zone settings, comprise the disconnect auxiliary contacts (IN204 and IN205), the circuit breaker auxiliary contact (CB52A1), the circuit breaker closing signal (CBCLST1), and the coupler status timed-out bit (CB52T1). (See *Figure 1.108* and *Protection Group Settings on page A.1.133* for more detail.)

In this application, the disconnect provides only one (89B) disconnect auxiliary contact. We cannot use the disconnect monitoring logic because the disconnect monitoring logic requires two disconnect auxiliary contacts. For installations with only one disconnect auxiliary contact, use the zone-switching supervision logic. (See *Section 1: Protection Functions in the Reference Manual* for more information.) Enable the zone switching supervision by setting EZSWSUP := Y. Connect the open and close signals from the disconnects in parallel (see *Figure 1.106*).

In this application, we assign this parallel connection to relay input IN203. Set ZSWO := IN203.

Alarm ZSWOAL stays asserted indefinitely in the event of the disconnect auxiliary contact failing to change status. Use pushbutton {PB5} to reset Alarm ZSWOAL when a disconnect auxiliary contact fails to change status. Set RZSWOAL := PB5.

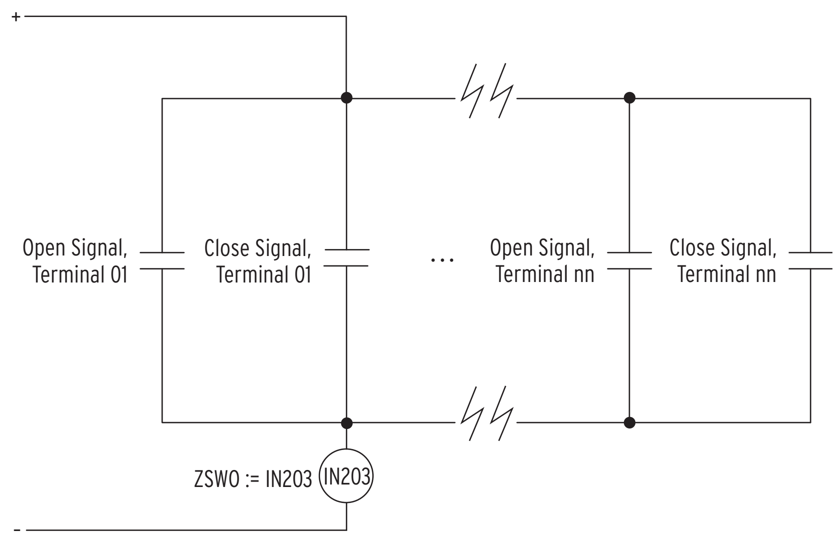


Figure 1.106 External Wiring and Initiation Input for Zone-Switching Supervision

Measure each disconnect travel time.

Set the zone-switching operation pickup delay (ZSWOPU) to a value longer than the time necessary for the slowest disconnect to complete an open-to-close, or close-to-open operation. Based on previous experience with similar equipment, we set the ZSWOPU to 3600 cycles in this example. *Figure 1.107* shows the zone configuration settings for this application.

The zone configuration default settings are for a specific substation with arbitrarily selected alias names, serving only as an example.

For ease of setting zone configuration settings for the new substation, delete the terminal-to-bus-zone connections default settings. With the terminal-to-bus-zone connections default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.107* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?600 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE_A, BUS_A, P
?   DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I01,BZ1,P <Enter>
```

```
TIE_A to BUS_A Connection (SELogic Equation)
I01BZ1V := NA
?  IN204 AND IN205 AND (CB52A1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,BZ2,N <Enter>
TIE_A to TRANS_A Connection (SELogic Equation)
I01BZ2V := NA
?  IN204 AND IN205 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,BZ1,P <Enter>
MEXCO_A to BUS_A Connection (SELogic Equation)
I02BZ1V := NA
?  IN206 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,BZ2,P <Enter>
MEXCO_A to TRANS_A Connection (SELogic Equation)
I02BZ2V := NA
?  IN207 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,BZ1,P <Enter>
RIODJ_A to BUS_A Connection (SELogic Equation)
I03BZ1V := NA
?  IN208 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,BZ2,P <Enter>
RIODJ_A to TRANS_A Connection (SELogic Equation)
I03BZ2V := NA
?  IN209 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,BZ1,P <Enter>
BOGOT_A to BUS_A Connection (SELogic Equation)
I04BZ1V := NA
?  IN210 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,BZ2,P <Enter>
BOGOT_A to TRANS_A Connection (SELogic Equation)
I04BZ2V := NA
?  IN211 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,BZ1,P <Enter>
PANAM_A to BUS_A Connection (SELogic Equation)
I05BZ1V := NA
?  IN212 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I05,BZ2,P <Enter>
PANAM_A to TRANS_A Connection (SELogic Equation)
I05BZ2V := NA
?  IN216 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?  BZ1,BZ2 <Enter>
BUS_A to TRANS_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN\
216) <Enter>
Connection to Remove Terminals when BUS_A and TRANS_A merge (SELogic Equation)
BZ1BZ2R := NA
?  (IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN\
216) <Enter>
Terminals Removed when BUS_A and TRANS_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  I01 <Enter>
Trip Terminals TIE_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
?

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  NOT CSL1 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  > <Enter>
Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?Y <Enter>
Zone Switching Operation (SELogic Equation)
ZSWO := NA
?  IN203 <Enter>
Reset Zone Switching Op Alarm (SELogic Equation)
RZSWOAL := NA
?  PB5 <Enter>
Zone Switching Op Pickup Delay (0-99999 cyc)         ZSWOPU  := 1800   ?3600 <Enter>
```

```
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.107 Zone Configuration Group Settings for Application 4

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, beginning with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the sensitive differential element, the restrained differential element and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information).

We need one coupler security logic for this application. Set ECSL := 1. Set ETOS := N, EBFL := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N because we do not use the terminal out of service function, breaker failure protection, overcurrent elements, voltage elements, or advance settings in this application.

Setting NUMBK to 5 (Global settings) makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. Each of the five analog channels has a corresponding differential trip bit that asserts (*Table 1.61*) when the differential element asserts.

Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip. When applying the coupler security logic as in this example, include the differential element trip output (87R1) and the 87BTR01 differential trip bit in the tie-breaker trip logic.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Figure 1.108 shows the combination of the coupler security logic and the zone supervision with the input settings applied. Notice that Gate 1 and Gate 2 represent the tie-breaker terminal-to-bus-zone connection settings; they are not part of the fixed logic.

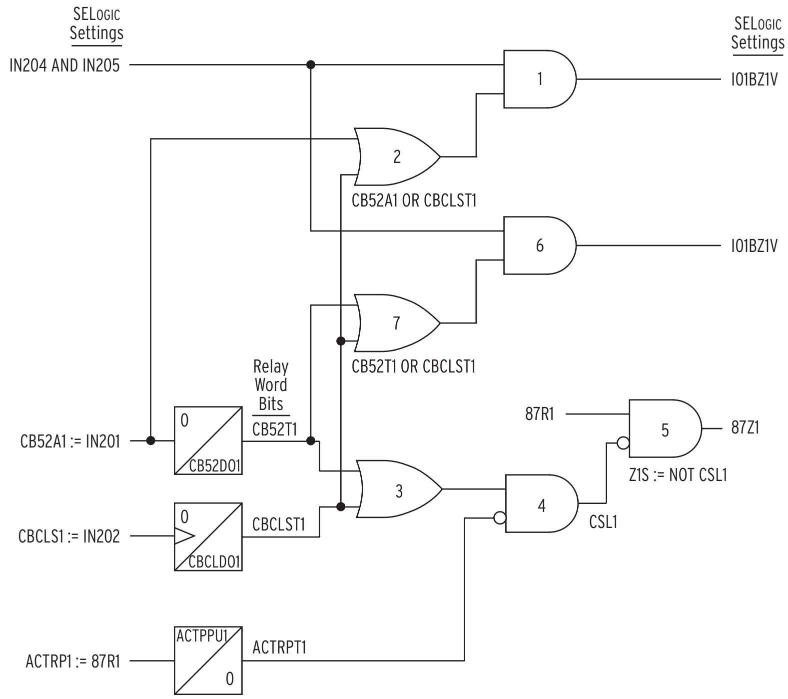


Figure 1.108 Coupler Security Logic With Applied Input Settings

The protection philosophy calls for the loss of only one zone when a fault between the tie-breaker CT and circuit breaker occurs. Use the coupler security logic to prevent the loss of Busbar 1 for a fault between the tie-breaker CT and circuit breaker. Be aware, however, that using this logic delays relay operation for all busbar faults on Busbar 1.

Assume for this application that the maximum circuit breaker tripping time is 2 cycles and that the maximum closing time is 4 cycles. Refer to *Figure 1.108*, and notice the difference in the CB52A1 and CBCLS1 inputs from the regular coupler security application. Input CBCLS1 provides the closing signal information to the relay. For an open-to-close operation, Input CBCLS1 asserts when the operator issues a closing signal to the circuit breaker, asserting Relay Word bits I01BZ1V and I01BZ2V. When Relay Word bits I01BZ1V and I01BZ2V assert, the relay considers the CT in the differential equations. Inserting the CTs in the differential equations before primary current flows emulates the early make, late break timing requirement for the disconnect auxiliary contacts. Set the timer dropout time (CBCLDO1) to a value longer than the maximum breaker closing time. In this example, allow a short safety margin and set CBCLDO1 to 5 cycles (default value). A setting of 5 cycles allows the circuit breaker ample time to change state, during which time Relay Word bit CB52A1 asserts.

When opening the circuit breaker, the inverse applies. For a close-to-open circuit breaker operation, we must guard against prematurely removing the CTs from the differential equations due to circuit breaker auxiliary contact misalignment. We use CB52T1 in the tie-breaker terminal-to-bus-zone connection settings to accomplish this for Zone 2. However, because we supervise all Zone 1 faults, premature removal of the CTs does not adversely affect Zone 1 differential elements.

Figure 1.109 shows just the tie breaker and two terminals of the application. The single CT on the tie breaker has one core, providing CT information to both differential elements. The challenge to the coupler security logic is to trip BZ2 and not BZ1 for Fault F1. This requirement contradicts the existing configuration, for it calls for the coupler security logic to prevent BZ1 from operating for an in-zone fault (fault on Busbar 1) and for BZ2 to operate for an out-of-zone fault (fault on Busbar 1).

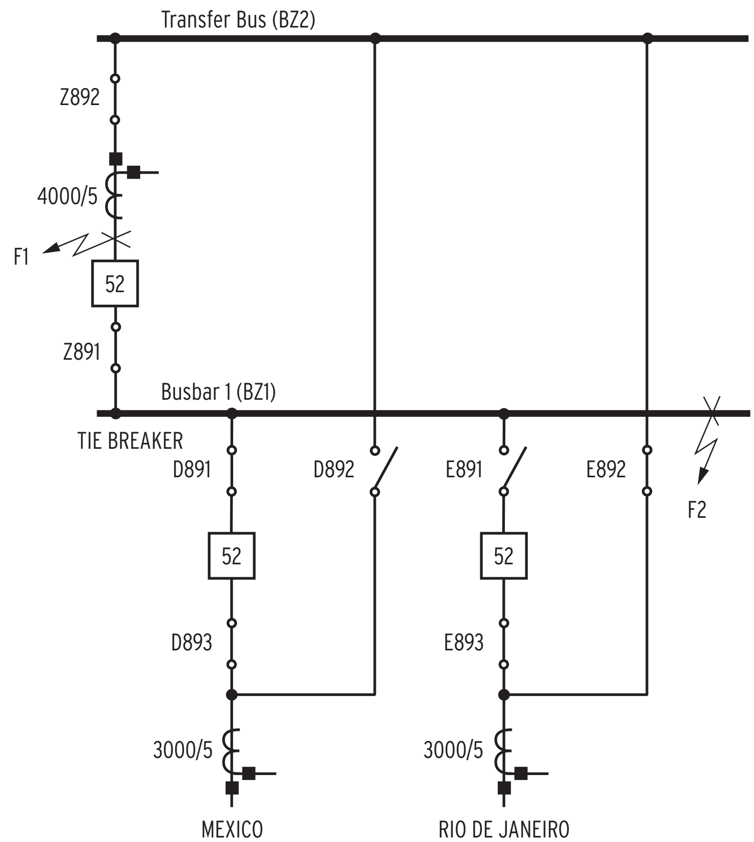


Figure 1.109 Single CT Application With Faults Between the Circuit Breaker and Tie-Breaker CT

Consider the operation when Fault F1 occurs without the coupler security logic. Differential protection BZ2 is stable, and differential protection BZ1 immediately trips the Mexico circuit breaker and the tie-breaker circuit breaker. However, tripping the Mexico circuit breaker and the tie-breaker circuit breaker does not clear Fault F1. Fault current still flows from the Rio de Janeiro Feeder, through the transfer bus, and into the fault. Although breaker failure protection will operate to trip the Rio de Janeiro circuit breaker, this operation takes place after the breaker failure time delay. After the tie-breaker breaker failure timer times out, all circuit breakers in BZ2 zone trip, resulting in both BZ1 and BZ2 tripping to clear Fault F1.

If a delay in bus-zone protection operation is in order, implement the coupler security logic in such a way that tripping of the BZ1 bus-zone is only permitted when the tie-breaker circuit breaker is open. To prevent tripping BZ1, configure the relay to achieve the following:

- ➤ Check if the tie-breaker circuit breaker is closed.
- ➤ If the tie-breaker circuit breaker is closed, trip only the tie breaker to interrupt the fault current from BZ1; trip no other circuit breakers.

- ➤ If the tie breaker is open, allow normal busbar protection tripping.
- ➤ When the tie breaker is open, remove the tie-breaker CT from the differential calculations of BZ1 and eventually BZ2.

To check the tie-breaker status and remove the CT from the supervised zone when the tie breaker is open, use the tie-breaker auxiliary contact in the tie-breaker terminal-to-bus-zone connection settings. To remove the CT from the unsupervised zone, use the coupler status timed-out bit (CB52T1) in the tie-breaker terminal-to-bus-zone connection settings. To trip only the tie breaker for a fault on Busbar 1 requires the following two settings:

- ➤ supervising the BZ1 differential element
- ➤ issuing a trip signal to the tie breaker first

Supervise the BZ1 differential element output with the negated output from the coupler security logic (Z1S := NOT CSL1). We assign 87R1, the unsupervised output from the BZ1 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. When accelerated trip timer output (ACTRPT1) asserts, Gate 4 in *Figure 1.108* turns off and Relay Word bit CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z1S asserts, removing the supervision from the BZ1 differential element.

Supervising the BZ1 differential element in this way prevents the tripping of all terminals in BZ1, including the tie breaker. To trip the tie breaker, include 87R1, the unsupervised output from Differential Element 1 in the trip equation of the tie breaker.

After the tie breaker opens (2 cycles), we remove the tie-breaker CT from the differential calculations of BZ1 but not the BZ1 supervision. Maintain the BZ1 supervision for at least another 1.25 cycles (add a safety margin of 0.75 cycle) to allow the differential element to reset. Achieve this delay by setting ACTPPU1 to at least 4 cycles.

For Fault F1, BZ1 operates, asserting Relay Word bit 87R1. When Relay Word bit 87R1 asserts, the accelerated trip timer starts timing. Because of the BZ1 zone supervision (NOT CSL1), 87Z1 cannot assert, and only the bus tie breaker receives a trip signal.

Two cycles later, the tie-breaker trips, interrupting the fault current contribution from BZ1. Assume the circuit breaker auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ1V and eventually I01BZ2V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. For Fault F1, the tie breaker is open, but fault current still flows through the CT. Removing the tie-breaker CTs from all differential calculations does not trip BZ1 (no fault current contribution from BZ1) but causes BZ2 to operate (BZ2 balancing tie-breaker CT removed), tripping all circuit breakers on the transfer bus. Removing the bus sectionalizer CTs also deasserts Relay Word bit 87R1, causing the accelerated trip timer to stop timing. Fault F1 is now cleared, although there is a time delay.

For Fault F2, the initial tripping is the same as for Fault F1: BZ1 operates, asserting Relay Word bit 87R1. When Relay Word bit 87R1 asserts, the accelerated trip timer starts timing. Because of the BZ1 zone supervision (NOT CSL1), 87Z1 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie-breaker circuit breaker trips, and the auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ1V and eventually I01BZ2V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. Because the circuit breaker is open, terminals from BZ2 no longer contribute to the fault, and BZ2 is stable. However, the BZ1 zone supervision (NOT CSL1) still supervises the BZ1 trip output for another two cycles. Two cycles later, Accelerate Trip Timer ACTRP1 times out, causing CSL1 to deassert. When Relay Word bit CSL1 deasserts, Relay Word bit Z1S asserts, removing the zone supervision from BZ1, issuing a trip signal to all circuit breakers on Busbar 1.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 1.110* shows the group settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?1 <Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Coupler 1 Security Logic
Coupler 1 Status (SELogic Equation)
CB52A1 := NA
?  IN201 <Enter>
Coupler 1 Status Dropout Delay (0.00-1000 cyc)       CB52D01 := 4.00   ?<Enter>
Coupler 1 Close Command (SELogic Equation)
CBCLS1 := NA
?  IN202 <Enter>
Coupler 1 Close Command D/O Delay (0.00-1000 cyc)    CBCLD01 := 5.00   ?<Enter>
Coupler 1 Acc Trip (SELogic Equation)
ACTRP1 := NA
?  87R1 <Enter>
Coupler 1 Acc Trip Pickup Delay (0.00-1000 cyc)      ACTPPU1 := 4.00   ?<Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  87R1 OR 87BTR01 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  87BTR02 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  87BTR03 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BTR04
?  87BTR04 <Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
```

```
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  87BTR05 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?<Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.110 Protection Group Settings for Application 4

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA. *Figure 1.111* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>

OUT106 := NA
?  > <Enter>

Interface Board #1

OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>
```

```
OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?  END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.111 Control Output Settings for Application 4

This concludes the settings for Application 4.

Application 5: Double Bus With Bus Coupler

This application describes the busbar arrangement shown in *Figure 1.112*, double bus with tie breaker (buscoupler). The busbar arrangement consists of two busbars (main busbar and transfer busbar), four terminals and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

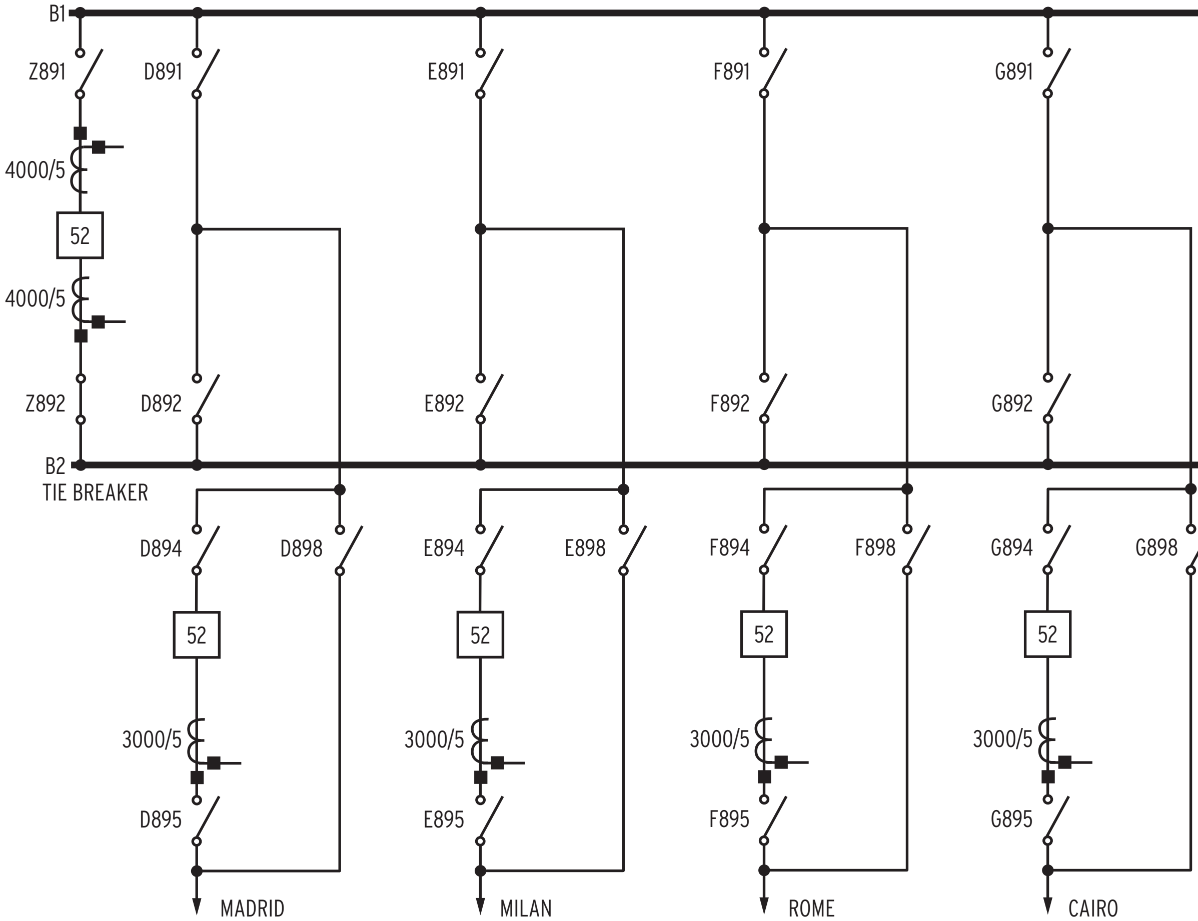


Figure 1.112 Double Bus With Buscoupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (buscoupler) configuration.

- Description:
  - Double bus with tie breaker
- Current Transformers:
  - Inboard
- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Two CTs, configured in overlap
- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the differential protection.
4. Use the disconnect monitor logic
5. Use external breaker failure protection.
6. Ensure stable differential protection for all operating conditions.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. Requirement 6 of the protection philosophy calls for stable differential protection for all operating conditions. There are two network conditions when the differential protection can become unstable:

- when disconnects *n*891 and *n*892 (*n* = D, E, F,G) of any feeder are closed at the same time
- when the transfer disconnect of any feeder is closed

By declaring the appropriate conditions in the bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable when disconnects *n*891 and *n*892 are closed simultaneously. We use the zone supervision logic to ensure stable differential protection during the time when one of the transfer disconnects is closed.

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 1.65* shows the selection of the standard functions.

Table 1.65 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch.
Circuit breaker status logic	No	Not required.
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available.
Differential protection	Yes	Busbar protection.
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	Use the sensitive differential element as CT open circuit detection.
Zone supervision logic	Yes	Use the zone supervision logic to ensure stable differential protection for all operating conditions.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available so this logic is not required.
Coupler security logic	No	Two CTs in overlap configuration do not require the coupler security logic.
Circuit breaker failure protection	Yes	External breaker failure.
Instantaneous overcurrent protection	No	Not required.
Time-overcurrent protection	No	Not required.
Phase voltage elements	No	Not required.
Zero- or negative-sequence voltage elements	No	Not required.

User-Defined Functions

Identify logic functions we need for the application that is not part of the standard logic in the relay. We comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and 3 voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and up to 54 CTs we install 3 SEL-487B relays. Use *Equation 1.17* to calculate number of current channels at the station, and use *Equation 1.18* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs} \qquad \textbf{Equation 1.17}$$

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections} \qquad \textbf{Equation 1.18}$$

The number of per-phase CTs at the station is 18 (tie breaker has 6 CT cores), and one SEL-487B suffices. However, the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays. This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires three disconnect monitoring logic and the tie breaker requires two; the number of disconnect logics required is therefore six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.19* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics} \qquad \textbf{Equation 1.19}$$

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions, and records the terminals in each bus-zone. The relay then uses this information to only trip the terminals in the bus-zone with the failed breaker, when a circuit breaker fails. Wire an output from each breaker failure relay on each of the terminals to the SEL-487B. *Table 1.66* summarizes the input contact required for this application.

Table 1.66 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 14 = 28
Number of relay inputs required for breaker failure protection	5
Total number of inputs	33

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs; and five of the six independent input contacts for the breaker failure inputs. From the input contact perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.67* shows the breakdown and the total number of relay output contacts required for tripping.

Table 1.67 Breakdown and Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts; high-speed, high-interrupting output contacts provide for faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts, and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the number of the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and external circuit breaker failure inputs to specific relay input contacts

- ➤ link relay element/logic outputs to specific relay output contacts
- ➤ assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- ➤ Relay Word bit
- ➤ Analog quantity
- ➤ Terminal name
- ➤ Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.68* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.68* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.112*.

Table 1.68 CT-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.69*.

Table 1.69 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input to Logic Allocation

Table 1.66 shows that we require 33 digital inputs. We now assign the 33 digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input Contact to Logic Allocation, Interface Board 1 (200)

Table 1.70 and *Table 1.71* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.70 Disconnect and Circuit Breaker Failure Contact Input Allocation

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN208	MADRID terminal disconnect (ZONE1_A) NO contact
IN209	MADRID terminal disconnect (ZONE1_A) NC contact
IN210	MADRID terminal disconnect (ZONE2_A) NO contact
IN211	MADRID terminal disconnect (ZONE2_A) NC contact
IN212	MADRID terminal disconnect (TRANS _A) NO contact
IN216	MADRID terminal disconnect (TRANS _A) NC contact
IN217	MILAN terminal disconnect (ZONE1_A) NO contact
IN218	MILAN terminal disconnect (ZONE1_A) NC contact
IN219	MILAN terminal disconnect (ZONE2_A) NO contact
IN220	MILAN terminal disconnect (ZONE2_A) NC contact
IN221	MILAN terminal disconnect (TRANS _A) NO contact
IN222	MILAN terminal disconnect (TRANS _A) NC contact

Input Contact to Logic Allocation, Interface Board 2 (300)

Table 1.71 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.71 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact

Table 1.71 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

Referring to *Table 1.65*, the following is a discussion on each selected function.

Disconnect Monitoring Logic

Figure 1.113 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Dynamic Zone Selection Logic on page R.1.15* for more information on the disconnect auxiliary contact requirements).

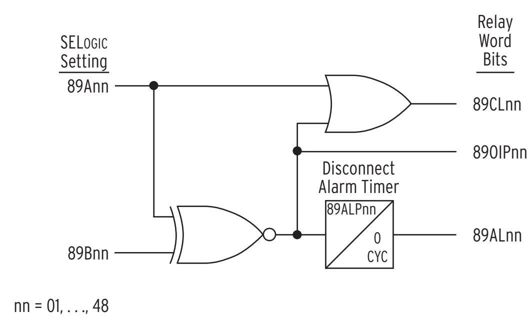


Figure 1.113 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.72 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.72 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO
89B02	TIE-BREAKER disconnect (ZONE2_A) NC
89A03	MADRI_A disconnect (ZONE1_A) NO contact
89B03	MADRI_A disconnect (ZONE1_A) NC contact
89A04	MADRI_A disconnect (ZONE2_A) NO contact
89B04	MADRI_A disconnect (ZONE2_A) NC contact
89A05	MADRI_A disconnect (TRANS_A) NO contact
89B05	MADRI_A disconnect (TRANS_A) NC contact
89A06	MILAN_A disconnect (ZONE1_A) NO contact

Table 1.72 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89B06	MILAN _A disconnect (ZONE1_A) NC contact
89A07	MILAN _A disconnect (ZONE2_A) NO contact
89B07	MILAN _A disconnect (ZONE2_A) NC contact
89A08	MILAN _A disconnect (TRANS_A) NO contact
89B08	MILAN _A disconnect (TRANS_A) NC contact
89A09	ROME_A disconnect (ZONE1_A) NO contact
89B09	ROME _A disconnect (ZONE1_A) NC contact
89A10	ROME _A disconnect (ZONE2_A) NO contact
89B10	ROME _A disconnect (ZONE2_A) NC contact
89A11	ROME _A disconnect (TRANS_A) NO contact
89B11	ROME _A disconnect (TRANS_A) NC contact
89A12	CAIRO _A disconnect (ZONE1_A) NO contact
89B12	CAIRO _A disconnect (ZONE1_A) NC contact
89A13	CAIRO _A disconnect (ZONE2_A) NO contact
89B13	CAIRO _A disconnect (ZONE2_A) NC contact
89A14	CAIRO _A disconnect (TRANS_A) NO contact
89B14	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.114 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.73* shows the Relay Word bits and description for the zone differential protection outputs.

Table 1.73 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

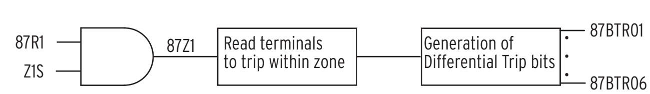


Figure 1.114 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.154* for more information). *Table 1.74* shows the primitive analog channel names, and the differential trip bit names for the differential trip bits.

Table 1.74 Differential Trip Bit Names and Associated Terminal Names

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 1.115 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF06 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR06 are the outputs from the station breaker failure logic. Relay Breaker failure trip bits SBFTR01–SBFTR06 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

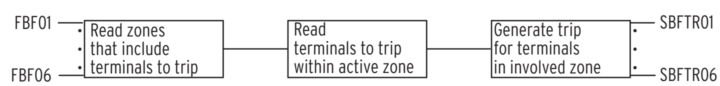


Figure 1.115 Breaker Failure Trip Logic

Table 1.75 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 1.75 Station Breaker Failure Trip Bit Names and Associated Terminal Names

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05
SBFTR06	Associated with Terminal 06

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip six terminals.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 1.116* shows the logic for the external breaker failure function.

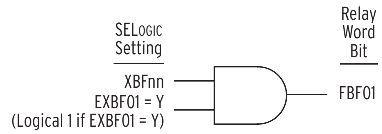


Figure 1.116 Breaker Failure Logic for External Breaker Failure

We assign the relay breaker failure inputs shown in *Table 1.70* to the appropriate XBF*nn* (*nn* = 01 through 06) of the breaker failure protection logic (see *Protection Group Settings on page A.1.162*). *Table 1.76* shows the primitive names and assignments.

Table 1.76 Breaker Failure Logic Output Relay Word Bits

Logic Name	Description
IN201	TIE1_A breaker failure protection asserted
IN201	TIE2_A breaker failure protection asserted
IN202	MADRI_A breaker failure protection asserted
IN203	MILAN_A breaker failure protection asserted
IN301	ROME_A breaker failure protection asserted
IN302	CAIRO_A breaker failure protection asserted

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.67 shows the breakdown of the five relay outputs we need for Application 5. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.77* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.78* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.77 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.78* shows the assignment for the five terminals of the A-phase relay.

Table 1.78 Assignment of the Output Contacts

Output Contact Assignment	Description
OUT201[a]	Tie-Breaker trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High speed, high interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 1.117*.

1. Write down the bus-zone, terminal and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the terminal digital inputs to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

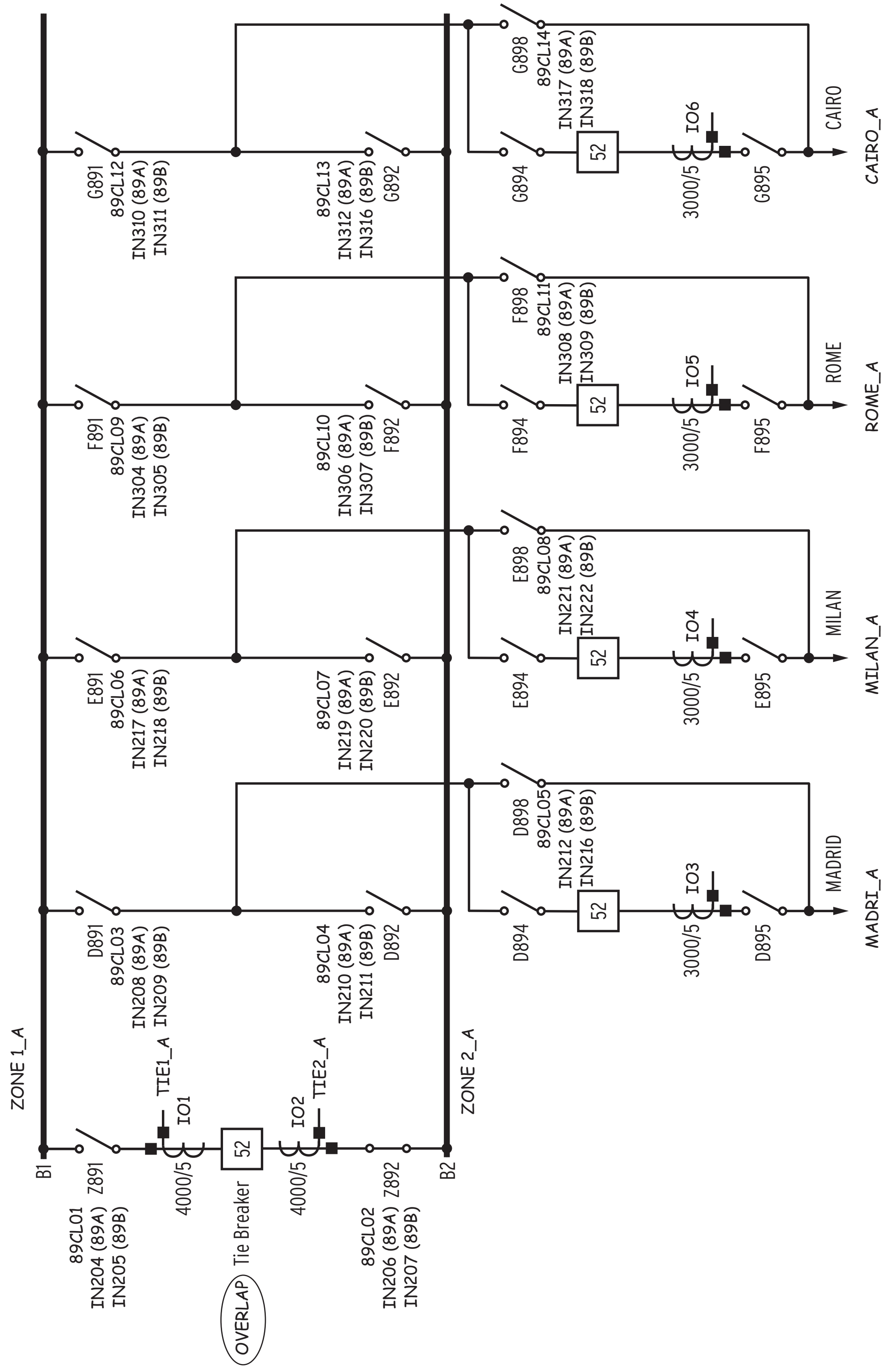


Figure 1.117 Substation Layout With Specific Information

Setting the Relay

The following describes the settings for this application. For this application example, we set the following setting classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings
- ➤ Protection Group Settings
- ➤ Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.118*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.118 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.119*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.119 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.120*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE1_A <Enter>
20:
?  I02,TIE2_A <Enter>
21:
?  I03,MADRI_A <Enter>
22:
```

```
?   I04,MILAN_A <Enter>
23:
?   I05,ROME_A <Enter>
24:
?   I06,CAIRO_A <Enter>
25:
?   BZ1,ZONE1_A <Enter>
26:
?   BZ2,ZONE2_A <Enter>
27:
?   END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.120 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from protection setting Group 1 to protection setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.121* shows the setting changes we need for our example.

Because we declared the alias names in the previous setting class, use either the alias names or the primitive names when entering settings.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 14 disconnect logics although there are 28 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01 through 48). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                         NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-48)                      NUMDS   := N      ?14 <Enter>
Nominal System Frequency (50,60 Hz)                 NFREQ   := 60     ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                    EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                     GINPU   := 0.17   ?> <Enter>
Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)               89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)               89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)               89ALP03 := 300    ?<Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)               89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.
N/O Contact Input -DS14 (SELogic Equation)
89A14 := NA
?  IN317 <Enter>
N/C Contact Input -DS14 (SELogic Equation)
89B14 := NA
?  IN318 <Enter>
DS14 Alarm Pickup Delay (0-99999 cyc)               89ALP14 := 300    ? <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.121 Global Settings for Application 5

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the London feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion we define the following terms:

➤ Source busbar: the busbar to which all terminals are connected, except the terminal on transfer.

➤ Transfer busbar: the busbar to which the terminal on transfer is connected.

➤ Transfer disconnect: the disconnect, when closed, bypasses the circuit breaker (e.g., disconnect G898 on the CAIRO Terminal).

Although the relay is flexible enough to accept settings for the many disconnect combinations, we will configure the relay according to the following operating conditions:

➤ Only one terminal will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z892 or Z891) and the transfer disconnect (*n*898, *n* = D, E, F and G) of only one of the four feeders can be closed simultaneously.

➤ Either Busbar B1 or Busbar B2 can be the source busbar.

➤ When closing the transfer disconnect, the protection of the transfer busbar becomes part of the line protection.

➤ The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step.

Table 1.79 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Assume that the tie breaker and tie-breaker disconnects are closed. For brevity, we consider only the MADRID and CAIRO Feeders in the following discussion. Consider a case where we put the CAIRO Feeder on transfer, with Busbar B2 selected as the source busbar.

Table 1.79 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Switch Terminals TD, TE, and TF to the source busbar (B2).	Assume that all FDRs are connected to B1. Close the disconnects that connect the terminals to Busbar B2 (D892, E892, F892, and G892), and open the disconnects that connect the terminals to Busbar B1 (D891, E891, and F891). After Step 1, CAIRO is the only feeder connected to Busbar B1, see *Figure 1.122*. Both Bus-zone B2 (I03 + I01 = $I_s - I_s = 0$) and Bus-Zone B1 are balanced (I02 + I06 = $I_s - I_s = 0$).
2	Close the transfer disconnect (G898) of the terminal going on transfer.	This operation forms a parallel path, with current I_S splitting at the G894 and G898 junction; not all current flows through the CAIRO CT. There are still two bus-zones (B1 and B2), but because the current from the CAIRO CT is missing (worst case), Bus-Zone B1 can misoperate. Remove Bus-Zone B1 by removing the CAIRO CT and tie-breaker channel I02 from the differential calculations. (See the ensuing discussion and *Figure 1.123*). The transfer busbar is now part of the line protection.
3	Open the circuit breaker of the terminal going on transfer.	Opening the CAIRO circuit breaker interrupts the current path through the circuit breaker. Tie-breaker channel I01 remains part of the differential calculations to balance the current flow to the CAIRO Feeder.
4	Open the source busbar disconnect (G894) and the line disconnect (G895) to isolate the circuit breaker.	Step 4 is shown here to complete the operating sequence; the operation has no effect on the busbar protection.

Figure 1.122 shows the station after Step 1 in *Table 1.79*. Step 1 is standard operating procedure and requires no special busbar protection settings. With all transfer disconnects open, all the CT secondary currents are available, and both Bus-Zones B1 and B2 are balanced.

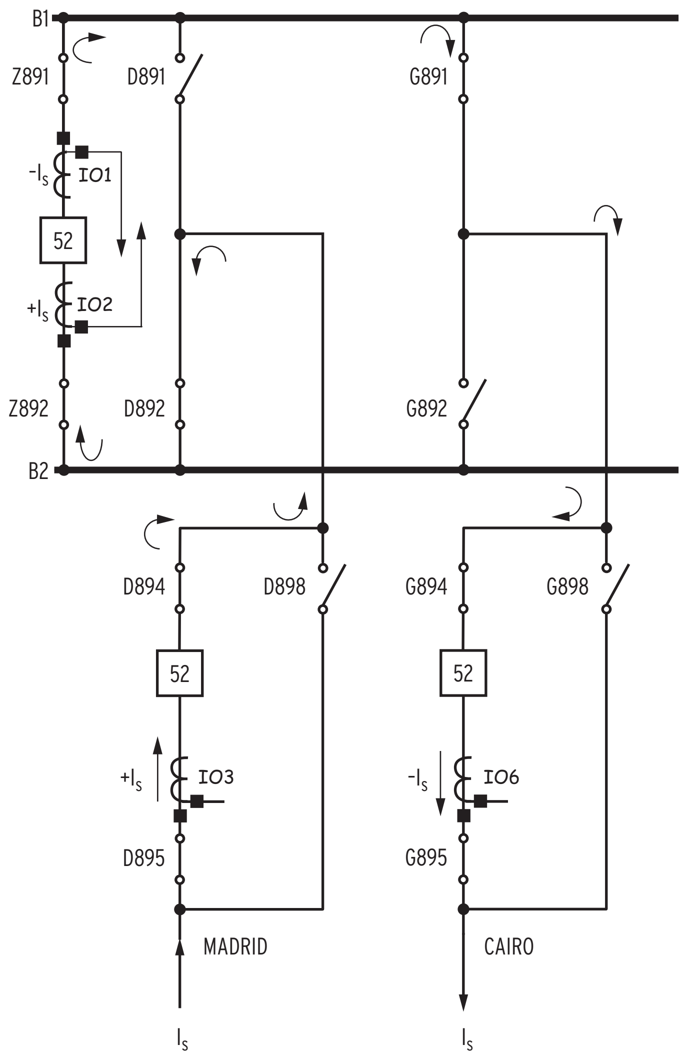


Figure 1.122 Bus-Zone B1 and Bus-Zone B2 Are Balanced When Both Transfer Disconnects Are Open

Figure 1.123 shows the current distribution for the condition when disconnect G891 and disconnect G898 are both closed. Current I_S enters the MADRID terminal, flows through the tie breaker, busbar B1, and up to the junction between disconnect G894 and G898. At this junction, the current splits into i_a and i_b. As a worst-case scenario, assume the entire current, I_S, flows through disconnect G898, with no current flowing through the CAIRO CT. To balance the B1 differential element, we need the sum of the currents in the B1 element to equal zero. Without the CAIRO CT current contribution, the differential element is unbalanced and can result in misoperation. To conclude, the current input from the CAIRO CT is uncertain when disconnect G891 and disconnect G898 are both closed, and disappears when the circuit breaker opens. For these reasons, Bus-Zone B1 cannot form a reliable differential zone when disconnect G898 closes. Differential Element B2 remains stable, and the B2 Busbar protection is secure.

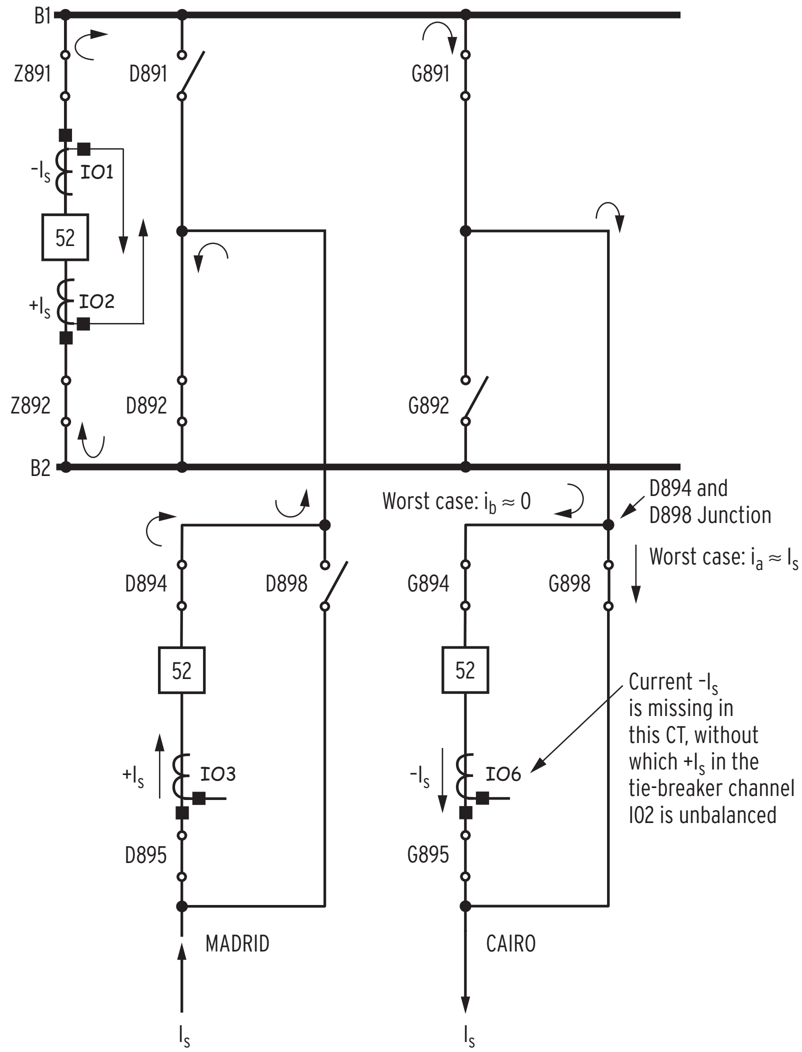


Figure 1.123 Current Distribution During Transfer Procedure Using Inboard CTs

By removing the CAIRO CT as well as the tie-breaker I02 channel from the differential calculations, we effectively remove Differential element B1. We can achieve the same result in two ways:

- ➤ by using the zone supervision setting (Z*n*S)
- ➤ entering values for each of the terminal-to-bus-zone settings

This example uses the first option (i.e., the zone supervision setting).

Consider also that by removing Differential Element B1, the transfer busbar is without protection. One solution is to use the tie-breaker I02 CT for the line protection, thereby including the transfer busbar as part of the line. When using the SEL-421 as line protection, program the selection functions in the relay to select current I02 as an alternate current source.

To configure the correct disconnect combinations, use the following conditions:

1. With no feeder on transfer, manipulate the tie-breaker CTs with the bus-zone-to-bus-zone connections.
2. A feeder is on transfer when any *n*898 AND *n*891, or any *n*898 AND *n*892 (*n* = D, E, F and G) disconnects are closed simultaneously.
3. When a feeder is on transfer and B2 is the source busbar, remove I02. B2 is the source busbar when *n*891 AND *n*898 (*n* = D, E, F and G) disconnects are closed.
4. When a feeder is on transfer and B1 is the source busbar, remove I01. B1 is the source busbar when *n*892 AND *n*898 (*n* = D, E, F and G) disconnects are closed.

Z1S:= **NOT ((89CL03 AND 89CL05) OR (89CL06 AND 89CL08) OR (89CL09 AND 89CL11) OR (89CL12 AND 89CL14))**

Z2S:= **NOT ((89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13 AND 89CL14))**

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example.

For the ease of setting the zone configuration settings for the new substation, delete the existing zone configuration default settings.

With the zone configuration default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.124* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE1_A, ZONE1_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?  89CL02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE1_A <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?  89CL01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?  89CL03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?  89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE1_A,P <Enter>
```

```
MILAN_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
?   89CL06 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?   89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?   89CL09 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?   89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I06BZ1V := NA
?   89CL12 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I06BZ2V := NA
?   89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?   ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?   (89CL03 AND 89CL04) OR (89CL06 AND 89CL07) OR (89CL09 AND 89CL10) OR (89CL12\
 AND 89CL13) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?   BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?   TIE1_A,TIE2_A <Enter>
Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?   Y <Enter>
Bus-Zone, Bus-Zone
? <Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?   NOT ((89CL03 AND 89CL05) OR (89CL06 AND 89CL08) OR (89CL09 AND 89CL11) OR (8\
9CL12 AND 89CL14)) <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?   NOT ((89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (8\
9CL13 AND 89CL14)) <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.124 Zone Configuration Group Settings for Application 5

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element and the Directional Element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set TOS := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N because we do not use the Coupler Security Logic, overcurrent elements, terminal out of service, or voltage elements in this application.

Because breaker failure protection measures each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, but six current channels (tie breaker has two CTs). Select six as the number of breaker failure logics for this application.

This application assumes a single breaker failure input from the tie-breaker protection. With a single breaker failure input from the tie-breaker protection, set both tie-breaker breaker failure initiate setting (XBF01 and XBF02) equal to IN201. For tie breakers with two breaker failure relays, allocate an additional relay input for the second breaker failure input, and equate each relay input to an XBF*nn* settings. For example, assume the two breaker failure inputs are assigned to relay input IN201 and relay input IN202. With these input assignments, set XBF01 := IN201 and XBF02 := IN202.

Setting NUMBK equal to five makes five corresponding trip equations (TR01 through TR05) available for setting. There are five trip equations available, but there are six analog channels (I01 though I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.74*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Each of the six analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 1.75*) when the breaker failure element asserts. Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

Because the tie breaker has two analog channels, but only one circuit breaker, include both Differential Trip bits (87BTR01 and 87BTR02) as well as both station breaker failure trip bits (SBFTR01 and SBFTR02) in the trip equation of the tie breaker (TR01).

Figure 1.125 shows the protection group settings for this application.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?<Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N       ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y       ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N       ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N       ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFIDO01 := 1.50    ? <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N       ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFIDO02 := 1.50    ?<Enter>
.
.
.

External Breaker Fail -BK06 (Y,N)                    EXBF06  := N       ?Y <Enter>
External Brkr Fail Init -BK06 (SELogic Equation)
XBF06 := NA
?  IN302 <Enter>
Brkr Fail Init Dropout Delay -BK06 (0.00-1000 cyc)   BFIDO06 := 1.50    ? <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR SBFTR02 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>

Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  SBFTR03 OR 87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  SBFTR04 OR 87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  SBFTR06 OR 87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ? <Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
```

```
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.125 Protection Group Settings for Application 5

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts. Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA.

Figure 1.126 shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>

OUT106 := NA
?  > <Enter>

Interface Board #1

OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?  END <Enter>

Output
.
.
.
```

```
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.126 Control Output Settings for Application 5

This concludes the settings for Application 5.

Application 6: Double and Transfer Bus With Two Busbars

This describes the busbar arrangement shown in *Figure 1.127*. The busbar arrangement consists of two busbars (main busbar and transfer busbar), four terminals and a tie breaker. Consider the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection functions selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation and alias name assignment
- ➤ Station layout update
- ➤ Relay setting and configuration

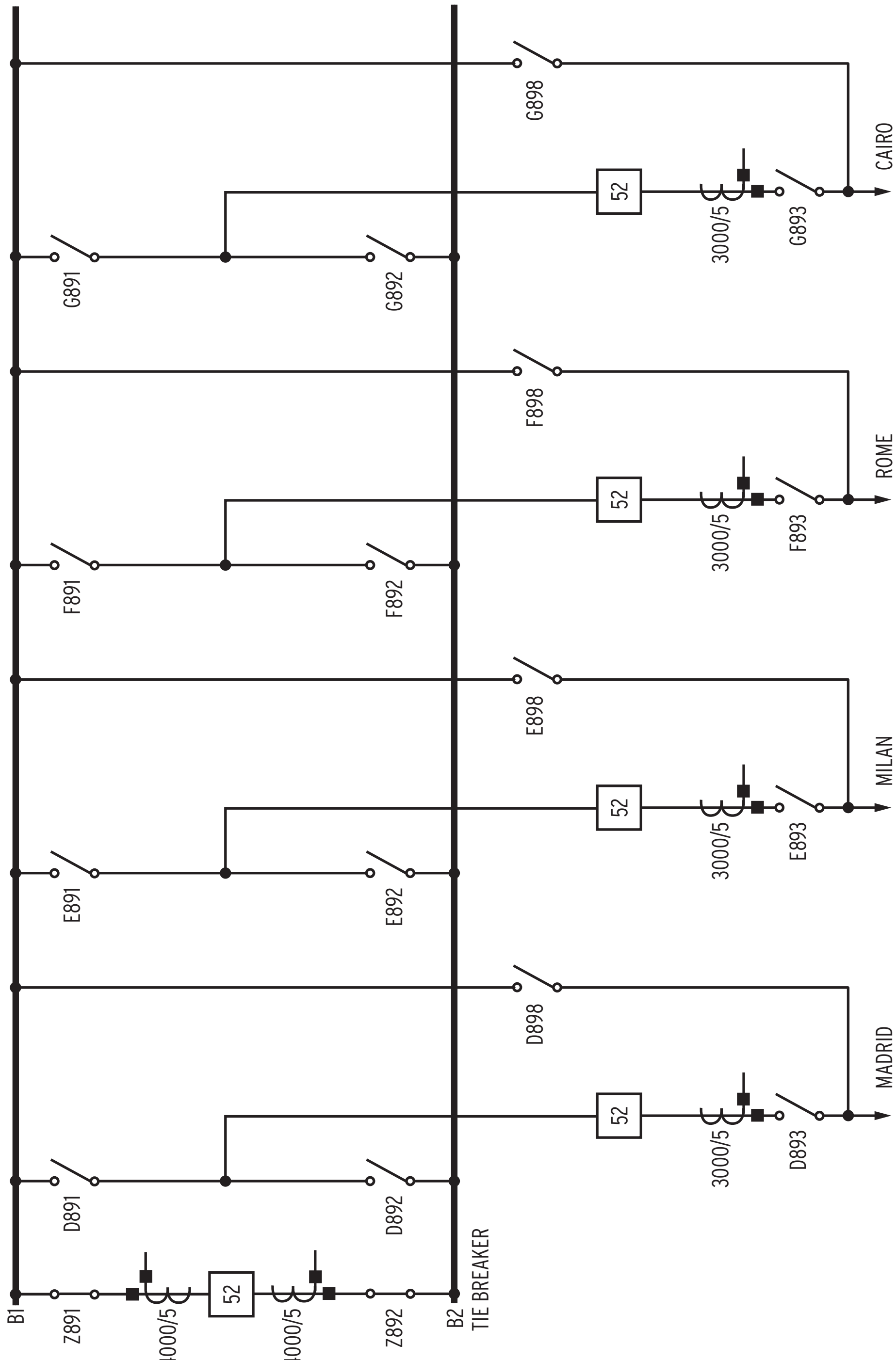


Figure 1.127 Double Bus and Transfer Bus With Buscoupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (buscoupler) configuration.

- Description:
  - Double bus with tie breaker
- Current Transformers:
  - Inboard

- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Two CTs, configured in overlap
- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open circuit CT.
3. Ensure stable differential protection for all operating conditions.
4. Use the disconnect auxiliary contacts to dynamically configure the station.
5. Use the disconnect monitor logic.
6. Use external breaker failure protection.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. Requirement 3 of the protection philosophy calls for stable differential protection for all operating conditions.

There are two network conditions when the differential protection can become unstable: when disconnects *n*891 and *n*892 (*n* = D, E, F,G) of any feeder are closed at the same time, or when the transfer disconnect of any feeder is closed. By declaring the appropriate conditions in the bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable when disconnects *n*891 and *n*892 are closed simultaneously. We use the zone supervision logic to ensure stable differential protection during the time when one of the transfer disconnects is closed.

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 1.80* shows the selection of the standard functions.

Table 1.80 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the station according to the disconnect positions.

Table 1.80 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Functions	Selection	Comment
Sensitive differential protection	Yes	Use the sensitive differential element as CT open circuit detection.
Zone supervision logic	Yes	Use the zone supervision logic to compensate for the inboard CTs during the bypass period, as well as when a feeder is on transfer.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	No	Not required
Circuit breaker failure protection	Yes	External breaker failure
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need for the application that is not part of the standard logic in the relay. We comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

➤ the number of relays (single-relay application or three-relay application)

➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For station with more than 18 and up to 54 CTs we install three SEL-487B relays. Use *Equation 1.20* to calculate number of current channels at the station, and use *Equation 1.21* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.20**

# of bus-zones required = # of per-phase station bus sections **Equation 1.21**

The number of per-phase CTs at the station is 18 (tie breaker has 6 CT cores), and one SEL-487B suffices. However, the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the 4 feeders requires 3 disconnect monitoring logic and the tie breaker requires 2; the number of disconnect logics required is therefore 14. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.22* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics} \quad \textbf{Equation 1.22}$$

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions, and records the terminals in each bus-zone. The relay then uses this information to only trip the terminals in the bus-zone with the failed breaker, when a circuit breaker fails. Wire an output from each breaker failure relay on each of the terminals to the SEL-487B. *Table 1.81* summarizes the input contact required for this application.

Table 1.81 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 14 = 28
Number of relay inputs required for breaker failure protection	5
Total number of inputs	33

The relay main board has seven inputs, which are not enough inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent input contacts. Use the grouped inputs for the disconnect auxiliary contact inputs and the six independent inputs for the breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.82* shows the breakdown and the total number of relay output contacts required for tripping.

Table 1.82 Breakdown and Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts, and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay.

However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.83* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.83* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.127*.

Table 1.83 CT-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.84*.

Table 1.84 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input-to-Logic Allocation

Table 1.81 shows that we require 33 digital inputs. We now assign the digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input Contact-to-Logic Allocation, Interface Board 1 (200)

Table 1.85 and *Table 1.86* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.85 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE2_A) NC contact

Table 1.85 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN206	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN208	MADRID terminal disconnect (ZONE1_A) NO contact
IN209	MADRID terminal disconnect (ZONE1_A) NC contact
IN210	MADRID terminal disconnect (ZONE2_A) NO contact
IN211	MADRID terminal disconnect (ZONE2_A) NC contact
IN212	MADRID terminal disconnect (TRANS _A) NO contact
IN216	MADRID terminal disconnect (TRANS _A) NC contact
IN217	MILAN terminal disconnect (ZONE1_A) NO contact
IN218	MILAN terminal disconnect (ZONE1_A) NC contact
IN219	MILAN terminal disconnect (ZONE2_A) NO contact
IN220	MILAN terminal disconnect (ZONE2_A) NC contact
IN221	MILAN terminal disconnect (TRANS _A) NO contact
IN222	MILAN terminal disconnect (TRANS _A) NC contact

Input Contact to Logic allocation, Interface Board 2 (300)

Table 1.86 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.86 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

Referring to *Table 1.80*, the following is a discussion on each selected function.

Disconnect Monitoring Logic

Figure 1.128 shows one of the 48 disconnect monitor logic circuits available in the relay. (See *Figure 1.20*).

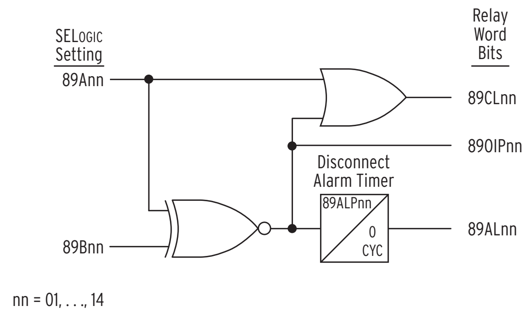


Figure 1.128 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.87 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.87 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Disconnect Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO contact
89B02	TIE-BREAKER disconnect (ZONE2_A) NC contact
89A03	MADRI_A disconnect (ZONE1_A) NO contact
89B03	MADRI_A disconnect (ZONE1_A) NC contact
89A04	MADRI_A disconnect (ZONE2_A) NO contact
89B04	MADRI_A disconnect (ZONE2_A) NC contact
89A05	MADRI_A disconnect (TRANS_A) NO contact
89B05	MADRI_A disconnect (TRANS_A) NC contact
89A06	MILAN_A disconnect (ZONE1_A) NO contact
89B06	MILAN _A disconnect (ZONE1_A) NC contact
89A07	MILAN _A disconnect (ZONE2_A) NO contact
89B07	MILAN _A disconnect (ZONE2_A) NC contact
89A08	MILAN _A disconnect (TRANS_A) NO contact
89B08	MILAN _A disconnect (TRANS_A) NC contact
89A09	ROME_A disconnect (ZONE1_A) NO contact
89B09	ROME _A disconnect (ZONE1_A) NC contact
89A10	ROME _A disconnect (ZONE2_A) NO contact
89B10	ROME _A disconnect (ZONE2_A) NC contact
89A11	ROME _A disconnect (TRANS_A) NO contact

Table 1.87 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Disconnect Input	Description
89B11	ROME _A disconnect (TRANS_A) NC contact
89A12	CAIRO _A disconnect (ZONE1_A) NO contact
89B12	CAIRO _A disconnect (ZONE1_A) NC contact
89A13	CAIRO _A disconnect (ZONE2_A) NO contact
89B13	CAIRO _A disconnect (ZONE2_A) NC contact
89A14	CAIRO _A disconnect (TRANS_A) NO contact
89B14	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.129 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.88* shows the Relay Word bits and description for the zone differential protection outputs.

Table 1.88 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

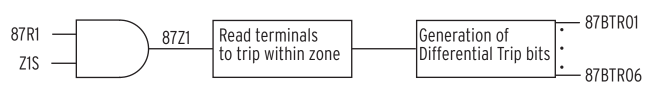


Figure 1.129 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.179* for more information). *Table 1.89* shows the primitive analog channel names, and the differential trip bit names for the differential trip bits.

Table 1.89 Differential Trip Bit Names and the Associated Terminals (Sheet 1 of 2)

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03

Table 1.89 Differential Trip Bit Names and the Associated Terminals (Sheet 2 of 2)

Differential Trip Bit	Description
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 1.130 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF06 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR06 are the outputs from the station breaker failure logic. Relay Breaker failure trip bits SBFTR01–SBFTR06 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

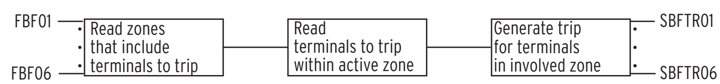


Figure 1.130 Breaker Failure Trip Logic

Table 1.90 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 1.90 Station Breaker Failure Trip Relay Word Bit Names and Associated Terminals

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05
SBFTR06	Associated with Terminal 06

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip six terminals.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 1.131* shows the logic for the external breaker failure function.

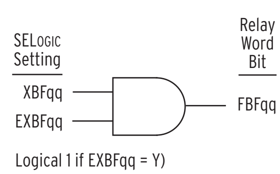


Figure 1.131 Breaker Failure Logic for External Breaker Failure

Table 1.85 and *Table 1.86* show the appropriate XBFqq (qq = 1–6) and relay input assignment (see *Protection Group Settings on page A.1.186*).

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.82 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.91* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 1.92* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.91 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.92* shows the assignment for the five terminals of the A-phase relay.

Table 1.92 Assignment of the Output Contacts

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 1.132*.

1. Write down the bus-zone, terminal and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

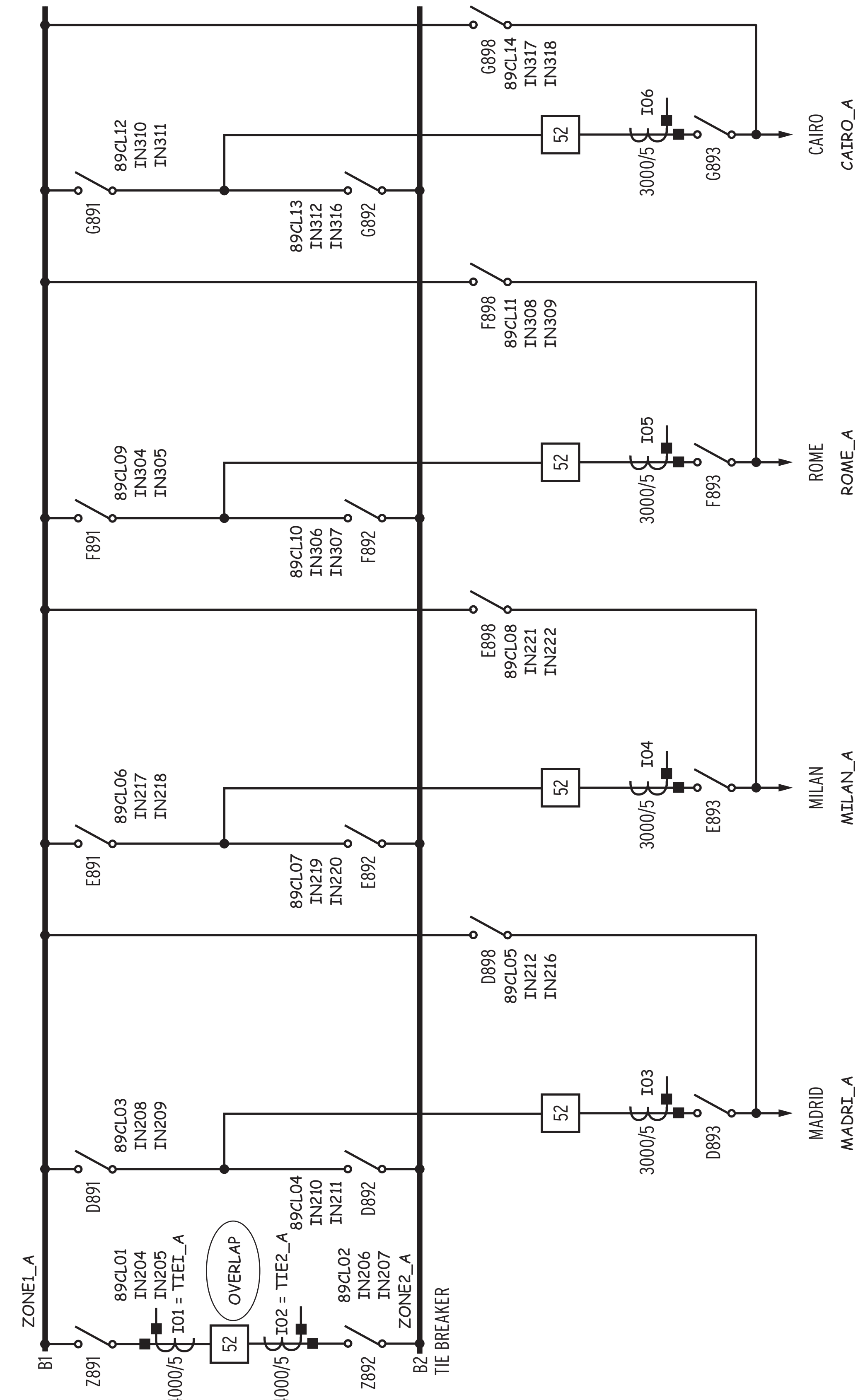


Figure 1.132 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following setting classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.133*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.133 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.134*.

```
1: I01,"FDR_1"
? DELETE 43 <Enter>
```

Figure 1.134 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.135*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE1_A <Enter>
20:
?  I02,TIE2_A <Enter>
21:
?  I03,MADRI_A <Enter>
22:
```

```
?   IO4,MILAN_A <Enter>
23:
?   IO5,ROME_A <Enter>
24:
?   IO6,CAIRO_A <Enter>
25:
?   BZ1,ZONE1_A <Enter>
26:
?   BZ2,ZONE2_A <Enter>
27:
?   END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.135 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.136* shows the setting changes we need for our example. Because we declared the alias names in the previous setting class, use either the alias names or the primitive names when entering settings.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 14 disconnect logics although there are 28 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01 through 14). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 1.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                     NUMBK   := 5     ?<Enter>
Number of Disconnects (N,1-48)                  NUMDS   := N     ?14 <Enter>
Nominal System Frequency (50,60 Hz)             NFREQ   := 60    ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                EDCMON  := N     ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                 GINPU   := 0.17  ?> <Enter>
Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?   > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?   > <Enter>
```

```
Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?   IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?   IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)             89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?   IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?   IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)             89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?   IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?   IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)             89ALP03 := 300    ?<Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?   IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?   IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)             89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.
N/O Contact Input -DS14 (SELogic Equation)
89A14 := NA
?   IN317 <Enter>
N/C Contact Input -DS14 (SELogic Equation)
89B14 := NA
?   IN318 <Enter>
DS14 Alarm Pickup Delay (0-99999 cyc)             89ALP14 := 300    ?<Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.136 Global Settings for Application 6

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfiguring the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page R.1.15* for more information). In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration, and assign the input currents from the CTs to the appropriate differential elements. For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the Milan feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion we define the following terms:

- ➤ Source busbar: the busbar to which all terminals are connected, except the terminal on transfer.
- ➤ Transfer busbar: the busbar to which the terminal on transfer is connected (B1).
- ➤ Transfer disconnect: the disconnect, when closed, bypasses the circuit breaker (e.g., Disconnect G898 on the Cairo Terminal).

Although the relay is flexible enough to accept settings for the many disconnect combinations, we will configure the relay according to the following operating conditions:

- ➤ Only one terminal will be on transfer at any given time, i.e., the transfer Disconnect (*n*898, *n* = D, E, F and G) of only one of the four feeders can be closed at a time.
- ➤ Only Busbar B2 can be the source busbar.
- ➤ The transfer busbar (B1) becomes part of the line protection when a terminal is on transfer.
- ➤ The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step.

Table 1.93 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Assume that Disconnects Z891 and Z892 and the tie-breaker circuit breaker are closed. For brevity, we consider only the MADRID and CAIRO terminals in the following discussion. Consider the case where we put Terminal CAIRO on transfer.

Table 1.93 Fixed Operating Sequence to Put a Terminal on Transfer

Step Number	Description	Comment
1	Switch terminals TD, TE, and TF to the source busbar (B2).	Close all disconnects that connect the terminals to busbar B2 (D892, E892, F892, and G892), and open all disconnects that connect the terminals to busbar B1 (D891, E891, F891, and G891). No current flows through the tie breaker, see *Figure 1.137*. Bus-Zone B1 does not operate because no current flows through the tie breaker. Bus-Zone B2 is balanced because I03 + I06 = 0.
2	Close the transfer Disconnect (G898) of the terminal going on transfer.	This operation forms a parallel path, with ($i_a + i_b - i_a - i_b$) current I_s splitting into i_a and i_b at the D892 and Busbar B2 junction, as shown in *Figure 1.138*. To overcome this problem, remove tie-breaker Channel I02 from the B1 differential calculations when G898 closes. (See the ensuing discussion and *Figure 1.138*).

Table 1.93 Fixed Operating Sequence to Put a Terminal on Transfer

Step Number	Description	Comment
3	Open the circuit breaker of the terminal going on transfer.	Opening the CAIRO circuit breaker interrupts the current path through the circuit breaker. Tie-breaker Channel I01 remains part of the B2 differential calculations to balance the current flow to the CAIRO Terminal.
4	Open the source busbar Disconnect (G892) and the line Disconnect (G893) to isolate the circuit breaker.	Step 4 is shown here to complete the operating sequence; the operation has no effect on the busbar protection.

Figure 1.137 shows the station after Step 1 in *Table 1.93*. Step 1 is standard operating procedure and requires no special busbar protection settings. Because tie-breaker Disconnect Z891 is still closed, both bus-zones B1 and B2 are active. Bus-Zone B1 has only one CT (tie-breaker Channel I02) in place, but because no current flows through the tie breaker, the relay does not operate. Having both zones active provides the benefit of detecting faults on B1 during these operating conditions.

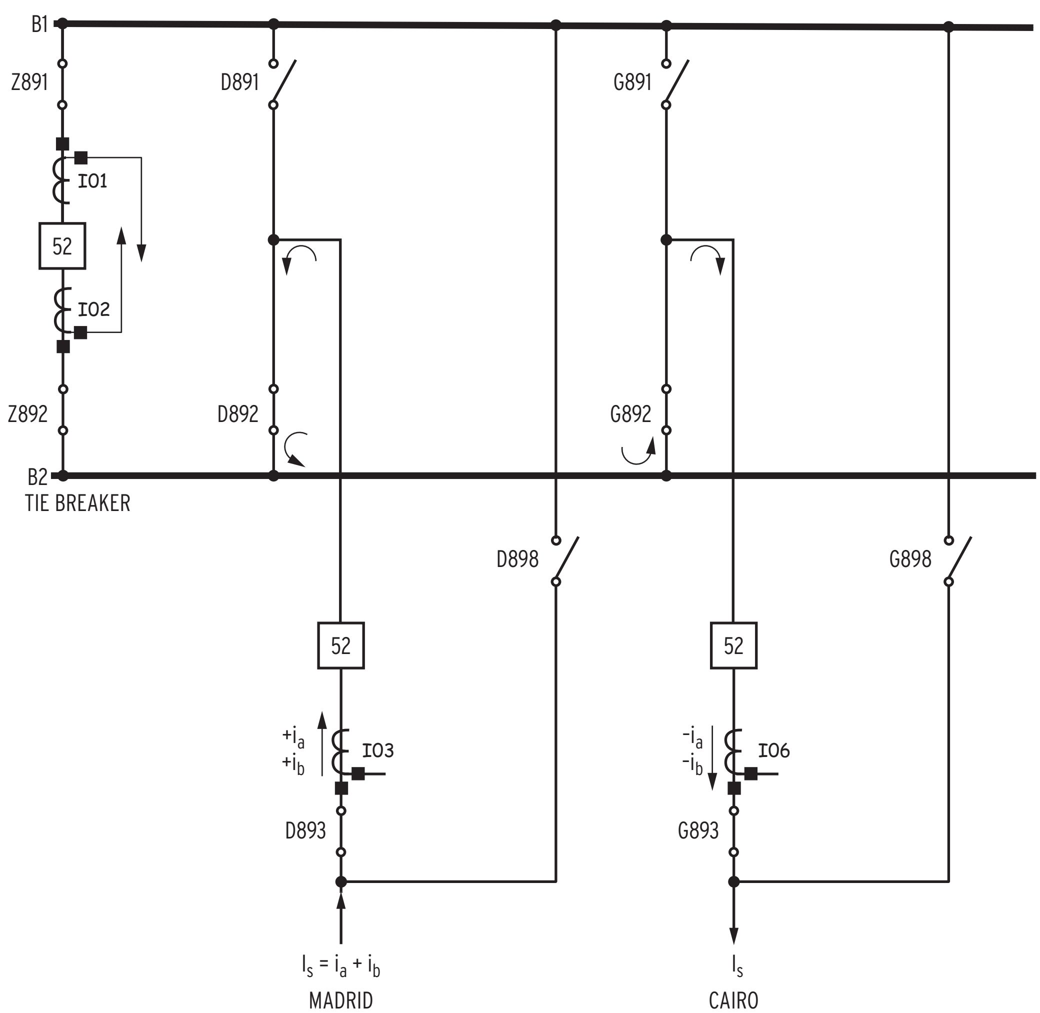


Figure 1.137 Bus-Zones B1 and B2 Are Balanced When All Transfer Disconnects Are Open

Closing Disconnect G898 in Step 2 of *Table 1.93* forms a parallel path. Current I_s enters at the MADRID terminal and splits into i_a and i_b at the D892 and Busbar B2 junction. This current distribution unbalances B1 because current $–i_a$ is missing in the CAIRO CT. The two differential elements calculate the differential currents as follows:

Element for Busbar B1:

$$\begin{aligned} I_{diff} &= (I02) + 0 \text{ (no other CT in place)} \\ &= i_a + 0 \\ &= i_a \text{ (element is unbalanced)} \end{aligned}$$ **Equation 1.23**

Element for Busbar B2:

$$\begin{aligned} I_{diff} &= (I01) + (I03) + (I06) \\ &= (i_a + i_b) - i_a - i_b \\ &= 0 \text{ (element is balanced)} \end{aligned}$$ **Equation 1.24**

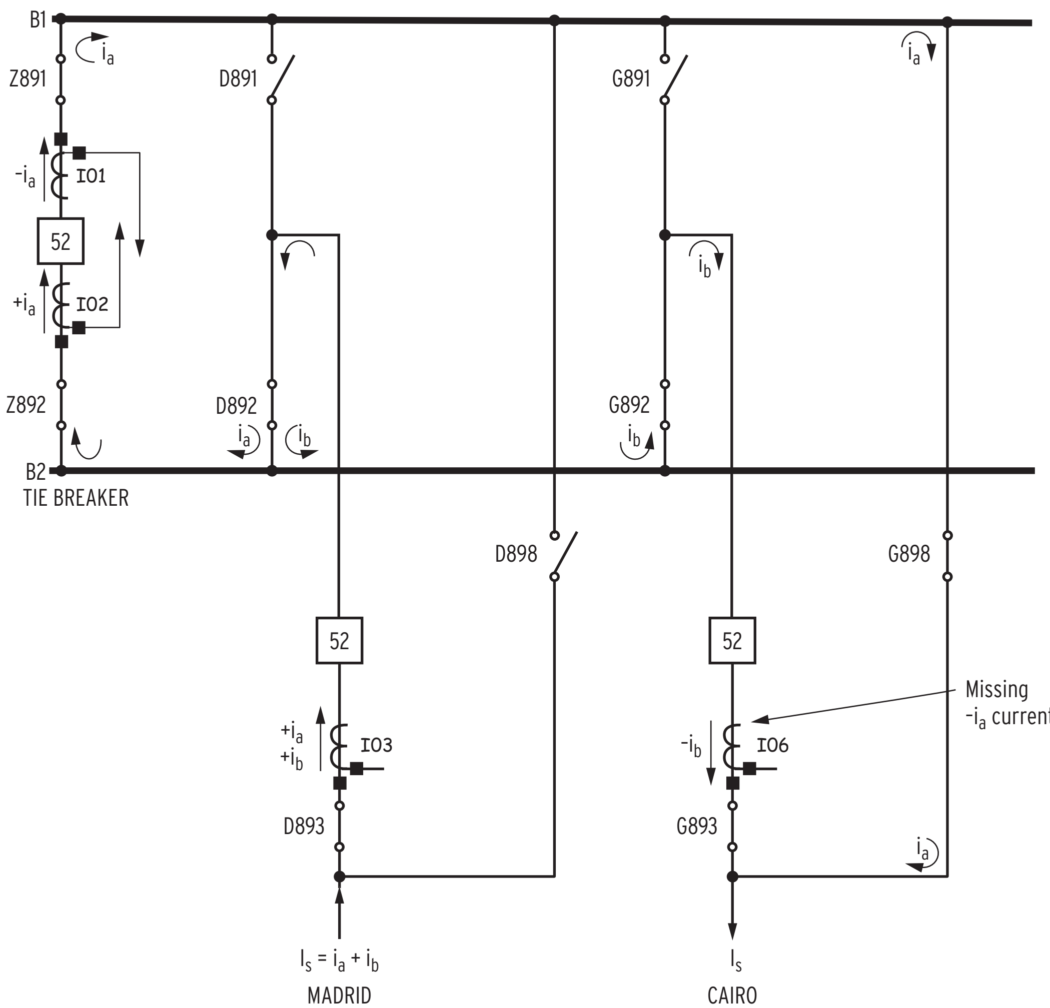


Figure 1.138 Current Distribution During Transfer Procedure Using Inboard CTs

In Step 3 of *Table 1.93*, we open the CAIRO circuit breaker, and the parallel path no longer exists. Current i_b disappears, and I_s flows as shown in *Figure 1.139*. The differential element for Busbar B2 is stable (I01 + I03 = 0), but the differential element for Busbar B1 is unbalanced. To conclude, the differential element for Busbar B1 is unbalanced during the transition period (when a parallel path exists) as well as when the terminal is on transfer.

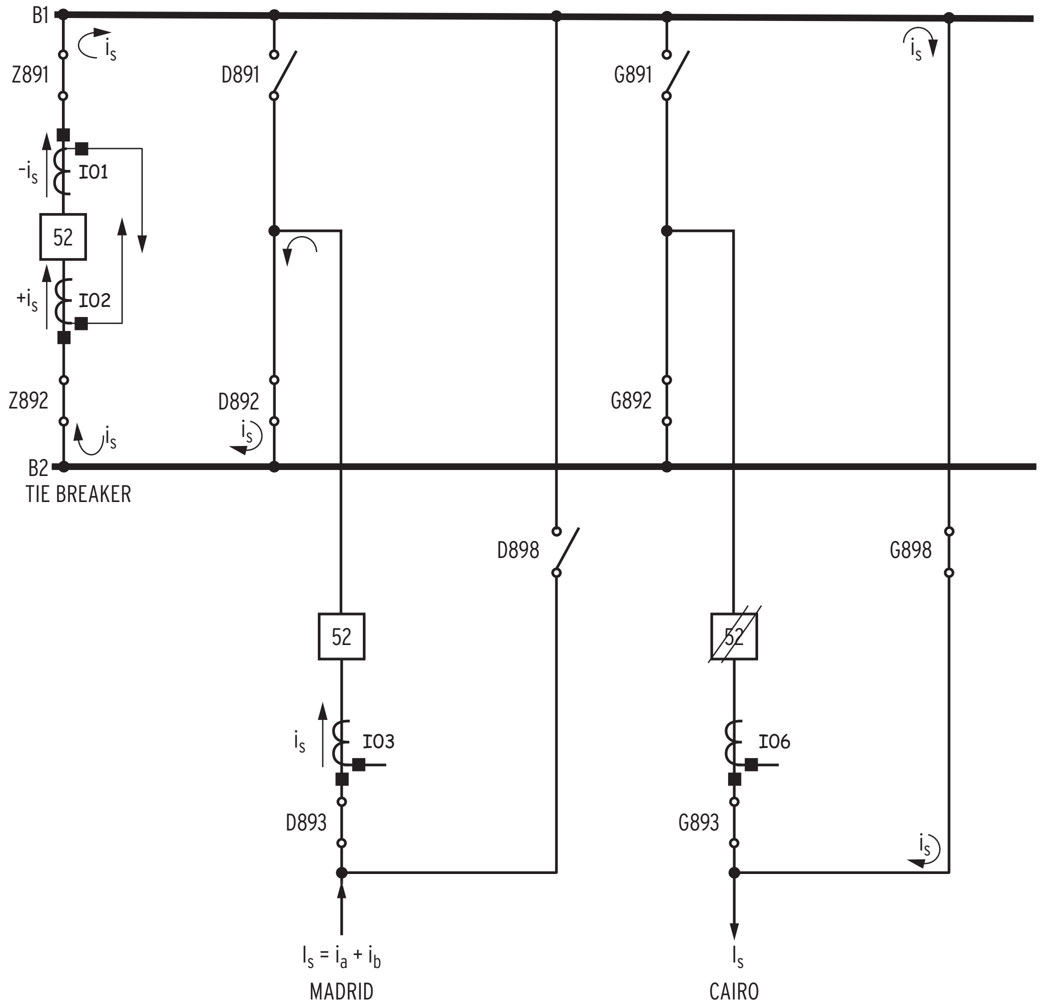


Figure 1.139 Current Distribution After Opening the Circuit Breaker of the Terminal Going on Transfer

Because Disconnect G898 bypasses the CAIRO CT, we cannot provide differential protection for Busbar B1. Because we cannot provide differential protection for Busbar B1, we need to remove the existing differential B1 element to prevent misoperation. We remove differential B1 element by using a zone supervision setting (Z*n*S).

In this application, the tie-breaker current assignment to the differential elements depends on the position of only one of the tie-breaker disconnects: current channel I01 is assigned to B2 when Z892 is closed. Likewise, current channel I02 is assigned to B1 when Z891 is closed. The assignment of the feeder currents to the differential elements depends solely on the corresponding B1 and B2 disconnect positions (*n*891 and *n*892).

Consider also that by removing Differential Element B1, the transfer busbar is without protection. One solution is to use the tie-breaker I02 CT for the line protection, thereby including the transfer busbar as part of the line. When using the SEL-421 as line protection, program the selection functions in the relay to select current I02 as an alternate current source.

To configure the correct disconnect combinations, use the following conditions:

- ➤ With no terminal on transfer, manipulate the tie-breaker CTs with the bus-zone-to-bus-zone connections.
- ➤ A terminal is on transfer when any *n*898 (*n* = D, E, F and G) disconnect is closed.
- ➤ When a terminal is on transfer, disable the differential element for Busbar B1.

Set the Zone Supervision setting for Busbar B1 as follows: Z1S:= NOT (89CL05 OR 89CL08 OR 89CL11 OR 89CL14). *Figure 1.140* shows the Zone Configuration settings for this application.

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example. For the ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.140* shows the Zone Configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE1_A, ZONE1_A, P
?   DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I01,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?   89CL02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I02,ZONE1_A,P <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?   89CL01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?   89CL03 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?   89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
?   89CL06 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?   89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE1_A, <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?   89CL09 <Enter>
```

```
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?   89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I06BZ1V := NA
?   89CL12 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I06BZ2V := NA
?   89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?   ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?   (89CL03 AND 89CL04) OR (89CL06 AND 89CL07) OR (89CL09 AND 89CL10) OR (89CL12\
 AND 89CL13) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?   BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?   TIE1_A,TIE2_A <Enter>
Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?   Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?   NOT(89CL05 OR 89CL08 OR 89CL11 OR 89CL14) <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?<Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.140 Zone Configuration Group Settings for Application 6

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element and the Directional Element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information) to use the sensitive differential element for this requirement. Set TOS := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N because we do not use the Coupler Security Logic, overcurrent elements, terminal out of service, or voltage elements in this application.

Because breaker failure protection measures each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, but six current channels (tie breaker has two CTs). Therefore, select six as the number of breaker failure logics for this application.

This application assumes a single breaker failure input from the tie-breaker protection. With a single breaker failure input from the tie-breaker protection, set both tie-breaker breaker failure initiate setting (XBF01 and XBF02) equal to IN201. For tie breakers with two breaker failure relays, allocate an additional relay input for the second breaker failure input, and equate each relay input to an XBF*nn* settings. For example, assume the two breaker failure inputs are assigned to relay input IN201 and relay input IN202. With these input assignments, set XBF01 := IN201 and XBF02 := IN202.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01 through 52A05), and five corresponding trip equations (TR01 through TR05) available for setting. There are five trip equations available, but there are six analog channels (I01 though I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.89*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Each of the six analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 1.90*) when the breaker failure element asserts. Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

Because the tie breaker has two analog channels, but only one circuit breaker, include both differential trip bits (87BTR01 and 87BTR02) as well as both station breaker failure trip bits (SBFTR01 and SBFTR02) in the trip equation of the tie breaker (TR01). *Figure 1.41* shows the protection group settings for this application.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?<Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
```

```
Advanced Settings (Y,N)                              EADVS   := N       ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N       ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFIDO01 := 1.50    ? <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N       ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFIDO02 := 1.50    ?<Enter>
.
.
.

External Breaker Fail -BK06 (Y,N)                    EXBF06  := N       ?Y <Enter>
External Brkr Fail Init -BK06 (SELogic Equation)
XBF05 := NA
?  IN302<Enter>
Brkr Fail Init Dropout Delay -BK05 (0.00-1000 cyc)   BFIDO05 := 1.50    ?<Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR SBFTR02 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  SBFTR03 OR 87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  SBFTR04 OR 87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?4 <Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  SBFTR06 OR 87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?4 <Enter>
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.141 Protection Group Settings for Application 6

This concludes the protection group settings. The next settings class is control output settings.

Control Output Settings

In this setting class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relay in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA. *Figure 1.142* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?   TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?   TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?   TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?   TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>

Output
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.142 Control Output Settings for Application 6

Application 7: Double and Transfer Bus (Outboard CTs)

This application describes the busbar arrangement shown in *Figure 1.143*. The busbar arrangement consists of three busbars, four terminals, and a tie breaker. Use the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection function selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation
- ➤ Station layout update
- ➤ Relay setting and configuration

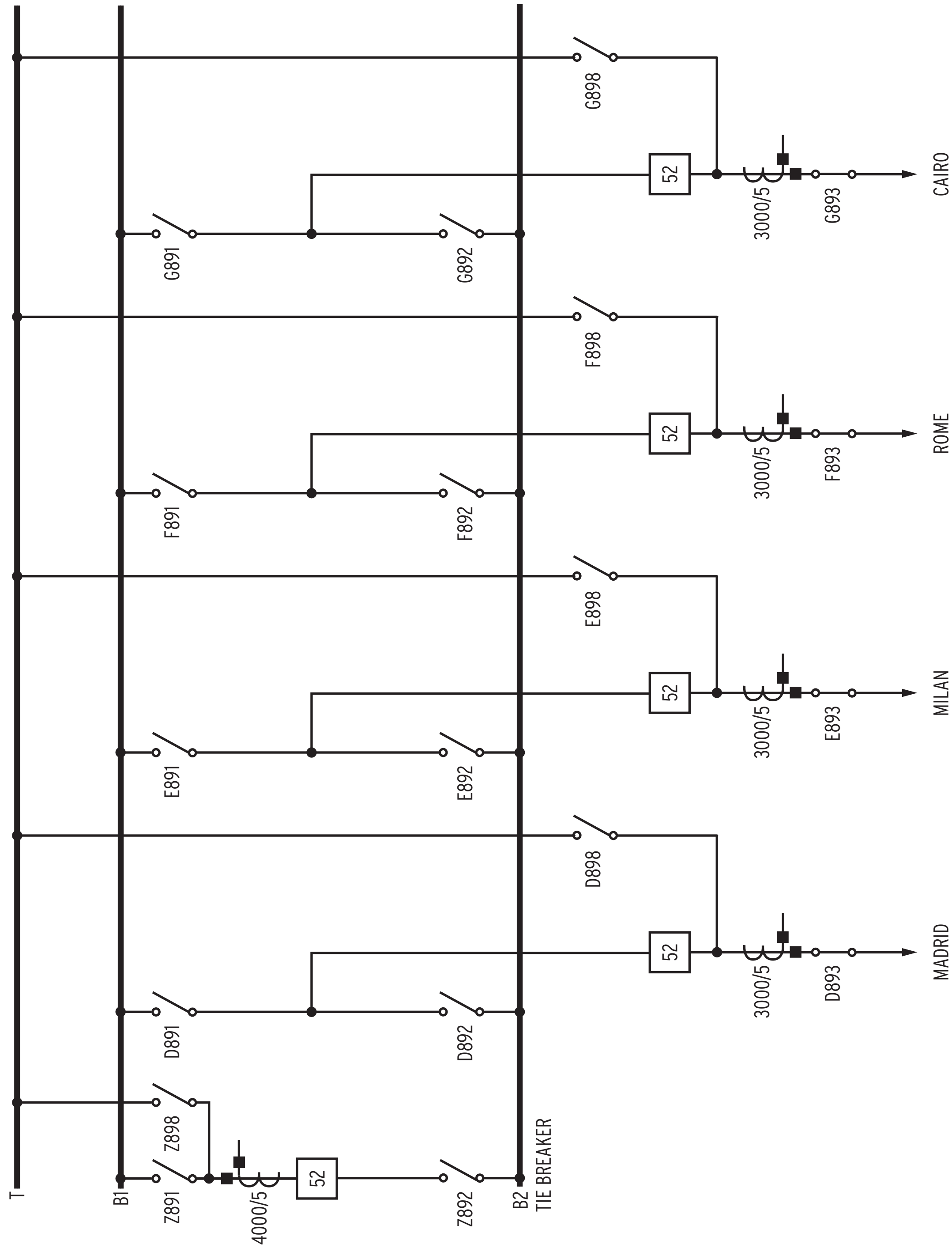


Figure 1.143 Double Bus and Transfer Bus With Buscoupler (Tie Breaker) and Outboard CTs

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and it declares the tie-breaker (buscoupler) configuration.

- Description:
  - Double bus with transfer busbar
- Current transformers:
  - Outboard (free standing)

- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Single CT with one core used for busbar protection
- Future expansion:
  - Five feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every application uses all these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the station.
4. Use the disconnect monitor logic.
5. Use external breaker failure protection.
6. Prevent the loss of Busbar B2 for a fault between the tie breaker and tie-breaker CT.

Protection Functions Selection

We select protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for the use of breaker failure protection but not for overcurrent protection. The SEL-487B offers a number of protection functions as standard features, but it also offers the capability through SELOGIC control equations for you to create user-configurable functions.

To prevent tripping of Busbar B2 when there is a fault between the tie breaker and tie-breaker CT, we can delay tripping of Busbar B2 and trip the tie breaker first (see *Protection Group Settings on page A.1.209*). We then remove the tie-breaker currents from the differential calculations of both zones to trip Busbar B1 and not Busbar B2.

To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created with SELOGIC control equations).

Standard Functions

Refer to *Protection Philosophy* and select the standard functions necessary for the application. *Table 1.94* shows the selection of standard functions.

Table 1.94 Selection of the Standard Protection Functions

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Use the zone supervision logic as part of preventing the loss of Busbar B2 for a fault between the tie breaker and the tie-breaker CT.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	Yes	Use the coupler security logic in a single CT application for enhanced protection for faults between the tie-breaker CT and the circuit breaker.
Circuit breaker failure protection	Yes	External breaker failure
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need that is not part of the standard relay logic in the relay. In this application, we comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay).

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.25* to calculate the number of current channels at the station, and use *Equation 1.26* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.25**

# of bus-zones required = # of per-phase station CTs **Equation 1.26**

The number of per-phase CTs at the station is 15 (tie breaker has three CT cores), so one SEL-487B suffices. However, the requirement for 5 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, the tie breaker and each of the 4 feeders require 3 disconnect monitoring logics; the number of disconnect logics required therefore is 15. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.27* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.27**

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions, and records the terminals in each bus-zone. When a circuit breaker fails, the relay uses this information to only trip the terminals in the bus-zone with the failed circuit breaker. Wire a breaker failure output contact from each breaker failure relay on each of the terminals to the SEL-487B.

We will use the coupler security logic to prevent tripping of Busbar B2 when there is a fault between the tie breaker and the tie-breaker CT. The coupler security logic requires three inputs: a close signal, a circuit breaker 52A auxiliary contact, and an input for the accelerated tripping function (see *Figure 1.108* for more information). We need one input for the circuit breaker 52A auxiliary contact and one input for the closing signal. For the accelerated tripping input (ACTRP1), we use the output from the B2 differential element (87R2). *Table 1.95* summarizes the input contact necessary for this application.

Table 1.95 Relay Input Contacts Requirement

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 15 = 30
Number of relay inputs required for breaker failure protection	5
Number of relay inputs required for the coupler security logic on the tie breaker	2 (one closing signal and one circuit breaker auxiliary 52A contact)
Total number of inputs	37

The relay main board has seven input contacts, an insufficient number of inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs, and use the six independent inputs for the breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.96* shows the breakdown and the number of relay output contacts necessary for tripping.

Table 1.96 Breakdown and Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays required for the application
- the number of inputs
- the number of output contacts
- the selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay inputs
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog Quantity
- Terminal Name
- Bus-Zone Name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.97* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.97* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.143*.

Table 1.97 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT, A-phase	I01	TIE_A
MADRID terminal, A-phase	I02	MADRI_A
MILAN terminal, A-phase	I03	MILAN_A
ROME terminal, A-phase	I04	ROME_A
CAIRO terminal, A-phase	I05	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use three bus-zone alias names, as shown in *Table 1.98*.

Table 1.98 Alias Names for the Three Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A
BZ3	Transfer busbar	TRANS_A

Input-to-Logic Allocation

Table 1.95 shows that we require 37 digital inputs. We now assign the digital inputs to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input-to-Logic Allocation, Interface Board 1 (200)

Table 1.99 and *Table 1.100* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure (only one breaker failure initiate input for the tie breaker) initiate input signals, tie-breaker 52A auxiliary contact, and the tie-breaker closing signal to these relay inputs.

Table 1.99 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN208	TIE-BREAKER disconnect (TRANS _A) NO contact
IN209	TIE-BREAKER disconnect (TRANS _A) NC contact
IN210	MADRID terminal disconnect (ZONE1_A) NO contact
IN211	MADRID terminal disconnect (ZONE1_A) NC contact
IN212	MADRID terminal disconnect (ZONE2_A) NO contact
IN213	TIE-BREAKER circuit breaker 52A auxiliary contact
IN214	TIE-BREAKER circuit breaker closing signal
IN216	MADRID terminal disconnect (ZONE2_A) NC contact
IN217	MADRID terminal disconnect (TRANS _A) NO contact
IN218	MADRID terminal disconnect (TRANS _A) NC contact
IN219	MILAN terminal disconnect (ZONE1_A) NO contact
IN220	MILAN terminal disconnect (ZONE1_A) NC contact

Table 1.99 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN221	MILAN terminal disconnect (ZONE2_A) NO contact
IN222	MILAN terminal disconnect (ZONE2_A) NC contact
IN223	MILAN terminal disconnect (TRANS _A) NO contact
IN224	MILAN terminal disconnect (TRANS _A) NC contact

Input-to-Logic Allocation, Interface Board 2 (300)

Table 1.100 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 1.100 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

The following discussion references *Table 1.94* in explaining each selected function.

Disconnect Monitoring Logic

Figure 1.144 shows one of the 48 disconnect monitor logic circuits available in the relay.

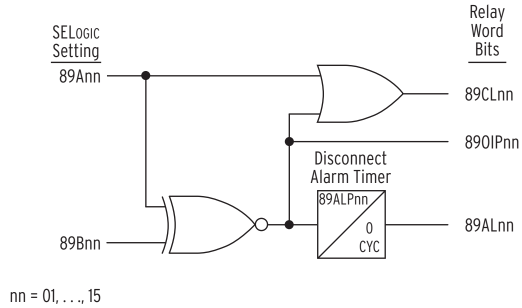


Figure 1.144 Disconnect Monitoring Logic Circuit for Terminal 01

Table 1.101 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.101 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO contact
89B02	TIE-BREAKER disconnect (ZONE2_A) NC contact
89A03	TIE-BREAKER disconnect (TRANS_A) NO contact
89B03	TIE-BREAKER disconnect (TRANS_A) NC contact
89A04	MADRI_A disconnect (ZONE1_A) NO contact
89B04	MADRI_A disconnect (ZONE1_A) NC contact
89A05	MADRI_A disconnect (ZONE2_A) NO contact
89B05	MADRI_A disconnect (ZONE2_A) NC contact
89A06	MADRI_A disconnect (TRANS_A) NO contact
89B06	MADRI_A disconnect (TRANS_A) NC contact
89A07	MILAN_A disconnect (ZONE1_A) NO contact
89B07	MILAN_A disconnect (ZONE1_A) NC contact
89A08	MILAN_A disconnect (ZONE2_A) NO contact
89B08	MILAN_A disconnect (ZONE2_A) NC contact
89A09	MILAN_A disconnect (TRANS_A) NO contact
89B09	MILAN_A disconnect (TRANS_A) NC contact
89A10	ROME_A disconnect (ZONE1_A) NO contact
89B10	ROME_A disconnect (ZONE1_A) NC contact
89A11	ROME_A disconnect (ZONE2_A) NO contact
89B11	ROME_A disconnect (ZONE2_A) NC contact
89A12	ROME_A disconnect (TRANS_A) NO contact
89B12	ROME_A disconnect (TRANS_A) NC contact
89A13	CAIRO_A disconnect (ZONE1_A) NO contact
89B13	CAIRO_A disconnect (ZONE1_A) NC contact
89A14	CAIRO_A disconnect (ZONE2_A) NO contact
89B14	CAIRO_A disconnect (ZONE2_A) NC contact

Table 1.101 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89A15	CAIRO_A disconnect (TRANS_A) NO contact
89B15	CAIRO_A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect inputs to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.145 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.102* shows Relay Word bits and description for the differential protection outputs.

Table 1.102 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip
87Z3	Transfer zone differential element trip

Differential trip bits 87BTR01–87BTR05 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

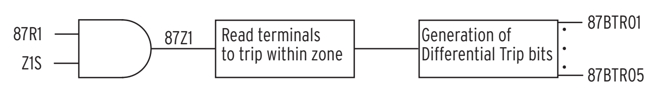


Figure 1.145 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page A.1.205*). *Table 1.103* shows the differential trip bit names and the associated terminal current channels.

Table 1.103 Differential Trip Bit and Associated Terminals

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 1.146 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF05 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR05 are the outputs from the station breaker failure logic. Breaker failure trip bits SBFTR01–SBFTR05 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

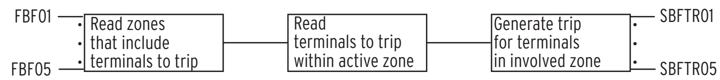


Figure 1.146 Breaker Failure Trip Logic

Table 1.104 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 1.104 Station Breaker Failure Trip Bits and Associated Terminals

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip five circuit breakers.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 1.147* shows the logic for the external breaker failure function.

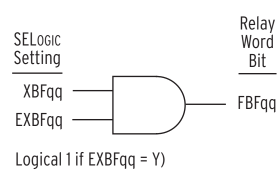


Figure 1.147 Breaker Failure Logic for External Breaker Failure

We assign the relay breaker failure inputs shown in *Table 1.99* and *Table 1.100* to the appropriate XBF*qq* (*qq* = 01 through 05) of the breaker failure protection logic (see *Protection Group Settings on page A.1.209*). *Table 1.105* shows the relay input and terminal assignments.

Table 1.105 Breaker Failure Logic Input Relay Word Bits

Logic Name	Description
IN201	TIE_A breaker failure protection asserted
IN202	MADRI_A breaker failure protection asserted
IN203	MILAN_A breaker failure protection asserted
IN301	ROME_A breaker failure protection asserted
IN302	CAIRO_A breaker failure protection asserted

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.96 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.106* shows TEST and ALARM protection logic output assignment to the main board output contacts. *Table 1.107* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.106 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.107* shows the assignments for the five terminals of the A-phase relay.

Table 1.107 Assignment of the Output Terminals

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip output
OUT202[a]	MADRID trip output
OUT203[a]	MILAN trip output
OUT204[a]	ROME trip output
OUT205[a]	CAIRO trip output

[a] High speed, high interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 1.148*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Allocate the terminal CTs to the relay input current channels.
3. Allocate the terminal auxiliary contacts to the relay digital inputs.
4. Allocate the digital outputs from the relay to the terminals.

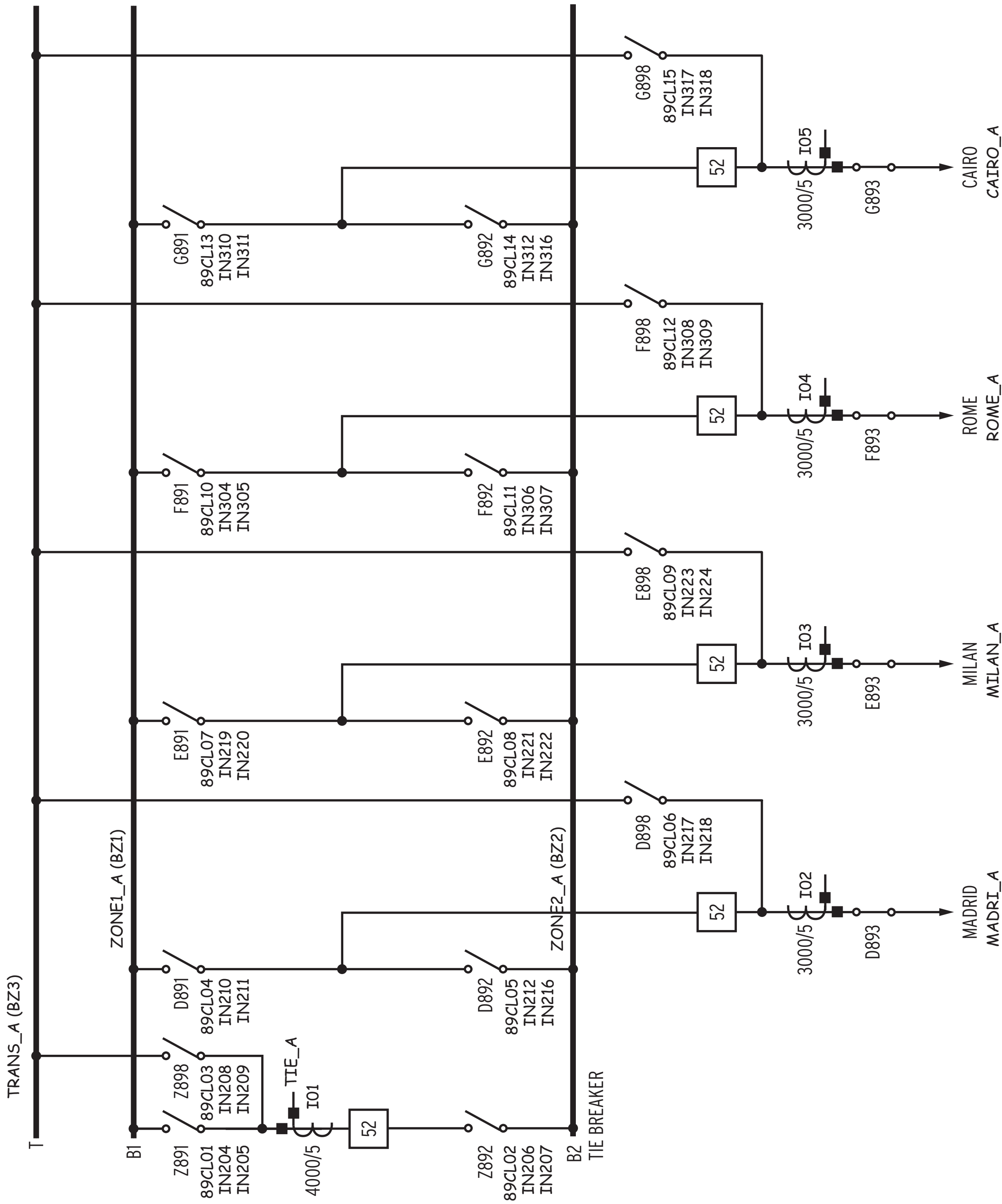


Figure 1.148 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. We set the following settings classes:

- ➤ Alias Settings
- ➤ Global Settings
- ➤ Zone Configuration Group Settings

- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias settings class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.149*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.149 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.150*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.150 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the settings list.

Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.151*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE_A <Enter>
20:
?  I02,MADRI_A <Enter>
21:
?  I03, MILAN_A <Enter>
22:
?  I04, ROME_A <Enter>
23:
?  I05, CAIRO_A <Enter>
24:
?  BZ1,ZONE1_A <Enter>
25:
?  BZ2,ZONE2_A <Enter>
26:
?  BZ3,TRANS_A <Enter>
```

```
27:
?  END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.151 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.152* shows the settings changes we need for our example. Because we declared the alias names in the previous settings class, use either the alias names or the primitive names when entering settings.

Set NUMBK to 5 because there are five circuit breakers at the station. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting.

Declare here the input for the breaker status logic (52A01) for current channel I01 (52A01:= IN213). Set the remaining four circuit breaker auxiliary input equations (52A02–52A05) to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 15 disconnect logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–15). Travel time is the period during which both disconnect auxiliary contacts are in the open position. Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                     NUMBK   := 5     ?<Enter>
Number of Disconnects (N,1-48)                  NUMDS   := N     ?15 <Enter>
Nominal System Frequency (50,60 Hz)             NFREQ   := 60    ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                EDCMON  := N     ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                 GINPU   := 0.17  ?> <Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
```

```
Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  IN213 <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
? <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)           89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)           89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)           89ALP03 := 300    ?400 <Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)           89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 1.152 Global Settings

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism for automatically reconfiguring the zone of protection, without any wiring changes (see *Dynamic Zone Selection Logic on page R.1.15* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements.

For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay. Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the Milan feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect that connects the feeder to the transfer busbar (Disconnect G898 on the CAIRO Feeder)

Although the relay is flexible enough to accept settings for many possible disconnect combinations, we will configure the relay according to the following operating conditions:

1. Only one terminal will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z898) and the transfer disconnect (*n*898, *n* = D, E, F, G) of only one of the four terminals can be closed simultaneously.
2. Only Busbar B2 can be the source busbar.
3. The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step. *Table 1.108* shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Refer to *Figure 1.155* and consider a case in which we put the CAIRO Feeder on transfer. Assume that the tie breaker is closed and that tie-breaker disconnect Z891 and disconnect Z892 are closed.

Table 1.108 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Switch all terminals to the source busbar (B2).	Close all the disconnects that connect the terminals to ZONE2_A (D892, E892, etc.)
2	Open the tie-breaker circuit breaker. Open Disconnect Z891, and close Disconnect Z898.	Closing Disconnects Z891 and Z898 forms the path from source busbar to transfer busbar (Busbar B2 to Busbar T).
3	Close the tie-breaker circuit breaker.	Busbar B2 and Busbar T are at the same potential.
4	Close the transfer disconnect of the terminal going on transfer (G898).	The relay now forms a differential zone for the transfer busbar.
5	Open the circuit breaker of the terminal going on transfer (Cairo circuit breaker).	Terminal G is now on transfer. Operation of disconnect G893 does not affect the busbar protection, and is not mentioned.

The zone configuration default settings are settings for a specific substation with arbitrarily selected alias names serving only as an example.

We use a combination of the zone supervision and coupler security logic to prevent tripping Busbar 2 for a fault between the tie-breaker circuit breaker and CT. For the zone supervision setting, we supervise the BZ2 differential element output by the negated coupler security output (ZS2 := NOT CSL1) see the *Protection Group Settings on page A.1.209* for more information.

For ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 1.153* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000    ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600     ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600     ? <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600     ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE_A, ZONE1_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE2_A,P <Enter>
TIE_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?  (89CL01 OR 89CL03) AND 89CL02 AND (CB52A1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE1_A,N <Enter>
TIE_A to ZONE1_A Connection (SELogic Equation)
I01BZ1V := NA
?  89CL01 AND 89CL02 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,TRANS_A,N <Enter>
TIE_A to TRANS_A Connection (SELogic Equation)
I01BZ3V := NA
?  89CL03 AND 89CL02 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?  89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I02BZ2V := NA
?  89CL05 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I02,TRANS_A,P <Enter>
MADRI_A to TRANS_A Connection (SELogic Equation)
I02BZ3V := NA
?  89CL06 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?  89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?  89CL08 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,TRANS_A,P <Enter>
MILAN_A to TRANS_A Connection (SELogic Equation)
I03BZ3V := NA
?  89CL09 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
```

```
?   89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?   89CL11 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,TRANS_A,P <Enter>
ROME_A to TRANS_A Connection (SELogic Equation)
I04BZ3V := NA
?   89CL12 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?   89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?   89CL14 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,TRANS_A,P <Enter>
CAIRO_A to TRANS_A Connection (SELogic Equation)
I05BZ3V := NA
?   89CL15 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?   ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?   (89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?   BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?   I01 <Enter>
Trip Terminals TIE_A (Y,N)
BZ1BZ2T := N
?   Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>
Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?<Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?   NOT CSL1 <Enter>
Zone 3 Supervision (SELogic Equation)
Z3S := 1
?   <Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.153 Zone Configuration Group Settings

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the sensitive differential element, the restrained differential element and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13*). Because we do not use the terminal out of service, overcurrent elements, or voltage elements in this application, set ETOS := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N.

Because the relay associates breaker failure protection with each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, and also five current channels (tie breaker has one CT channel). Therefore, select 5 as the number of breaker failure logics for this application. Setting NUMBK equal to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. Be sure to include the Differential Trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the {TARGET RESET} pushbutton on the front panel. An alternative way is to enter specific reset conditions at the ULTR*kk* settings.

Each of the five analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 1.105*) when the breaker failure element asserts.

Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

We use a combination of the zone supervision and coupler security logics to prevent tripping Busbar 2 for faults between the tie-breaker circuit breaker and the CT.

Figure 1.154 shows the combination of the coupler security logic and the zone supervision, with the input settings applied. Notice that Gate 1 and Gate 2 represent the tie-breaker terminal-to-bus-zone connection settings; they are not part of the logic.

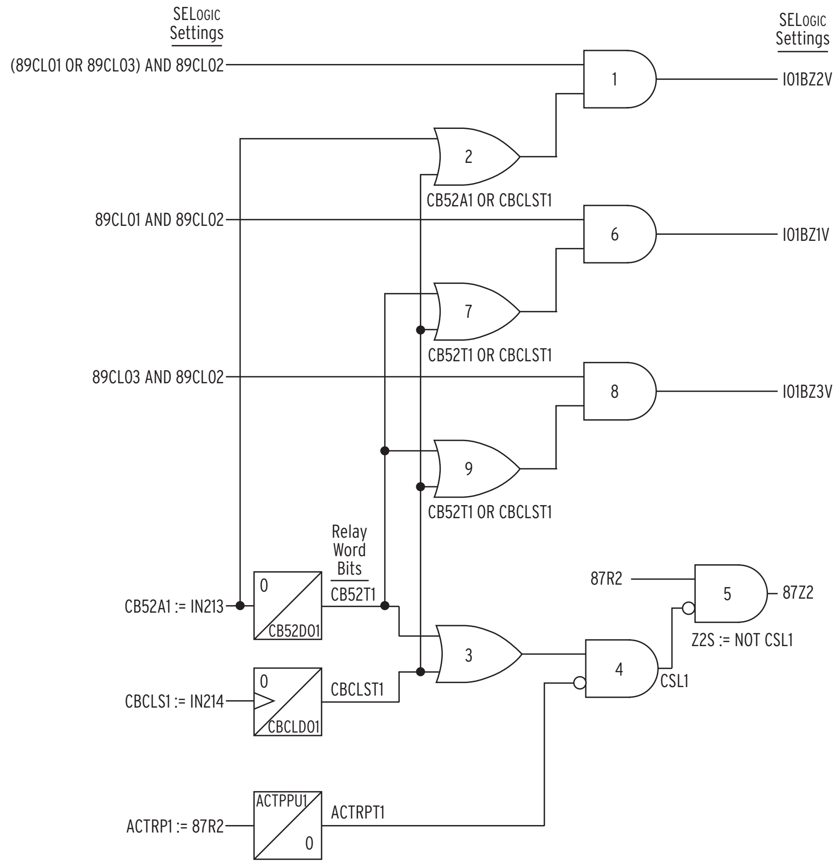


Figure 1.154 Combination of the Coupler Security Logic and the Zone Supervision to Prevent the Loss of Two Zones

Assume for this application that the maximum circuit breaker tripping time is 2 cycles and that the maximum closing time is 3 cycles. Refer to *Figure 1.154*, and notice that Inputs CB52A1 and CBCLS1 provide the circuit breaker status and the closing signal information to the relay. These two inputs are in parallel, complementing each other to provide accurate circuit breaker status during open-to-close and close-to-open circuit breaker operations.

When the operator issues a closing signal to the circuit breaker, Input CBCLS1 asserts, asserting Relay Word bit CBCLST1. We used CBCLST1 in the I01BZ1V, I01BZ2V, and I01BZ3V terminal-to-bus-zone settings. When Relay Word bits I01BZ1V, I01BZ2V, and I01BZ3V assert, the relay considers the CT in the differential calculations.

Set the timer dropout time (CBCLDO1) to a value longer than the maximum breaker closing time. In this example, allow a short safety margin and set CBCLDO1 to 5 cycles (default value).

Inserting the CTs in the differential equations before primary current flows emulates the early make, late break timing requirement for the disconnect auxiliary contacts. A setting of 5 cycles allows the circuit breaker ample time to change state, during which time the CB52A1 Relay Word bit asserts.

When opening the circuit breaker, the inverse applies. For a close-to-open circuit breaker operation, we must guard against prematurely removing the CTs from the differential equations due to circuit breaker auxiliary contact misalignment. We use CB52T1 in the tie-breaker terminal-to-bus-zone connection settings to accomplish this for Zone 1 and Zone 3. However, because we supervise all Zone 2 faults, premature removal of the CTs does not adversely affect Zone 2 differential elements.

Two tie-breaker operating conditions are possible: when the tie breaker connects between Busbar B1 and Busbar B2 (Disconnect Z891 and Disconnect Z892 are closed) or when the tie breaker connects between Busbar B2 and the Transfer busbar (Disconnect Z892 and Disconnect Z898 are closed).

The following discussion describes the prevention of the loss of Busbar 2 when the tie breaker connects between Busbar B1 and Busbar B2, but the same argument applies when a feeder is on transfer.

Figure 1.155 shows Busbar B1, Busbar B2, the tie breaker, and two of the four terminals at the station. The challenge to the coupler security logic is to trip Busbar B1 and not Busbar B2 for Fault F1. This requirement contradicts the existing configuration, for it calls for the coupler security logic to prevent the differential element of Busbar B2 from operating for an in-zone fault (fault on Busbar 2), and for the differential element of Busbar B1 to operate for an out-of-zone fault (fault on Busbar 2).

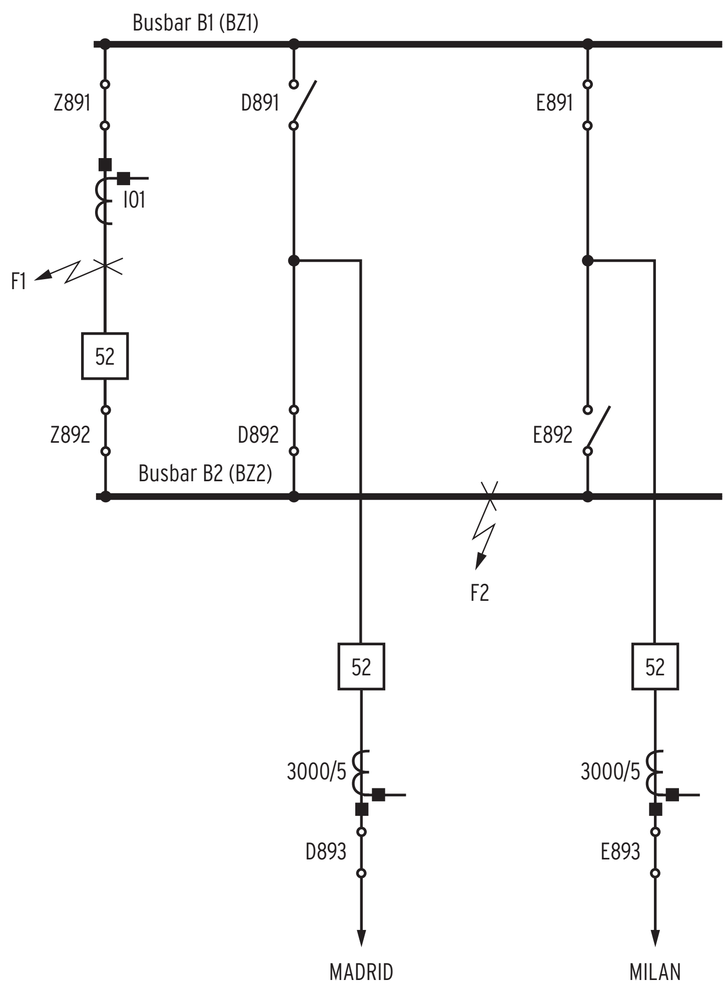


Figure 1.155 Single CT Application With Faults Between the Circuit Breaker and Tie-Breaker CT

Consider the operation when Fault F1 occurs without the coupler security logic. Differential protection B1 is stable, and differential protection B2 immediately trips the MADRID circuit breaker and the tie-breaker circuit breaker. However, tripping the MADRID circuit breaker and the tie-breaker circuit breaker does not clear Fault F1. Fault current still flows from the MILAN Feeder through Busbar B1 and into the fault. Although breaker failure protection will operate to trip the MILAN circuit breaker, this operation takes place after the breaker failure time delay. After the tie-breaker breaker failure timer times out, all circuit breakers in B1 trip, resulting in both B1 and B2 tripping to clear Fault F1.

If a delay in bus-zone protection operation is in order, implement the coupler security logic in a way that trips bus-zone B2 only when the tie-breaker circuit breaker is open. To prevent tripping of bus-zone B2, configure the relay to achieve the following:

1. Check if the tie breaker is closed. If the tie breaker is closed, trip only the tie breaker to interrupt the fault current from B2; trip no other circuit breakers. If the tie breaker is open, allow normal busbar protection tripping.
2. When the tie breaker is open, remove the tie-breaker CT from the differential calculations of B2 and eventually B1.

To check the tie-breaker status and remove the CT from the supervised zone when the tie breaker is open, use the tie-breaker auxiliary contact in the tie-breaker terminal-to-bus-zone connection settings. To remove the CT from the unsupervised zone, use the coupler status timed-out bit (CB52T1) in the tie-breaker terminal-to-bus-zone connection settings. To trip only the tie breaker for a fault on Busbar 2 requires the following two settings:

➤ Supervising the BZ2 differential element
➤ Issuing a trip signal to the tie breaker first

Supervise the BZ2 differential element output with the negated output from the coupler security logic (Z2S := NOT CSL1). We assign 87R2, the unsupervised output from the BZ2 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. When accelerated trip timer output (ACTRPT1) asserts, Gate 4 in *Figure 1.154* turns off and Relay Word bit CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, removing the supervision from the BZ2 differential element.

Supervising the BZ2 differential element in this way prevents the tripping of all terminals in BZ2, including the tie breaker. To still trip the tie breaker, include 87R2, the unsupervised output from Differential Element 2, in the trip equation of the tie breaker.

After the tie breaker opens, we remove the tie-breaker CT from the differential calculations of BZ2 but not the BZ2 supervision. Maintain the BZ2 supervision for at least another 1.25 cycles (add a safety margin of 0.75 cycle) to allow the differential element to reset. Achieve this delay by setting ACTPPU1 to at least 4 cycles.

For Fault F1, BZ2 operates, asserting Relay Word bit 87R2. When Relay Word bit 87R2 asserts, the accelerated trip timer starts timing. Because of the BZ2 zone supervision (NOT CSL1), 87Z2 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie breaker trips, interrupting the fault current contribution from BZ2. Assume the circuit breaker auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ2V and eventually I01BZ1V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. For Fault F1, the bus coupler circuit breaker is open, but fault current still flows through the CT. BZ2 is stable when the relay removes the CTs because the bus coupler circuit breaker is open, and terminals from BZ2 no longer contribute to the fault. However, removing the CTs causes BZ1 to operate because the BZ1 balancing current from the bus coupler CT disappeared. Removing the bus sectionalizer CTs also deasserts Relay Word bit 87R2, causing the accelerated trip timer to stop timing. Fault F1 is now cleared, by tripping the correct busbar, although after a time delay.

For Fault F2, the initial tripping is the same as for Fault F1: BZ2 operates, asserting Relay Word bit 87R2. When Relay Word bit 87R2 asserts, the accelerated trip timer starts timing. Because of the BZ2 zone supervision (NOT CSL1), 87Z2 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie breaker trips, and the auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ2V and eventually I01BZ1V to also deassert. When Relay Word bits I01BZ2V and I01BZ1V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. Because the bus coupler circuit breaker is open, terminals from BZ1 no longer contribute to the fault and BZ1 is stable. However, the BZ2 zone supervision (NOT CSL1) still supervises the BZ2 trip output for another two cycles. Two cycles later, Accelerate Trip Timer ACTRP1 times out, causing CSL1 to deassert. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, removing the zone supervision from BZ2 and issuing a trip signal to all circuit breakers on Busbar 2.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 1.156* shows the Group 1 settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?1 <Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6      ?5 <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N      ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Coupler 1 Security Logic

Coupler 1 Status (SELogic Equation)
CB52A1 := NA
?  IN213 <Enter>
Coupler 1 Status Dropout Delay (0.00-1000 cyc)       CB52DO1 := 4.00   ?<Enter>
Coupler 1 Close Command (SELogic Equation)
CBCLS1 := NA
?  IN214 <Enter>

Coupler 1 Close Command D/O Delay (0.00-1000 cyc)    CBCLDO1 := 5.00   ?<Enter>
```

```
Coupler 1 Acc Trip (SELogic Equation)
ACTRP1 := NA
?  87R2 <Enter>
Coupler 1 Acc Trip Pickup Delay (0.00-1000 cyc)      ACTPPU1 := 4.00   ?<Enter>

Breaker 01 Failure Logic

External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>

Breaker 02 Failure Logic

External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN202 <Enter>

Breaker 03 Failure Logic

External Breaker Fail -BK03 (Y,N)                    EXBF03  := N      ?Y <Enter>
External Brkr Fail Init -BK03 (SELogic Equation)
XBF03 := NA
?  IN203 <Enter>

Breaker 04 Failure Logic

External Breaker Fail -BK04 (Y,N)                    EXBF04  := N      ?Y <Enter>
External Brkr Fail Init -BK04 (SELogic Equation)
XBF04 := NA
?  IN301<Enter>

External Breaker Fail -BK05 (Y,N)                    EXBF05  := N      ?Y <Enter>
External Brkr Fail Init -BK05 (SELogic Equation)
XBF05 := NA
?  IN302 <Enter>
Brkr Fail Init Dropout Delay -BK05 (0.00-1000 cyc)   BFIDO05 := 1.50   ?<Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR 87R2 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.

Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?<Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.156 Protection Group Settings for Application 7

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101 through OUT106 = NA. *Figure 1.157* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>
Interface Board #1

OUT201 := NA
?   TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?   TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?   TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?   TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?   TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.157 Control Output Settings for Application 7

This concludes the settings for Application 7.

Application 8: Double and Transfer Bus (Inboard CTs)

This application describes the busbar arrangement shown in *Figure 1.158*. The busbar arrangement consists of three busbars, four terminals, and a tie breaker. Use the following to set and configure the relay:

- ➤ Busbar classification
- ➤ Protection philosophy
- ➤ Protection function selection
- ➤ Number of SEL-487B relays and I/O boards
- ➤ Input, logic, and output allocation
- ➤ Station layout update
- ➤ Relay setting and configuration

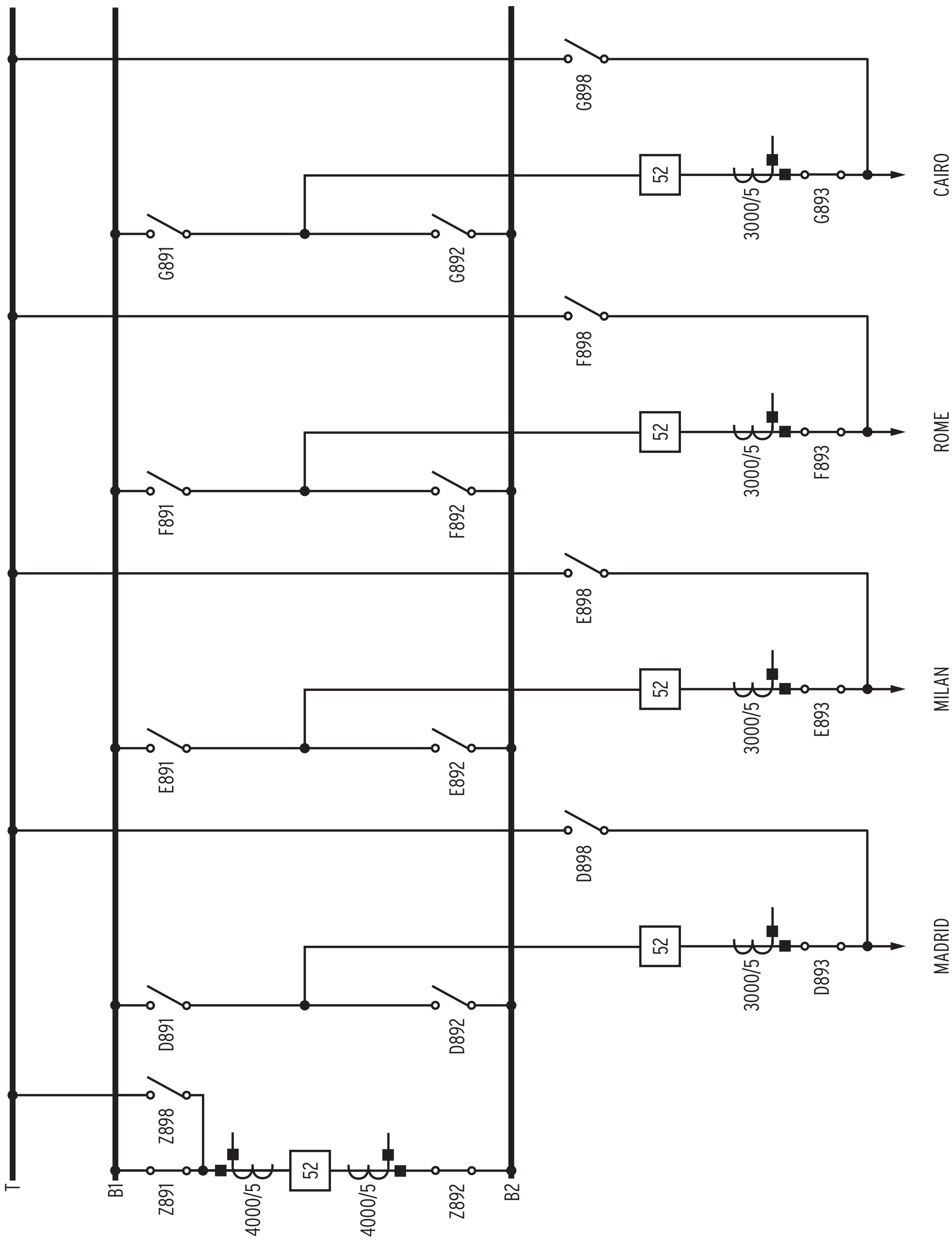


Figure 1.158 Double Bus and Transfer Bus With Buscoupler (Tie Breaker) and Inboard CTs

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and it declares the tie-breaker (buscoupler) configuration.

- ➤ Description:
  - ➢ Double bus with transfer busbar
- ➤ Current transformers:
  - ➢ Bushing (inboard)

- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Buscoupler (tie breaker):
  - Two CTs, configured in overlap
- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every application uses all these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the station.
4. Use the disconnect monitor logic.
5. Ensure stable differential protection for all operating conditions.

Protection Functions Selection

We select protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. The SEL-487B offers a number of protection functions as standard features, but it also offers the capability through SELOGIC control equations for you to create user-configurable functions. Requirement 5 of the protection philosophy calls for stable differential protection for all operating conditions. There are two network conditions when the differential protection can become unstable:

- when disconnects *n*891 and *n*892 (*n* = D, E, F, G) of any feeder are closed at the same time
- when the transfer disconnect of any feeder is closed

By following the correct operating sequence, and by declaring the appropriate conditions in the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable for all operating conditions.

Standard Functions

Refer to the *Protection Philosophy* and select the standard functions necessary for the application. *Table 1.109* shows the selection of standard functions.

Table 1.109 Selection of the Standard Protection Functions

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	Use the sensitive differential element as CT open-circuit detection.
Zone supervision logic	No	Not required. We achieve relay stability with terminal-to-bus-zone and bus-zone-to-bus-zone connection settings.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	No	Two CTs configured in overlap do not require the coupler security logic.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need that is not part of the standard relay logic in the relay. In this application, we comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- ➤ the number of relays (single-relay application or three-relay application)
- ➤ the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 18 current channels and three voltage channels. For stations with up to 18 CTs (per phase), we can install a single SEL-487B. For stations with more than 18 and as many as 54 CTs, we install three SEL-487B relays. Use *Equation 1.28* to calculate the number of current channels at the station, and use *Equation 1.29* to calculate the number of zones at the station.

# of current channels required = # of per-phase station CTs **Equation 1.28**

# of bus-zones required = # of per-phase station bus sections **Equation 1.29**

The number of per-phase CTs at the station is 18 (tie breaker has six CT cores), so one SEL-487B suffices. However, the requirement for four future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 18 analog input channels, we need three relays. This is known as a three-relay application. In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, all the B-phase CTs to Relay 2, and all the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, the tie breaker and each of the 4 feeders require 3 disconnect monitoring logics; the number of disconnect logics required is therefore 15. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs, an 89A and an 89B contact. Use *Equation 1.30* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

relay inputs required = 2 • # disconnect monitoring logics **Equation 1.30**

Table 1.110 summarizes the input contact required for this application.

Table 1.110 Relay Input Contacts Requirement

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 15 = 30
Total number of inputs	30

The relay main board has seven inputs, an insufficient number of inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs, and use the six independent inputs for future breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 1.111* shows the breakdown and the number of relay output contacts necessary for tripping.

Table 1.111 Breakdown and Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the {RELAY TEST MODE} pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board output contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B relays required for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- assign each CT input to a specific relay analog channel
- assign each disconnect input to specific relay inputs
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog Quantity
- Terminal Name
- Bus-Zone Name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 1.112* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 1.112* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 1.158*.

Table 1.112 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. Although there are three busbars at the station, we only provide differential protection for Busbar B1 and Busbar B2. Because the feeders have bushing CTs, the transfer busbar never forms part of the busbar protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 1.113*.

Table 1.113 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input-to-Logic Allocation

Table 1.110 shows that we require 30 digital inputs. We now assign the digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input-to-Logic Allocation, Interface Board 1 (200)

Table 1.114 and *Table 1.115* show the disconnect auxiliary contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we preserve these for future circuit breaker failure inputs.

Table 1.114 Disconnect Contact Input Allocations

Input	Description
IN204	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN208	TIE-BREAKER disconnect (TRANS_A) NO contact
IN209	TIE-BREAKER disconnect (TRANS_A) NC contact
IN210	MADRID terminal disconnect (ZONE1_A) NO contact
IN211	MADRID terminal disconnect (ZONE1_A) NC contact
IN212	MADRID terminal disconnect (ZONE2_A) NO contact
IN216	MADRID terminal disconnect (ZONE2_A) NC contact
IN217	MADRID terminal disconnect (TRANS_A) NO contact
IN218	MADRID terminal disconnect (TRANS_A) NC contact
IN219	MILAN terminal disconnect (ZONE1_A) NO contact
IN220	MILAN terminal disconnect (ZONE1_A) NC contact
IN221	MILAN terminal disconnect (ZONE2_A) NO contact
IN222	MILAN terminal disconnect (ZONE2_A) NC contact
IN223	MILAN terminal disconnect (TRANS_A) NO contact
IN224	MILAN terminal disconnect (TRANS_A) NC contact

Input-to-Logic Allocation, Interface Board 2 (300)

Table 1.115 shows the disconnect and auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we preserve these inputs for future circuit breaker failure inputs.

Table 1.115 Disconnect Contact Input Allocations

Input	Description
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

The following discussion references *Table 1.109* in explaining each selected function.

Disconnect Monitoring Logic

Figure 1.159 shows the disconnect monitor logic circuit available in the relay. See *Figure 1.20* for more information.

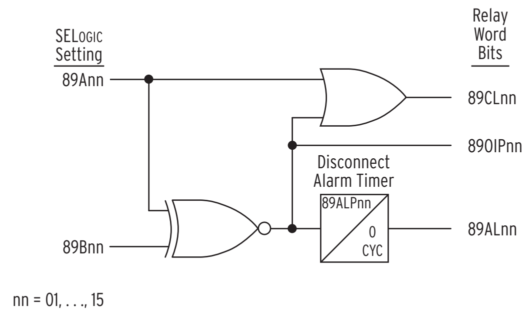


Figure 1.159 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 1.116 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 1.116 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO
89B02	TIE-BREAKER disconnect (ZONE2_A) NC
89A03	TIE-BREAKER disconnect (TRANS_A) NO
89B03	TIE-BREAKER disconnect (TRANS _A) NC
89A04	MADRI_A disconnect (ZONE1_A) NO contact
89B04	MADRI_A disconnect (ZONE1_A) NC contact
89A05	MADRI_A disconnect (ZONE2_A) NO contact
89B05	MADRI_A disconnect (ZONE2_A) NC contact
89A06	MADRI_A disconnect (TRANS_A) NO contact
89B06	MADRI_A disconnect (TRANS_A) NC contact
89A07	MILAN_A disconnect (ZONE1_A) NO contact
89B07	MILAN _A disconnect (ZONE1_A) NC contact
89A08	MILAN _A disconnect (ZONE2_A) NO contact
89B08	MILAN _A disconnect (ZONE2_A) NC contact
89A09	MILAN _A disconnect (TRANS_A) NO contact
89B09	MILAN _A disconnect (TRANS_A) NC contact
89A10	ROME_A disconnect (ZONE1_A) NO contact
89B10	ROME _A disconnect (ZONE1_A) NC contact
89A11	ROME _A disconnect (ZONE2_A) NO contact
89B11	ROME _A disconnect (ZONE2_A) NC contact

Table 1.116 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89A12	ROME _A disconnect (TRANS_A) NO contact
89B12	ROME _A disconnect (TRANS_A) NC contact
89A13	CAIRO _A disconnect (ZONE1_A) NO contact
89B13	CAIRO _A disconnect (ZONE1_A) NC contact
89A14	CAIRO _A disconnect (ZONE2_A) NO contact
89B14	CAIRO _A disconnect (ZONE2_A) NC contact
89A15	CAIRO _A disconnect (TRANS_A) NO contact
89B15	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hard wire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 1.160 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 1: Protection Functions in the Reference Manual* for more information.) *Table 1.117* shows Relay Word bits and description for the zone differential protection outputs. Because of the bushing (inboard) CTs, we cannot provide differential protection for the transfer busbar.

Table 1.117 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 1: Protection Functions in the Reference Manual* for more information.)

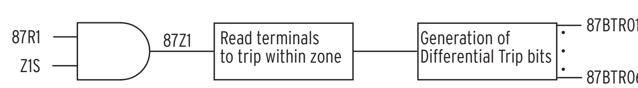


Figure 1.160 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see Global settings for more information). *Table 1.118* shows the differential trip bit names and the associated terminal current channels.

Table 1.118 Differential Trip Bit Names and Associated Terminal Names

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 1.111 shows the relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 1.119* shows TEST and ALARM protection logic output assignment to the main board output contacts. *Table 1.120* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 1.119 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 1.120* shows the assignment of the A-phase relay output terminals.

Table 1.120 Assignment of the Output Terminals

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 1.161*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.

4. Allocate the terminal auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

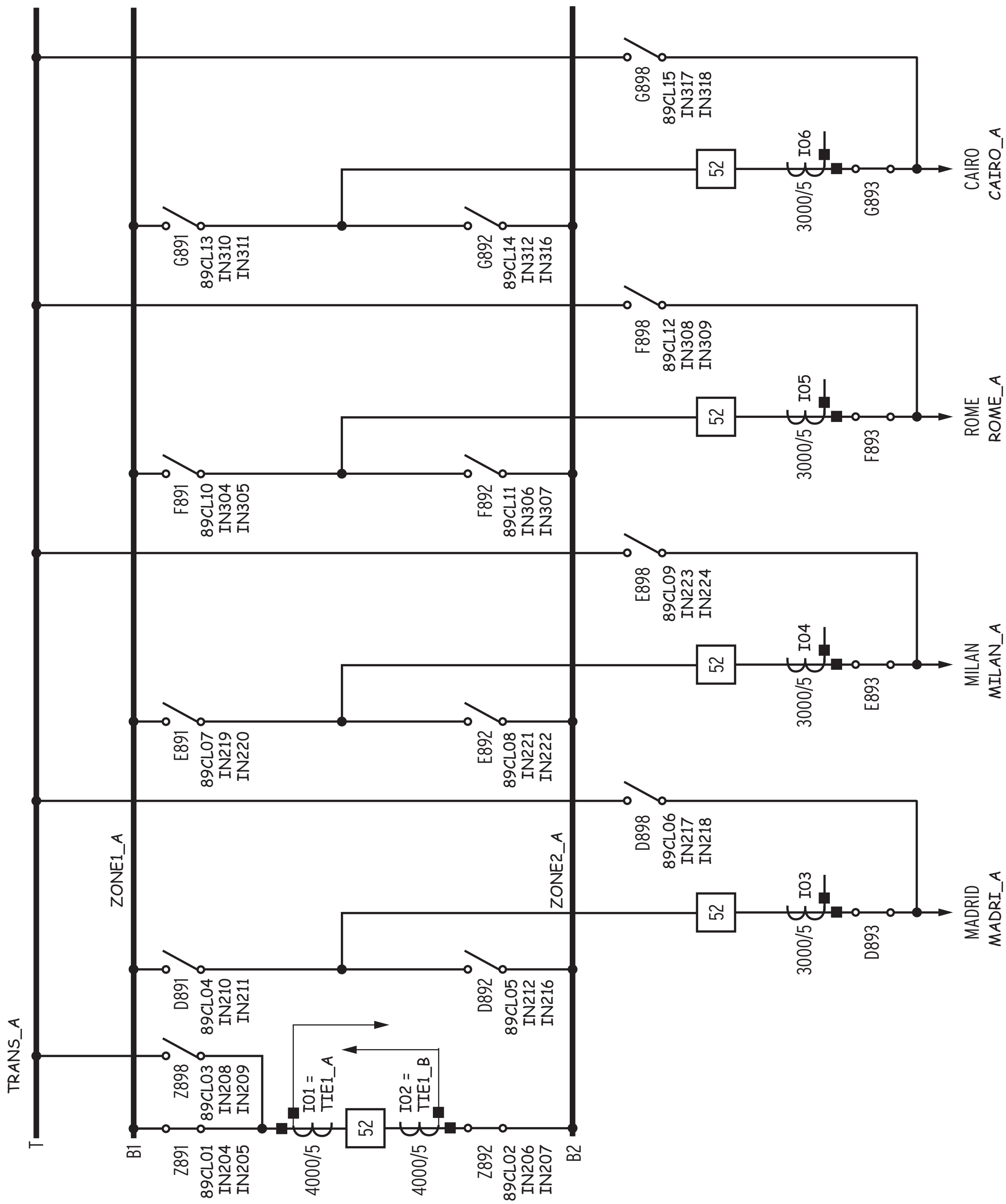


Figure 1.161 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following setting classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 1.162*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  LIST <Enter>

1: I01,"FDR_1"
2: I02,"FDR_2"
3: I03,"FDR_3"
4: I04,"TRFR_1"
5: I05,"TB_1"
6: I06,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.

60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"

1: I01,"FDR_1"
?
```

Figure 1.162 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 1.163*.

```
1: I01,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 1.163 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list.

Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 1.164*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  I01,TIE1_A <Enter>
20:
?  I02,TIE2_A <Enter>
21:
?  I03,MADRI_A <Enter>
22:
?  I04,MILAN_A <Enter>
23:
?  I05,ROME_A <Enter>
24:
?  I06,CAIRO_A <Enter>
25:
?  BZ1,ZONE1_A <Enter>
26:
?  BZ2,ZONE2_A <Enter>
27:
?  END <Enter>
Alias
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.164 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 1.165* shows the setting changes we need for our example. Because we declared the alias names in the alias setting class, use either the alias names or the primitive names when entering settings.

The NUMBK setting declares the number of circuit breakers at the station. In our example, there are five circuit breakers at the station, and we set NUMBK to 5. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting.

In this application, we do no require circuit breaker auxiliary contacts, therefore set all circuit breaker auxiliary input equations to NA.

The NUMDS setting declares the number of disconnect monitor logics we need, not the number of disconnect inputs. In our example, we need 15 disconnect monitor logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–15). Travel time is the period during which both disconnect auxiliary contacts are in the open position. Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global

General Global Settings

Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-18)                         NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-48)                      NUMDS   := N      ?15 <Enter>
Nominal System Frequency (50,60 Hz)                 NFREQ   := 60     ?> <Enter>

Global Enables

Station DC Battery Monitor (Y,N)                    EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.00-1 cyc)                     GINPU   := 0.17   ?> <Enter>

Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>

Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)               89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)               89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)               89ALP03 := 300    ?<Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)               89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.165 Global Settings for Application 8

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism for automatically reconfiguring the zone of protection, without any wiring changes. In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements.

For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay. Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays.

Because we wire a disconnect auxiliary contact to only one relay, jumper (hard wire) the contact to the two other relays. For example, when we close the busbar disconnect on the MILAN feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect, when closed, bypasses the feeder circuit breaker (e.g., Disconnect G898 on the CAIRO Feeder)

Although the relay is flexible enough to accept settings for many disconnect combinations, we will configure the relay according to a fixed operating sequence. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone settings for each step. The following defines the operating sequence for this application; many other operating sequences are possible and in use:

1. Only one feeder will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z898) and the transfer disconnect (*n*898, *n* = D, E, F and G) of only one of the four terminals can be closed simultaneously.
2. Only Busbar B2 can be the source busbar.
3. No busbar protection exists for the transfer busbar. The transfer busbar is always part of the line protection. This is the key statement from the setting viewpoint. By declaring appropriate terminal-to-bus-zone connection conditions, we can prevent relay misoperation when putting a feeder on transfer. In particular, we do not assign a differential element for the transfer busbar. Remove channel I02 from Busbar B1 differential calculations when any transfer disconnect closes.

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example.

For ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone settings. *Figure 1.166* shows the Zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE1_A, ZONE1_A, P
?   DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I01,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?   89CL02 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I02,ZONE1_A,P <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?   89CL02 AND 89CL01 AND NOT(89CL03 OR 89CL06 OR 89CL09 OR 89CL12 OR 89CL15) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?   89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I03,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?   89CL05 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
?   89CL07 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I04,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
I04BZ2V := NA
?   89CL08 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
I05BZ1V := NA
?   89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I05,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
I05BZ2V := NA
?   89CL11 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
I06BZ1V := NA
?   89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?   I06,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
I06BZ2V := NA
?   89CL14 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
Zone Configuration: Bus-Zone to Bus-Zone Connections
```

```
Bus-Zone, Bus-Zone
?   ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?   (89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?   (89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?   TIE1_A,TIE2_A <Enter>
Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?   Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)          E87ZSUP := N       ?<Enter>

Zone Switching Supervision

Zone Switching Supervision (Y,N)                     EZSWSUP := N       ?<Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.166 Zone Configuration Group Settings for Application 8

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advance settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the sensitive differential element, the restrained differential element, and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 1.11 on page R.1.9* and *Figure 1.17 on page R.1.13* for more information).

Because we do not use the coupler security logic, overcurrent elements, terminal out of service, breaker failure protection, or voltage elements in this application, set ESCL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, EVOLT := N, and EADVS := N.

Setting NUMBK equal to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. There are five trip equations available, but there are six analog channels (I01–I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 1.118*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **{TARGET RESET}** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Although each SEL-487B includes 18 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 1.167* shows the Group 1 settings.

```
=>>SET <Enter>
Group 1

Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y       ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N       ?<Enter>
Terminal Out of Service (N,1-18)                     ETOS    := 5       ?N <Enter>
Breaker Failure Logic (N,1-18)                       EBFL    := 6       ?N <Enter>
Definite Time Overcurrent Elements (N,1-18)          E50     := N       ?<Enter>
Inverse Time Overcurrent Elements (N,1-18)           E51     := N       ?<Enter>
Voltage Elements (Y,N)                               EVOLT   := Y       ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N       ?<Enter>

Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10    ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00    ?> <Enter>

Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05    ?> <Enter>

Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  87BTR01 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BTR04
?  87BTR05 <Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?<Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.167 Protection Group Settings for Application 8

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relay in a single output to the circuit breaker. Jumper (hard wire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **{RELAY TEST MODE}** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 1.168* shows the control output settings.

```
=>>SET O <Enter>
Output

Main Board

OUT101 := TRIP01 AND NOT TNS_SW
?   NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?   NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?   NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?   NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?   NA <Enter>

OUT106 := NA
?   > <Enter>

Interface Board #1

OUT201 := NA
?   TRIP01 AND NOT PLT03 <Enter>

OUT202 := NA
?   TRIP02 AND NOT PLT03 <Enter>

OUT203 := NA
?   TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?   TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?   TRIP05 AND NOT PLT03 <Enter>

OUT206 := NA
?   END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 1.168 Control Output Settings for Application 8

This concludes the settings for Application 8.

Section 2
Monitoring and Metering

Overview

The SEL-487B Relay provides extensive capabilities for monitoring substation components and metering important power system parameters. The relay provides the following useful features:

- Station dc battery system monitor
- Metering
  - Instantaneous primary and secondary current metering
  - Instantaneous primary and secondary voltage metering
  - Differential currents
  - Protection math variables
  - Automation math variables
  - Analog values used with MIRRORED BITS® communications
  - Station battery values

This section explains each of these features and gives practical examples for applying the dc battery monitor and using the **METER** command.

Station DC Battery System Monitor

The SEL-487B automatically monitors station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. Each relay provides one dc monitor channel, Vdc1. With the four voltage thresholds, you can create five sensing zones (low failure, low warning, normal, high warning, and high failure) for the dc voltage.

The ac ripple quantity indicates battery charger health. When configuring the ac ripple setting, DC1RP, you can define the ripple content of a dc supply as the peak-to-peak ac component of the output supply waveform.

The relay also provides measurements between the battery terminal voltages and station ground to detect positive and negative dc ground faults. *Figure 2.1* shows a typical dual-battery dc system.

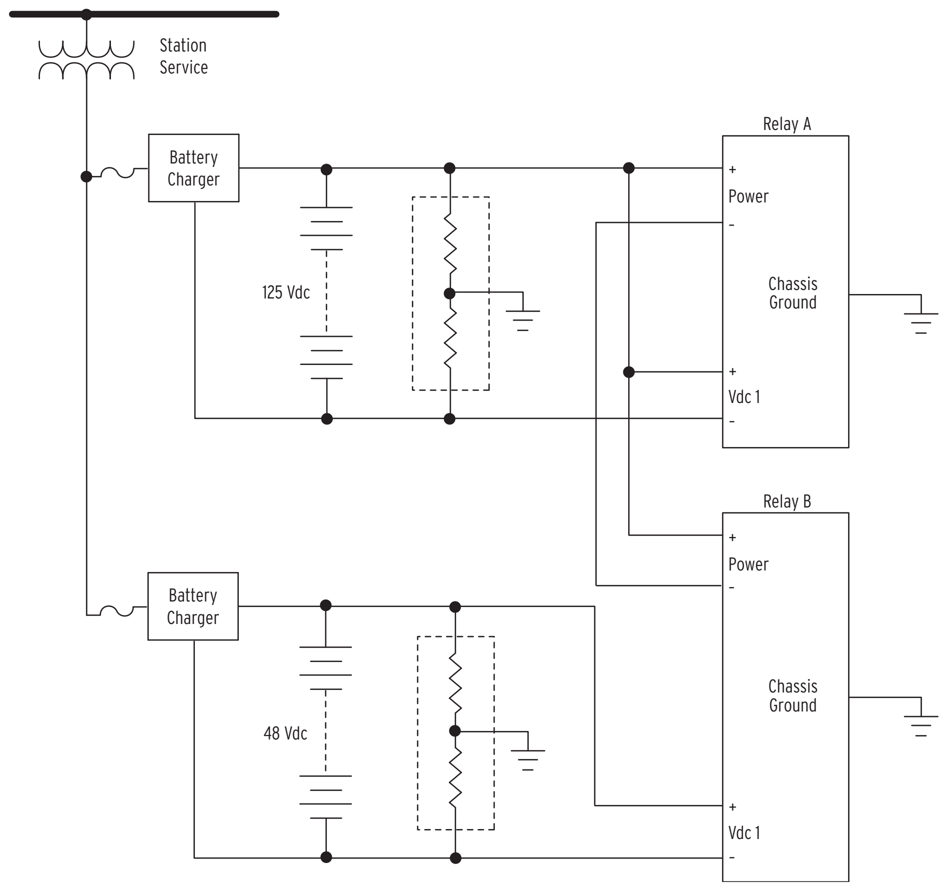


Figure 2.1 Typical Station DC Battery System

The dc battery monitor measures the station battery voltage applied at the rear-panel terminals labeled **Vdc1** (**+** and **–**). In a three-relay application, connect the 125 Vdc supply to the monitoring connections of the first relay, and the 48 Vdc supply to the monitoring connections of the second relay. See *Section 1: Protection Applications Examples in the Application Handbook* for more information about single- and three-relay applications.

NOTE: First enable Station DC Monitoring (with the Global setting EDCMON) to access station dc battery monitor settings.

Table 2.1 lists the station dc battery monitor settings and the corresponding Relay Word bits that assert when battery quantities exceed these settings thresholds. Use the **SET G** ASCII command from a terminal or use the ACSELERATOR QuickSet® SEL-5030 software **Global > Station DC Monitoring** branch of the Settings tree view to access the DC Monitor settings.

Table 2.1 DC Monitor Settings[a] and Relay Word Bit Alarms

Setting	Definition	Relay Word Bit
DC1LFP	Low-Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1LWP	Low-Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HWP	High-Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HFP	High-Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1RP	Peak-to-Peak AC Ripple Pickup (1–300 Vac)	DC1R
DC1GF	Ground Detection Factor (1.00–2.00) (advanced setting)	DC1G

[a] Minimum setting step size is 1 V for voltage settings.

Station DC Battery System Monitor Application

The dc monitor alarms for undervoltage or overvoltage dc battery conditions in five sensing regions. The following describes how to apply the dc battery monitor to a typical 125 Vdc protection battery system connected to one SEL-487B (Relay A in *Figure 2.1*) and a 48 Vdc communication equipment battery system connected to another SEL-487B (Relay B in *Figure 2.1*) in a three-relay application. Adjust the values used here to meet the specifications of your company.

Battery Voltage

When setting the station dc battery monitor, determine the minimum and maximum dc levels in the battery system. In addition, establish the threshold levels for different battery system states or conditions. The following voltage levels describe these battery system conditions:

- Trip/Close—the lowest dc voltage point that circuit breaker trip and close operations occur
- Open-circuit—the dc battery voltage when all cells are fully charged and disconnected from the battery charger or load
- Float low—the lowest charging voltage supplied by the battery charger
- Float high—the highest charging voltage supplied by the battery charger
- Equalize mode—a procedure where the batteries are overcharged intentionally for a preselected time in order to bring all cells to a uniform output

Set the low end of the allowable dc battery system voltage according to the recommendations of C37.90-1989 (R1994) IEEE® Standard for Relays and Relay Systems Associated with Electric Power. Section 6.4 in this standard is titled “Allowable Variation from Rated Voltage for Voltage Operated Auxiliary Relays.” This section calls for an 80 percent low-end voltage and 28, 56, 140, or 280 Vdc high-end voltages for the popular nominal station battery voltages. *Table 2.2* lists expected battery voltages under various conditions using commonly accepted per-cell voltages.

Table 2.2 Example DC Battery Voltage Conditions (Sheet 1 of 2)

Condition	Calculation	Battery Voltage (Vdc)
Trip/Close	80% • 125 Vdc	100.0
Open-Circuit	60 (cells) • 2.06 (volts/cell)	123.6
Float Low	60 (cells) • 2.15 (volts/cell)	129.0
Float High	60 (cells) • 2.23 (volts/cell)	133.8
Equalize Mode	60 (cells) • 2.33 (volts/cell)	139.8
Trip/Close	80% • 48 Vdc	38.4
Open Circuit	24 (cells) • 2.06 (volts/cell)	49.4
Float Low	24 (cells) • 2.15 (volts/cell)	51.6
Float High	24 (cells) • 2.23 (volts/cell)	53.5
Equalize Mode	24 (cells) • 2.33 (volts/cell)	55.9

Table 2.2 Example DC Battery Voltage Conditions (Sheet 2 of 2)

Condition	Calculation	Battery Voltage (Vdc)
Trip/Close	80% • 24 Vdc	19.2
Open Circuit	12 (cells) • 2.06 (volts/cell)	24.7
Float Low	12 (cells) • 2.15 (volts/cell)	25.8
Float High	12 (cells) • 2.23 (volts/cell)	26.8
Equalize Mode	12 (cells) • 2.33 (volts/cell)	28.0

Use the expected battery voltages in *Table 2.2* to determine the SEL-487B station dc battery monitor threshold settings. *Table 2.3* shows these threshold settings in Relay A for a nominal 125 Vdc battery system, and *Table 2.4* shows the settings in Relay B for a nominal 48 Vdc battery system.

Table 2.3 Example DC Battery Monitor Settings—125 Vdc for Relay A

Setting	Description	Indication	Value (Vdc)
DC1LFP	Low-fail threshold	Poor battery performance	100
DC1LWP	Low-warning threshold	Charger malfunction	127
DC1HWP	High-warning threshold	Equalization	137
DC1HFP	High-fail threshold	Charger malfunction	142

Table 2.4 Example DC Battery Monitor Settings—48 Vdc for Relay B

Setting	Description	Indication	Value (Vdc)
DC1LFP	Low-fail threshold	Poor battery performance	38
DC1LWP	Low-warning threshold	Charger malfunction	50
DC1HWP	High-warning threshold	Equalization	55
DC1HFP	High-fail threshold	Charger malfunction	57

AC Ripple

Another method for determining whether the substation battery charger has failed is to monitor the amount of ac ripple on the station dc battery system. The IEEE C37.90-1989 standard also identifies an "Allowable AC Component in DC Control Voltage Supply" (Section 6.5) as an alternating component (ripple) of 5 percent peak or less. (This definition is valid if the minimum instantaneous battery voltage is not less than 80 percent of the rated voltage.) The SEL-487B measures ac ripple as a peak-to-peak waveform, consequently, DC1RP (Relay A) and DC1RP (Relay B) should be set at or greater than 10 percent (2 • 5% peak) of the equalizing voltage. *Table 2.5* shows the ac ripple threshold settings for this example.

Table 2.5 Example DC Battery Monitor Settings—AC Ripple Voltages

Setting	Description	Indication	Value (Vac)
DC1RP	AC ripple threshold, Relay A	Charger malfunction	14
DC1RP	AC ripple threshold, Relay B	Charger malfunction	6

DC Ground

If a battery system is centered around chassis ground, the magnitude of the voltage measured from the positive terminal to ground and from the negative terminal of the battery to ground should be approximately half of the nominal battery system voltage. The ideal ratio of the positive-to-ground battery voltage to the negative-to-ground battery voltage is 1 to 1, or 1.00. *Equation 2.1* is the balanced ratio for a 125 Vdc battery system.

$$k = \frac{\mathrm{Vdc1}_{\mathrm{pos}}}{\mathrm{Vdc1}_{\mathrm{neg}}} = \frac{62.50\ \mathrm{V}}{62.50\ \mathrm{V}} = 1.00$$

Equation 2.1

If either terminal is partially or completely shorted to chassis ground, the terminal voltage will be less than the nominal terminal-to-ground voltage. This causes the ratio of positive voltage to negative voltage to differ from 1.00. *Equation 2.2* is an example of the unbalanced (grounding) ratio for a partial short circuit to ground on the negative side of a 125 Vdc battery system.

$$k = \frac{\mathrm{Vdc1}_{\mathrm{pos}}}{\mathrm{Vdc1}_{\mathrm{neg}}} = \frac{64.30\ \mathrm{V}}{60.70\ \mathrm{V}} = 1.06$$

Equation 2.2

The SEL-487B uses this voltage ratio to calculate a ground detection factor. *Figure 2.2* shows a graphical representation of the ground detection factor setting and battery system performance.

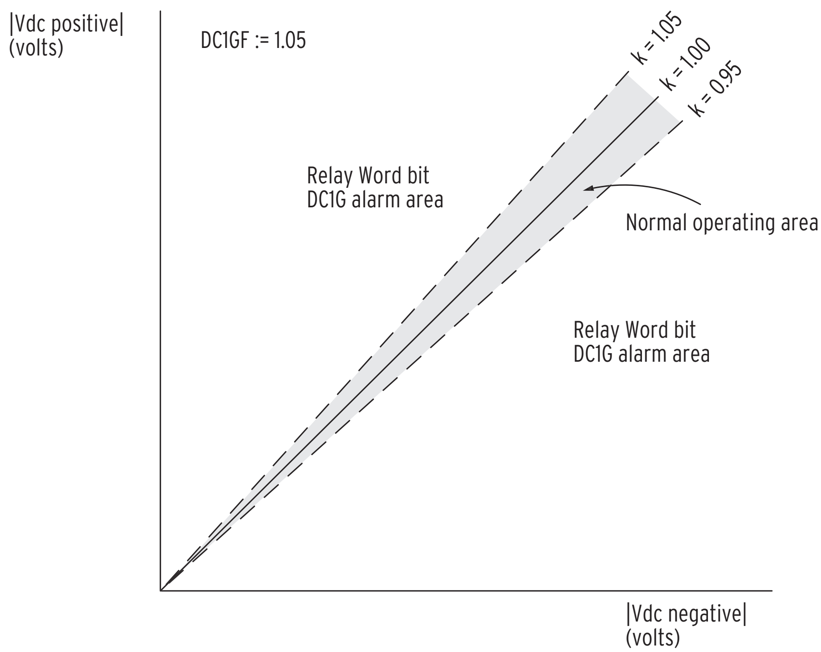


Figure 2.2 Ground Detection Factor Areas

If the ground detection factor ratio exceeds a setting threshold, the relay asserts the DC1G Relay Word bit. To set the ground detection factor threshold, enable the advanced Global settings (EGADVS := Y), and set the DC1GF threshold at a value close to 1.05 (the factory default setting) to allow for some slight battery system unbalance of around 5 percent. *Table 2.6* lists the ground detection factor threshold settings for this example.

Table 2.6 Example DC Battery Monitor Settings-Ground Detection Factor (EGADVS := Y)

Setting	Description	Indication	Value
DC1GF	Ground detection factor	Battery wiring ground(s)	1.05

DC Battery Monitor Alarm

You can use the battery monitor Relay Word bits to alert operators for out-of-tolerance conditions in the battery systems. Add the appropriate Relay Word bit to the SELOGIC® control equation that drives the relay control output you have selected for alarms. For example, use the b contact of control output OUT108. Set the SELOGIC control equation to include the battery monitor thresholds:

OUT108 := **NOT (HALARM OR SALARM OR DC1F OR DC1W OR DC1R OR DC1G)**
Output SELOGIC control equation

This example shows one setting possibility. You can implement many other methods as well. See *Alarm Output on page U.2.33* for more information.

DC Battery Monitor Metering

The SEL-487B monitors battery system voltages and records time stamps for voltage excursions. In addition, the relay records maximum and minimum battery voltages. *Figure 2.3* shows a sample dc battery monitor meter report. Use the **MET BAT** command from a communications terminal to obtain this report. For more information on the **MET** commands, see *METER on page R.7.22*.

```
=>MET BAT <Enter>

Relay 1                                    Date: 03/22/2001  Time: 09:37:10.035
Station A                                  Serial Number: 2001001234

Station Battery        VDC      VDCPO     VDCNE      VAC
   VDC1 (V)            24.17     11.98    -12.19      0.01

             VDC1(V)    Date       Time
Minimum        20.12 03/15/2001  14:28:59.172
Enter L-Zone         03/15/2001  14:28:51.490
Exit L-Zone          03/15/2001  14:29:05.035

Maximum        27.19 03/19/2001  08:34:49.761
Enter H-Zone         03/19/2001  08:34:27.172
Exit H-Zone          03/19/2001  08:37:01.041

LAST DC RESET:  03/15/2001  12:30:30.492

=>
```

Figure 2.3 Battery Metering: Terminal

Any battery voltage between setting DC1LWP and the dc battery monitor low limit of 15 Vdc is in the L-Zone. Any battery voltage between setting DC1HWP and the dc battery monitor high limit of 300 Vdc is in the H-Zone.

Reset DC Battery Monitor Metering

Use the **MET RBM** command from a communications terminal to reset the dc battery monitor. You can program a SELOGIC control equation RST_BAT (in Global settings) to control dc battery monitor reset. Enable data reset control with global setting EDRSTC := Y.

Metering

The SEL-487B provides one-cycle average metering for measuring power system conditions and differential protection values. Each SEL-487B processes 18 currents, 3 voltages, and 1 battery monitor.

Use the **MET** command to access the metering functions. Issuing the **MET** command with no options returns the fundamental frequency primary measurement quantities listed in *Table 2.7*.

Table 2.7 Instantaneous Metering Quantities—Voltages and Currents

Metered Quantity	Symbol	Units
Phase voltage magnitude	V01–V03	kV
Phase voltage angle	∠V01, –∠V03	degrees
Phase current magnitude	I01–I18	A
Phase current angle	∠I01, –∠I18	degrees

The **MET** command followed by a number, **MET *k***, specifies the number of times the command will repeat (*k* can range from 1 to 32767). This is useful for troubleshooting or investigating uncharacteristic power system conditions. With other command options, you can view currents from the terminals.

Table 2.8 shows the **MET** command options, followed by a short description of each option.

Table 2.8 MET Command—Metering Only

Name[a]	Description
MET *k*	Displays fundamental primary phase information *k* times for all terminals
MET *k* **CZ1**	Displays fundamental primary phase information *k* times for all terminals in Check Zone 1
MET *k* **Z***n*	Displays fundamental primary phase information *k* times for all terminals in Zone *n*
MET SEC *k*	Displays fundamental secondary phase information *k* times for all terminals
MET SEC *k* **CZ1**	Displays fundamental secondary phase information *k* times for all terminals in Check Zone 1
MET SEC *k* **Z***n*	Displays fundamental secondary phase information *k* times for all terminals in Zone *n*
MET DIF	Displays per unit operating and restraint currents for all active zones
MET BAT	Displays station battery measurements
MET RBM	Reset station battery max/min measurements
MET ANA	Displays the analog values used with MIRRORED BITS communications
MET PMV	Displays the last 16 Protection Math Variables
MET PMV A	Displays all the Protection Math Variables
MET AMV	Displays the last 16 Automation Math Variables
MET AMV A	Displays all the Automation Math Variables

[a] k = 1–32767; n = 1–6.

Use the **MET** command to obtain the current and voltage quantities in primary values, as shown in *Table 2.9*.

Table 2.9 Information Available With the MET Command

Command	Information
MET	Primary current magnitudes and angles from all 18 terminals in Amps. Primary voltage magnitudes and angles from the 3 voltage inputs in kV.

Figure 2.4 shows the relay response to the **MET** command of one phase in a three-relay application.

```
=>>MET <Enter>

Relay 1                                      Date: 05/14/2003  Time: 14:55:16.098
Station A                                    Serial Number: 2003000403

       Primary Currents
Terminal    MAG(A)   ANG(DEG)           Terminal    MAG(A)   ANG(DEG)
 FDR_1     2397.801     0.00             I10         0.000   -82.49
 FDR_2     2998.418     0.00             I11         0.000   -82.49
 FDR_3     1797.579   180.00             I12         0.000   -82.49
 TRFR_1    3597.560   180.00             I13         0.000   -82.49
 TB_1      5398.476   180.00             I14         0.000   -82.49
 TB_2      5398.476     0.00             I15         0.000   -82.49
 I07          0.000   -82.49             I16         0.000   -82.49
 I08          0.000   -82.49             I17         0.000   -82.49
 I09          0.000   -82.49             I18         0.000   -82.49

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        66.996     0.00
 V02       133.991  -120.00
 V03       133.991   120.00

=>>
```

Figure 2.4 Relay Response to the MET Command of One Phase of a Three-Relay Application

All angles are referenced to the voltage connected to Voltage Terminal V01. If voltage at Terminal V01 is not available, the relay selects V02 and then V03 as reference. In the absence of voltage inputs, the relay references the current input of I01, provided the current is above 0.05 • I_{NOM}. If I01 is not above this current level, the relay references the current from I02, if available. If I02 is not available, the relay continues to I03, I04, and so on until it finds a current input above 0.05 • I_{NOM}.

For check-zone-specific primary values information, use the **MET CZ1** command. *Table 2.10* shows the information, including the CT polarity, included in Check Zone 1.

Table 2.10 Information Available With the MET CZ1 Command

Command	Information
MET CZ1	Primary current magnitudes, angles, and CT polarities from the active terminals in Amps. Primary voltage magnitudes and angles from the three voltage inputs in kV.

For the relay to display any measured values, at least one Terminal-to-Check-Zone equation must be a logical 1 (i.e., at least one terminal must be connected to the Check Zone). *Figure 2.5* shows the relay response to the **MET CZ1** command if no such connection exists.

```
=>>MET CZ1 <Enter>
Specified zone is inactive
```

Figure 2.5 Response to MET CZ1 Command When All Terminals Are Inactive

Figure 2.6 shows the relay response of one phase in a three-relay application when Terminals I01 and I02 are connected to Check Zone 1.

```
=>>MET CZ1 <Enter>

Relay 1                                      Date: 02/06/2008  Time: 23:51:51.027
Station A                                    Serial Number: 0000000001

Current Terminals in Check Zone 1

       Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 FDR_1       98.131     0.00    P
 FDR_2       98.677   180.00    P

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        133.990     0.00
 V02        133.990  -119.99
 V03        133.990   120.00

=>>
```

Figure 2.6 Response to the MET CZ1 Command of One Phase in a Three-Relay Application

For zone-specific primary values information, use the **MET Z*n*** (*n* = 1–6) command. *Table 2.11* shows the information, including the CT polarity and Bus-Zones, included in Protection Zone *n*, if two Bus-Zones are combined.

Table 2.11 Information Available With the MET Zn Command

Command	Information
MET Z*n*	Primary current magnitudes, angles, and CT polarities from the active terminals in Amps. Primary voltage magnitudes and angles from the three voltage inputs in kV. Bus-Zones in Protection Zone *n*.

For the relay to display any measured values, at least one Terminal-to-Bus-Zone equation must be a logical 1 (i.e., at least one terminal must be connected to the specified Bus-Zone). *Figure 2.7* shows the relay response to the **MET Z*n*** command if no such connection exists.

```
=>>MET Z1 <Enter>
All terminals in the specified zone are inactive
```

Figure 2.7 Response to MET Z1 Command When All Terminals Are Inactive

Figure 2.8 shows the relay response of one phase in a three-relay application when Terminals I01 and I02 are connected to Bus-Zone 1.

```
=>>MET Z1 <Enter>

Relay 1                                    Date: 02/27/2003  Time: 13:56:37.718
Station A                                  Serial Number: 0000000001

Current Terminals in Protection Zone 1

       Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 FDR_1       98.131     0.00    P
 FDR_2       98.677   180.00    P

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        133.990     0.00
 V02        133.990  -119.99
 V03        133.990   120.00

Bus-Zones in Protection Zone 1
BUS_1


=>>
```

Figure 2.8 Response to the MET Z1 Command of One Phase in a Three-Relay Application

MET SEC provides secondary information similar to the **MET** command, but includes the CT and PT ratios, as shown in *Table 2.12*.

Table 2.12 Information Available With the MET SEC Command

Command	Information
MET SEC	Secondary current magnitudes, angles, and CT ratios from all 18 terminals in Amps. Secondary voltage magnitudes and angles from the three voltage inputs in Volts, and each PT ratio.

Figure 2.9 shows the relay response to the **MET SEC** command of one phase in a three-relay application.

```
=>>MET SEC <Enter>

Relay 1                                    Date: 05/14/2003  Time: 14:59:04.360
Station A                                  Serial Number: 2003000403

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR       Terminal   MAG(A)  ANG(DEG)  CTR
 FDR_1      3.996     0.00   600        I10        0.000   -82.49    600
 FDR_2      4.997     0.00   600        I11        0.000   -82.49    600
 FDR_3      2.996   180.00   600        I12        0.000   -82.49    600
 TRFR_1     5.996   180.00   600        I13        0.000   -82.49    600
 TB_1       8.997   180.00   600        I14        0.000   -82.49    600
 TB_2       8.997     0.00   600        I15        0.000   -82.49    600
 I07        0.000   -82.49   600        I16        0.000   -82.49    600
 I08        0.000   -82.49   600        I17        0.000   -82.49    600
 I09        0.000   -82.49   600        I18        0.000   -82.49    600

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000
 V03       66.996   120.00   2000

=>>
```

Figure 2.9 Relay Response to the MET SEC Command of One Phase of a Three-Relay Application

For check-zone-specific secondary information, use the **MET SEC CZ1** command. The information includes the CT polarity, as shown in *Table 2.13*.

Table 2.13 Information Available With the MET SEC CZ1 Command

Command	Information
MET SEC CZ1	Secondary current magnitudes, angles, CT ratios, and polarities from the active terminals in the check zone in Amps. Secondary voltage magnitudes and angles from the three voltage inputs in Volts, and each PT ratio.

Figure 2.10 shows the relay response to the **MET SEC CZ1** command of one phase in a three-relay application with these terminals connected to Check Zone 1.

```
=>>MET SEC CZ1 <Enter>

Relay 1                                     Date: 02/06/2008  Time: 23:51:51.027
Station A                                   Serial Number: 0000000001

Current Terminals in Check Zone 1

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR  POL
 FDR_1      3.996    0.00     600  P
 FDR_2      4.997    0.00     600  P

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000

=>>
```

Figure 2.10 Response to the MET SEC CZ1 Command of One Phase in a Three-Relay Application

For zone-specific secondary information, use the **MET SEC Z*n*** (*n* = 1–6) command. The information includes the CT polarity, as shown in *Table 2.14*.

Table 2.14 Information Available With the MET SEC Zn Command

Command	Information
MET SEC Z*n*	Secondary current magnitudes, angles, CT ratios, and polarities from the active terminals in the specific zone in Amps. Secondary voltage magnitudes and angles from the three voltage inputs in Volts, and each PT ratio. Bus-Zones in Protection Zone *n*.

Figure 2.11 shows the relay response to the **MET SEC Z*n*** command of one phase in a three-relay application with these terminals connected to Bus-Zone 1.

```
=>>MET SEC Z1 <Enter>

Relay 1                                     Date: 05/14/2003  Time: 15:00:43.237
Station A                                   Serial Number: 2003000403

Current Terminals in Protection Zone 1

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR  POL
 FDR_1      3.996     0.00    600  P
 FDR_2      4.997     0.00    600  P
 TB_1       8.997   180.00    600  P

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000
 V03       66.996   120.00   2000

Bus-Zones in Protection Zone 1
BUS_1
=>>
```

Figure 2.11 Relay Response to the MET SEC Z1 Command of One Phase in a Three-Relay Application

NOTE: A zone is active when any IqqBZpV (qq = 01–18, p = 1–6) Relay Word bit asserts. For example, Zone 1 becomes active when Relay Word bit I01BZ1V asserts. The check zone is active when any IqqCZ1V (qq = 01–18) Relay Word bit asserts and ECHKZN := Y.

View the differential currents of all active zones with the **MET DIF** command. The information includes per unit operating and restraint currents from each active zone, as well as the reference current, as shown in *Table 2.15*. The reference current is the product of the SEL-487B nominal current and the maximum CT ratio in an active zone as defined in the zone configuration settings.

Table 2.15 Information Available With the MET DIF Command

Command	Information
MET DIF	Operate current of all active zones in per unit. Restraint current of all active zones in per unit. Product of relay nominal current and highest CT ratio of the connected CTs, used as reference current.

Figure 2.12 shows the relay response to the **MET DIF** command of one phase in a three-relay application when Bus-Zones 1 and 2 are active.

```
=>>MET DIF <Enter>

Relay 1                                     Date: 02/27/2003  Time: 14:28:06.955
Station A                                   Serial Number: 0000000001

       Operate Currents     Restraint Currents
           (Per Unit)           (Per Unit)
ZONE          IOP                  IRT
  1           0.00                 0.25
  2           0.01                 0.44

Current Reference (A)
IREF
800

=>>
```

Figure 2.12 Relay Response to the MET DIF Command of One Phase in a Three-Relay Application

The relay includes 64 protection math variables and 256 automation math variables. Use the **MET PMV** and **MET AMV** commands to see the last 16 of each, as shown in *Table 2.16*.

Table 2.16 Information Available With the MET PMV and MET AMV Commands

Command	Information
MET PMV	PMV49–PMV64
MET AMV	AMV241–AMV256

To see all of the variables, use the **MET PMV A** and **MET AMV A** commands, as shown in *Table 2.17*.

Table 2.17 Information Available With the MET PMV A and MET AMV A Commands

Command	Information
MET PMV A	PMV01–PMV64
MET AMV A	AMV001–AMV256

Use the **MET ANA** command to display the analog values used with MIRRORED BITS communications, as shown in *Table 2.18*.

Table 2.18 Information Available With the MET ANA Command

Command	Information
MET ANA	Analog value in channel A Analog value in channel B

Section 3
Analyzing Data

Overview

The SEL-487B Relay features comprehensive power system data analysis capabilities. The relay provides these useful analysis tools:

- Event reporting
- Event reports
- Event summaries
- Event histories
- Combined event report
- SER (Sequential Events Recorder)

An event shows selected data of the power system at a specific time. Events include instances such as a relay trip, an abnormal situation in the power system that triggers a relay element, or an event capture command.

Information from relay event reports and SER data is very valuable if you are responsible for outage analysis, outage management, or relay settings coordination.

Data Processing

The SEL-487B is a microprocessor-based relay that samples power system conditions via CT and PT inputs. The relay converts these analog inputs to digital information for processing to determine relaying quantities for protection and automation. *Figure 3.1* shows a general overview of the input processing diagram for the SEL-487B. A CT or PT analog input begins at hardware acquisition and sampling, continues through software filtering, and progresses to protection, automation processing, and event storage.

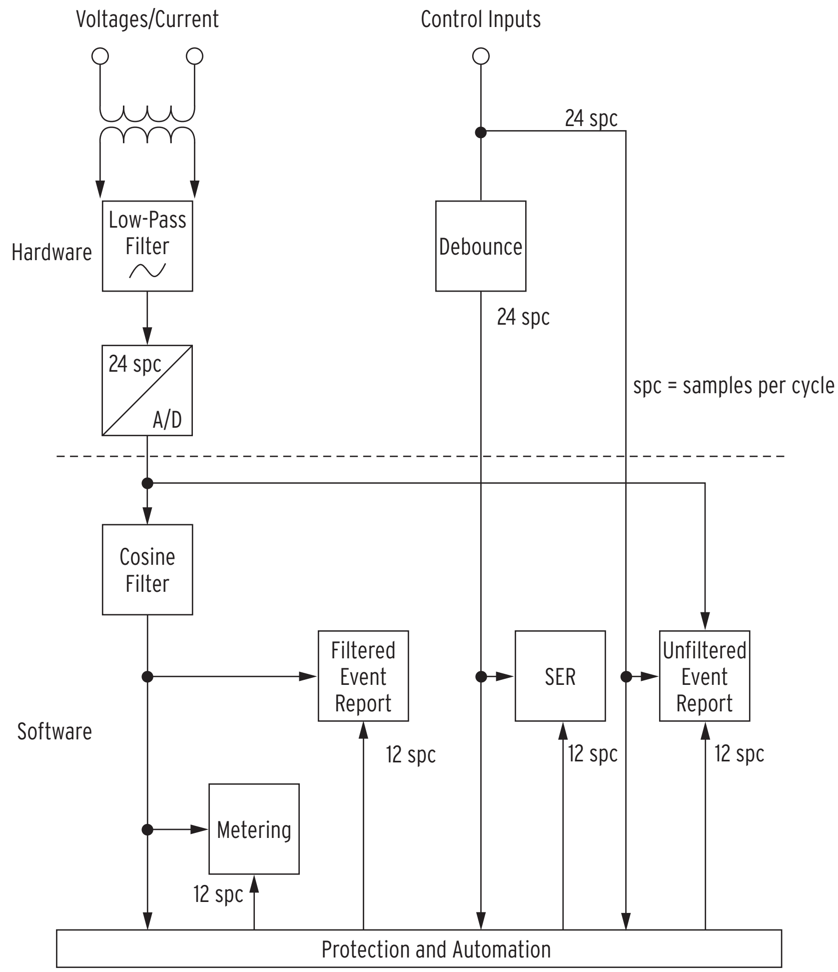


Figure 3.1 SEL-487B Input Processing

Raw and Filtered Data

The SEL-487B provides two types of data: unfiltered (raw) data and filtered data, available in ASCII or Compressed ASCII format. *Table 3.1* shows the various types of events reports and the contents of each.

Table 3.1 Event Report Types Available in the SEL-487B

Event File Types	Samples/Cycle	Type	Format
E4_10000.TXT	4	Filtered	ASCII
E1210000.TXT	12	Filtered	ASCII
E2410000.TXT	24	Raw	ASCII
D1210000.TXT	12	Filtered (differential)	ASCII
C1210000.TXT	12	Filtered	Compressed ASCII
C2410000.TXT	24	Raw	Compressed ASCII
Z2410000.TXT[a]	24/12	Raw and filtered (differential)	Compressed ASCII

[a] Combination of C2410000.TXT and D1210000.TXT.

Event File Types

When starting at the number 10000, the SEL-487B assigns a unique number to each event.

Triggering Data Captures and Event Reports

The SEL-487B displays power system data from event reports, event summaries, event histories, and SER data. For information on the SER, see *SER (Sequential Events Recorder) on page A.3.31*. Events can be triggered from both internal to the relay or external to the relay, depending on the event trigger conditions that you program in the relay.

Use an event trigger to initiate capturing an event report. Both raw data and filtered event reports use the same triggering methods. Any one of the five possible sources shown in *Table 3.2* can provide the trigger for a data capture.

Table 3.2 Five Sources That Can Initiate a Data Capture in the Relay

Event	Description
87BTR	Rising edge of Relay Word bit 87BTR on or after trigger
SBFTR	Rising edge of Relay Word bit SBFTR on or after trigger
TRIP	Rising edge of Relay Word bit TRIP on or after trigger
ER	Rising edge of ER, the event report trigger
TRI	Execution of the ASCII **TRIGGER** command

In previous SEL relays, the **PUL** command initiated event recording. If you want the **PUL** command to initiate data capture, add the Relay Word bit TESTPUL to the SELOGIC® control equation ER (See *SELOGIC Control Equation ER* and *Example 3.2*. For more information on the **PUL** command, see *PULSE on page R.7.29* and *Operating the Relay Inputs and Outputs on page U.4.40*.

Relay Word Bits 87BTR, SBFTR and TRIP

Relay Word bit 87BTR asserts when any one of the Relay Word bits 87BTR01–87BTR18 asserts, Relay Word bit SBFTR asserts when any one of Relay Word bits SBFTR01–SBFTR18 asserts, and Relay Word bit TRIP asserts when any one of Relay Word bits TRIP01–TRIP18 asserts. When any of the Relay Word bits 87BTR, SBFTR, or TRIP asserts, the relay automatically initiates event recording on the rising edge of the particular Relay Word bit state change. Therefore, enter only conditions for which these Relay Word bits do not already assert in the ER SELOGIC control equation. For information on Relay Word bits 87BTR, SBFTR, and TRIP see *Differential Trip Logic on page R.1.53*, *Circuit Breaker Failure Trip Logic on page R.1.41*, and *Breaker Trip Logic on page R.1.55*.

SELOGIC Control Equation ER

Program the SELOGIC control equation ER to trigger event reports for conditions other than 87BTR, SBFTR, or TRIP conditions. When ER asserts, the SEL-487B begins recording data if the relay is not already capturing data initiated by another trigger.

EXAMPLE 3.1 Triggering Event Report/Data Capture Using the ER SELOGIC Control Equation

This example shows how the elements in the ER SELOGIC control equation initiate relay data capture. See Section 2: SELOGIC Control Equation Programming in the Reference Manual for more information on rising-edge operators and SELOGIC control equations.

The factory default setting for the six Group settings SELOGIC control equations ER is:

ER := **R_TRIG 87ST** Event Report Trigger Equation (SELOGIC Equation)

Relay Word Bit 87ST is the OR combination of the six sensitive differential elements time-delayed outputs.

Use 87ST instead of the elaborate equation of 87ST1 OR 87ST2 OR 87ST3 OR 87ST4 OR 87ST5 OR 87ST6 to trigger an event when any time-delayed sensitive differential element operates.

The rising-edge operator, R_TRIG, occurs in front of element 87ST in the factory-default ER equation. Rising-edge operators are especially useful for generating an event report at fault inception. The relay processes the assertion elements with the R_TRIG operator for only one processing interval at the beginning of element assertion, clearing the way for other elements to also assert ER. Thus, the starting element in a continuously occurring fault does not mask other possible element triggers, provided that subsequent triggers are later than the time window as specified by the LER setting (**SET R)**. This allows another rising-edge sensitive element to generate another event report should an element stays asserted for the same continuous fault (such as an overcurrent situation with the R_TRIG 51P01 element).

Other elements in the ER SELOGIC control equation (for example, 51P01 if it was entered) can trigger event reports while the 87ST element remains asserted throughout the fault duration.

You can also use the falling-edge operator, F_TRIG, to initiate data captures. See *Section 2: SELOGIC Control Equation Programming in the Reference Manual* for more information on falling-edge operators.

EXAMPLE 3.2 Including PUL Command Triggering in the ER SELOGIC Control Equation

This example shows you how to add the effect of the **PUL** command to emulate previous SEL relays. The relay asserts Relay Word bit, TESTPUL, when any output pulses via the **PUL** command. For more information on the **PUL** command, see PULSE on page R.7.29.

Program the Group settings SELOGIC control equation ER as follows:

ER := **R_TRIG 87ST OR TESTPUL** Event Report Trigger Equation (SELOGIC Equation)

TRI (Trigger Event Report) Command

Use the **TRI** command from any communications port to trigger the SEL-487B to begin the recording of an event report. When testing with the **TRI** command, the relay records power system operating conditions that occur immediately after you issue the **TRI** command. See *TRIGGER on page R.7.49* and *Triggering an Event on page U.4.35* for more information on the **TRI** command.

Duration of Data Captures and Event Reports

The SEL-487B stores unfiltered raw data and filtered data. The number of stored unfiltered raw data captures and event reports is a function of the amount of data contained in each capture. You can configure the relay to record data captures at either 15, 30, 60, or 120 cycles, as shown in *Table 3.3*.

Table 3.3 LER and PRE Report Settings

Label	Description	Range	Default
LER	Length of event report	15, 30, 60, or 120 cycles	15 cycles
PRE	Length of prefault	1 – (LER – 2) cycles	5 cycles

The length of the data capture/event report (setting LER) and the pretrigger or prefault time (setting PRE) are related as shown in *Figure 3.2*. Setting LER is the overall length of the event report data capture; and setting PRE determines the time reserved in the LER period when the relay records pretrigger (prefault) data.

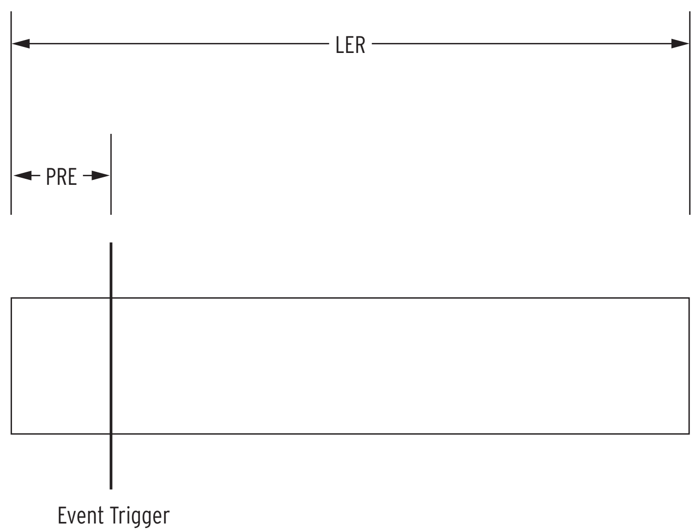


Figure 3.2 Data Capture/Event Report Times

The relay stores all data captures to volatile RAM and then moves these data to nonvolatile memory storage. There is enough volatile RAM to store one maximum length capture (maximum LER time). No data captures can be triggered while the volatile RAM is full; the relay must move at least one data capture to nonvolatile storage to reenable data capture triggering. Thus, to record different events sequentially, you must set LER to half or less than half of the maximum LER setting. The relay stores more sequential data captures as you set LER smaller.

The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

Table 3.4 shows the number of events the relay stores in nonvolatile memory for different LER settings.

Table 3.4 Event Report Nonvolatile Storage Capability

Event Report Length (LER)	Number of Events Stored
15 cycles	24
30 cycles	15
60 cycles	8
120 cycles	4

Event Report Oscillography

Use a terminal or SEL-supplied PC software to retrieve event report files stored in the relay and transfer these files to your computer. Both the ACSELERATOR QuickSet® SEL-5030 Software Program and the SEL-5601 Analytic Assistant read the event files that the relay generates for an event. See *Section 3: PC Software in the User's Guide* for instructions on viewing event report oscillography with the ACSELERATOR software.

Event Reports, Summaries, and Histories

Event reports simplify post-fault analysis and help you improve your understanding of protection scheme operations. Event reports also aid in testing and troubleshooting relay settings and protection schemes because these reports contain detailed data on voltage, current, and relay element status. For further analysis assistance, the relay appends the active relay settings to each event report. The relay stores event reports in nonvolatile memory, and you can clear the event report memory on a port-by-port basis (see the **EVE** command in *EVENT on page R.7.14*).

Alias Names

NOTE: If alias names were changed after an event was recorded, the relay uses the present alias names in subsequent event reports.

To customize your event report, rename any Relay Word bit, analog quantity, or default terminal name with more meaningful names to improve the readability of fault analysis and customized programming. See *Section 1: System Configuration Guideline and Application Examples* for more information. After renaming the primitive quantities, the alias names rather than the primitive names appear in the event reports and SER. The primitive names of the analog channels still appear in the event reports.

You decide the amount of information and length in an event report. See *Duration of Data Captures and Event Reports on page A.3.5*. You can view the information in one or more of the following forms:

- Event report
- Event summary
- Event history

Event Report

The relay generates event reports to display analog data, digital data (control inputs, control outputs, and the state of Relay Word bits), and relay settings. Each event report includes these components:

- Report header
- Analog section
  - Currents, voltages, and battery voltage

- Digital section
  - User-defined Relay Word bit elements, control outputs, control inputs
- Event summary
- Settings
  - Group settings
  - Zone configuration group settings
  - Global settings
  - Output settings
  - SELOGIC control equations protection logic
  - Alias settings

Viewing the Event Report

Step 1. Access event reports from the communications ports and communications cards at Access Level 1 and higher.

You cannot view event reports at the front panel, although you can view event summary information at the front-panel display; see *EVENT on page R.7.14*.

Step 2. You can independently acknowledge the oldest event report at each communications port (**EVE ACK** command) so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete sets of event reports.

a. To acknowledge the oldest event report, you must first view that event report at a particular port by using the **EVE N(EXT**) command (see *EVENT*).

Step 3. You can use the **EVE** command at a terminal to retrieve event reports by event order or by event serial number.

The relay labels each new event with a unique serial number as reported in the **HIS** command history report; see *Event History on page A.3.27*.

Event Numbering

Event reports are numbered with an event identifier starting at the number 10000 and ending at the number 42767. The event identifier is called the Event Number in the event reports and is a unique number generated sequentially as the events are recorded. Event numbers remain associated with a particular event, even when new events are recorded.

However, when using the **EVE**, **CEV**, **CSU**, or **SUM** commands, the relay displays the most recent event. For example, if three events were recorded, the event numbers are 10001, 10002, and 10003.

1. After the **EVE <Enter>** command is entered, the relay displays the newest event, which is 10003.

   a. To distinguish between the two sequences, include an argument *n* with the **EVE**, **CEV**, **CSU**, or **SUM** commands.

   When parameter *n* is 1 through 100, *n* indicates the order of the event report, the most recent event report is 1, the next most recent report is 2, and so on.

When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

2. You can retrieve analog or digital information separately, and you can exclude the summary or settings portions of the report. The default **EVE** command event report data resolution is 4 samples/cycle with the factory default setting for LER = 15 cycles.

Table 3.5 lists a summary of **EVE** commands. See *EVENT* for complete information on the **EVE** command. *Table 3.6* shows a few examples of command options that you can use with the **EVE** command. The **EVE L** and **EVE C** commands provide compatibility with older command sets.

Table 3.5 EVE Command

Command	Description
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.
EVE *n*	Return a particular *n* event report (including settings and summary) at full length with 4-samples/cycle data.
EVE A	Return only the analog information for the most recent event report with 4-samples/cycle data.
EVE C	Return the most recent report at full length with 12-samples/cycle data.
EVE D	Return only the digital information for the most recent event report with 4-samples/cycle data.
EVE DIF	Return the differential information of the most recent report with 4-samples/cycle data.
EVE L	Return the most recent event report at full length with 12-samples/cycle sampling.
EVE L*y*	Return *y* cycles of the most recent event report with 4-samples/cycle data.
EVE NEXT	Return the oldest unacknowledged event report with 4-samples/cycle data.
EVE NSET	Return the most recent event report without settings at full length with 4-samples/cycle data.
EVE NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data.
EVE S*x*[a]	Return the most recent event report at full length with *x*-samples/cycle data.

[a] Where x = 4 or 12.

Table 3.6 shows examples of the **EVE** command.

Table 3.6 EVE Command Examples

Example	Description
EVE L10 S12	Return 10 cycles of a 12-samples/cycle event report for the most recent event.
EVE L10 A	Return 10 cycles of the analog portion only of the most recent event report at 4-samples/cycle resolution.
EVE 2 NSET	For the second most recent event, return the event report with no settings at 4-samples/cycle data.

You can retrieve event reports with the ACSELERATOR software. See *Section 3: PC Software in the User's Guide* for more information on viewing event reports with the ACSELERATOR software.

You can also download event files from the relay.

Step 1. Use a terminal emulation program with file transfer capability.

Step 2. At the Access Level 1 prompt or higher, type **FILE DIR EVENTS <Enter>** to view the available events. *Figure 3.3* shows an example of the relay response to the **FILE DIR EVENTS** command.

```
=>>FILE DIR EVENTS <Enter>
C1210000.TXT                R   03/01/2003 14:23:19
C1210001.TXT                R   03/01/2003 14:48:21
C1210002.TXT                R   03/01/2003 14:48:24
C2410000.TXT                R   03/01/2003 14:23:19
C2410001.TXT                R   03/01/2003 14:48:21
C2410002.TXT                R   03/01/2003 14:48:24
CHISTORY.TXT                R
D1210000.TXT                R   03/01/2003 14:23:19
D1210001.TXT                R   03/01/2003 14:48:21
D1210002.TXT                R   03/01/2003 14:48:24
E1210000.TXT                R   03/01/2003 14:23:19
E1210001.TXT                R   03/01/2003 14:48:21
E1210002.TXT                R   03/01/2003 14:48:24
E2410000.TXT                R   03/01/2003 14:23:19
E2410001.TXT                R   03/01/2003 14:48:21
E2410002.TXT                R   03/01/2003 14:48:24
E4_10000.TXT                R   03/01/2003 14:23:19
E4_10001.TXT                R   03/01/2003 14:48:21
E4_10002.TXT                R   03/01/2003 14:48:24
HISTORY.TXT                 R
Z2410000.TXT                R   03/01/2003 14:23:19
Z2410001.TXT                R   03/01/2003 14:48:21
Z2410002.TXT                R   03/01/2003 14:48:24

=>>
```

Figure 3.3 Example of the Relay Response to the FILE DIR EVENTS Command

Step 3. Type **FILE READ EVENTS E4_*nnnnn*.TXT <Enter>** to retrieve a 4-sample event report (*nnnnn* is the event serial number).

Step 4. Start the terminal download routine to store the file on your computer.

The following discussion shows sample portions of an event report that you download from the relay using a terminal emulation program and the **EVE** command.

Report Header and Analog Section of the Event Report

Figure 3.4 shows a substation with two busbars (WEST and EAST), a tie breaker, and three terminals (LONDON, NEW YORK, and CANBERRA). In this example, the event report shows the individual phases of the power system. The EAST busbar comprises three phases with alias names EAST_A, EAST_B, and EAST_C. *Figure 3.4* shows only the A-phase alias names (EAST_A, for example), but the event report includes all three phases. Therefore, the LONDON terminal has three phases labeled LOND_A (A-phase), LOND_B (B-phase), and LOND_C (C-phase).

Assume that Fault F1, a three-phase fault, occurs on the EAST busbar. Because Fault F1 is a three-phase fault, all three of the phase elements assert. For example, differential elements for phases EAST_A, EAST_B, and EAST_C assert for Fault F1.

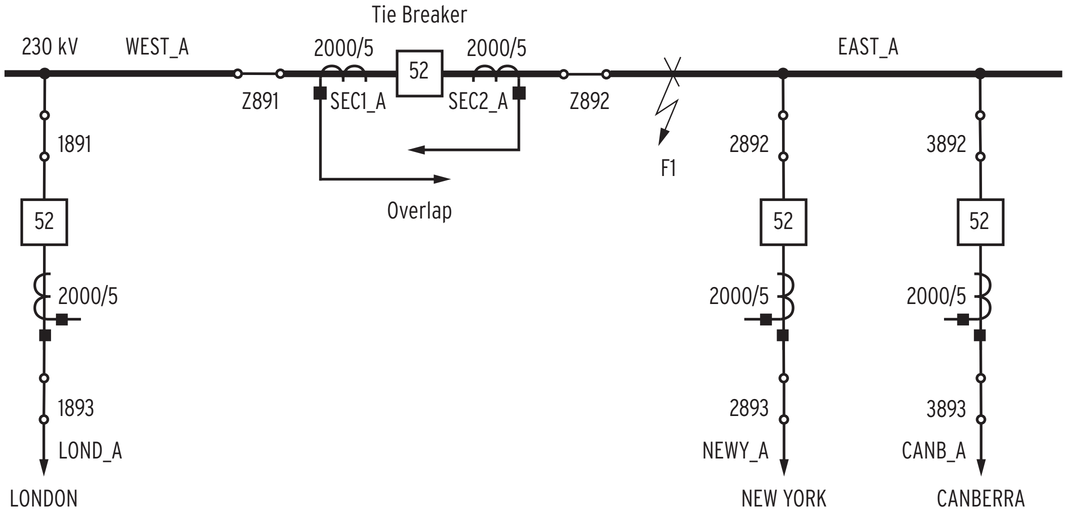


Figure 3.4 Substation With Two Busbars, a Tie Breaker, and Three Feeders

The first portion of an event report is the report header and the analog section. See *Figure 3.5* for the location of items included in a sample analog section of an event report. If you want to view only the analog portion of an event report, use the **EVE A** command.

The report header is the standard SEL-487B header listing the relay identifiers, date, and time. Report headers help you organize report data. Each event report begins with information about the relay and the event. The report header lists the:

➤ RID setting (Relay ID)

➤ SID setting (Station ID)

The FID string identifies the:

➤ Relay model

➤ Firmware version

➤ Date code of the firmware

See *Appendix A: Firmware and Manual Versions in the User's Guide* for a description of the FID string. The relay reports a date and time stamp to indicate the internal clock time when the relay triggered the event. The relay reports the firmware checksum as CID.

The event report column labels follow the header. The data underneath the analog column labels contain samples of the following:

➤ First nine currents channels in primary amps

➤ Three voltage channels in primary kilovolts

➤ Second group of nine current channels in primary amps

➤ Battery channel voltage in volts

These quantities are in instantaneous rms values and are described in *Table 3.7*. To obtain phasors, use the methods illustrated in *Obtaining RMS Phasors From 4-Samples/Cycle Event Reports on page A.3.12*, *Figure 3.6*, and *Figure 3.7*.

```
=>>EVE A <Enter>

Relay 1                                     Date: 07/24/2003  Time: 18:02:37.099
Station A                                   Serial Number: 2003004005
FID=SEL-487B-R102-V0-Z001001-D20030724 Event Number = 10057      CID=0xBF4D

                   Currents (Pri. Amps)                    Voltages (Pri. kV)
   I01   I02   I03   I04   I05   I06   I07   I08   I09      V01    V02    V03

[1]
   861 -1146   277   872 -1142   266   439  -568   124     99.4 -126.8   26.2
   829   339 -1162   820   352 -1159   401   185  -580     89.3   42.2 -131.0
  -862  1147  -276  -873  1142  -265  -438   568  -125    -99.4  126.8  -26.2
  -831  -342  1164  -818  -352  1161  -401  -185   582    -89.3  -42.2  131.0
.
.
.
[6]
  -637  2301 -1650  -668  2327 -1656  2562 -5257  2687     93.0 -112.3   18.1>
 -3399   301  3096 -3381   252  3142  5933   478 -6428     72.3   41.1 -112.9
  6481-10043  3496  6572-10045  3431-10565 15503 -4900    -68.5   81.0  -11.7
  8983  2019-10965  8901  2120-11025-13155 -3801 16970    -50.3  -30.7   80.7
[7]
-10822 14336 -3423-10940 14297 -3287 16439-21057  4554     50.5  -64.3   13.1
-10335 -4297 14572-10217 -4394 14600 14840  6832-21661     45.2   21.5  -66.5*
 10824-14331  3424 10940-14295  3285-16437 21055 -4552    -50.5   64.3  -13.1
 10329  4301-14568 10212  4397-14598-14832 -6836 21657    -45.2  -21.6   66.5
.
.
.
                   Currents (Pri. Amps)                   Battery (V)
   I10   I11   I12   I13   I14   I15   I16   I17   I18      VDC1

[1]
   901 -1127   216   907 -1122   206   455  -558    94     28.33
   789   393 -1174   775   411 -1174   380   211  -584     28.33
  -902  1127  -216  -910  1122  -206  -459   558   -95     28.32
  -786  -394  1175  -771  -410  1177  -378  -211   584     28.33
.
.
.
[6]
  -757  2479 -1711  -793  2526 -1725  2792 -5466  2663     28.32>
 -3304   -47  3354 -3282  -131  3424  5721  1056 -6813     28.32
  6862-10098  3164  6956-10115  3078-11115 15543 -4341     28.32
  8601  2731-11307  8511  2906-11390-12565 -4856 17455     28.32
[7]
-11304 14107 -2692-11417 14053 -2510 17099-20708  3453     28.33
 -9800 -4977 14729 -9677 -5140 14756 14065  7815-21866     28.33*
 11304-14104  2690 11413-14050  2510-17097 20705 -3451     28.33
  9795  4981-14725  9672  5143-14756-14059 -7820 21863     28.33
.
.
.
[15]
     1    -2    -1    -1     3     0     1    -1     5     28.32
     2     1     2    -2     1     3    -1     2     3     28.32
     0     1     2     5    -1    -3     0    -1    -2     28.32
     1    -2    -1     2    -1    -2     0    -2    -3     28.33

=>>
```

Header

Firmware ID

One Cycle of Data

See Figure 3.6 and Figure 3.7 to calculate phasors for this data

Trigger

1.25 Cycles After Event Trigger Current (to Event Summary)

Figure 3.5 Analog Section of the Event Report

Table 3.7 Event Report Metered Analog Quantities (Sheet 1 of 2)

Quantity	Description
I01	Channel 01 phase filtered instantaneous current
I02	Channel 02 phase filtered instantaneous current
I03	Channel 03 phase filtered instantaneous current
I04	Channel 04 phase filtered instantaneous current
I05	Channel 05 phase filtered instantaneous current
I06	Channel 06 phase filtered instantaneous current
I07	Channel 07 phase filtered instantaneous current

Table 3.7 Event Report Metered Analog Quantities (Sheet 2 of 2)

Quantity	Description
I08	Channel 08 phase filtered instantaneous current
I09	Channel 09 phase filtered instantaneous current
V01	Channel 01 phase filtered instantaneous voltage
V02	Channel 02 phase filtered instantaneous voltage
V03	Channel 03 phase filtered instantaneous voltage
I10	Channel 10 phase filtered instantaneous current
I11	Channel 11 phase filtered instantaneous current
I12	Channel 12 phase filtered instantaneous current
I13	Channel 13 phase filtered instantaneous current
I14	Channel 14 phase filtered instantaneous current
I15	Channel 15 phase filtered instantaneous current
I16	Channel 16 phase filtered instantaneous current
I17	Channel 17 phase filtered instantaneous current
I18	Channel 18 phase filtered instantaneous current
VDC1	Filtered dc monitor voltage

Figure 3.5 contains selected data from the analog section of a 4-samples/cycle event report initiated using the **TRIGGER** command. The bracketed numbers at the left of the report (for example, [6]) indicate the cycle number; *Figure 3.5* shows three cycles of 4-samples/cycle data.

The trigger row includes a > character following immediately after the V03 column to indicate the trigger point. This is the dividing point between the prefault or PRE time and the fault or remainder of the data capture.

The row that the relay uses for the currents in the event summary is the row with the largest current magnitudes; the relay marks this row on the event report with an asterisk * character immediately after the V03 column. The * takes precedence over the > if both occur on the same row in the analog section of the event report.

Obtaining RMS Phasors From 4-Samples/Cycle Event Reports

Use the column data in an event report to calculate rms values. You can use a calculator to convert rectangular data to phasor data, or use hand calculations to separately determine the magnitude and angle of the rms phasor.

Hand Calculation Method. The procedure in the following steps explains a method for obtaining a current phasor from the I01 channel data in the event report of *Figure 3.5*. You can process voltage data columns similarly. *Figure 3.6* and *Figure 3.7* show one cycle of I01 current in detail. *Figure 3.6* shows how to relate the event report ac current column data to the sampled waveform and rms values. *Figure 3.7* shows how to find the phasor angle. If you use the larger 12-samples/cycle event report, take every third sample and apply those values in this procedure.

This example demonstrates using a terminal emulation program. A more convenient method is to use the ACSELERATOR software or the SEL-5601 Analytic Assistant. These programs automate the analysis process presented in this example and provide you with voltage and current phasors as software outputs.

This example assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for step-by-step instructions. In addition, you must understand relay access levels and passwords. See *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

Step 2. Identify an event.

a. Type **HIS <Enter>**.

The **HIS** command gives a quick, one-row listing of relay-stored events. See *Event History on page A.3.27* for more information. This example uses the latest captured event.

b. If no events are available, use the **TRI** command to generate an event (see *Triggering Data Captures and Event Reports on page A.3.3*).

Step 3. Gather data from the event report.

a. Enable terminal data capture (usually a **Transfer > Capture Text** menu) in your terminal emulation program.

b. Type **EVE A <Enter>** at the => prompt to obtain the analog part of an event report similar to *Figure 3.5*. (See *Table 3.5* for a summary of **EVENT** commands.)

The relay responds with the analog portion of the event report.

Step 4. Calculate the phasor magnitude.

a. Select a cycle of data from the I01 column of the event report in *Figure 3.5*. Cycle [1] data for this example are shown in *Figure 3.6*.

b. Compute phasor magnitude using *Equation 3.1*:

$$\sqrt{X^2 + Y^2} = |\text{Phasor}| \quad \textbf{Equation 3.1}$$

In *Equation 3.1*, Y is the first row of the I01 column current of a data pair. The next row is X, the present value of the pair. For this example, the computation shown in *Figure 3.6*. yields 1195 A.

c. Compute phasor magnitudes from the remaining data pairs for Cycle [1].

d. Confirm that all values are similar.

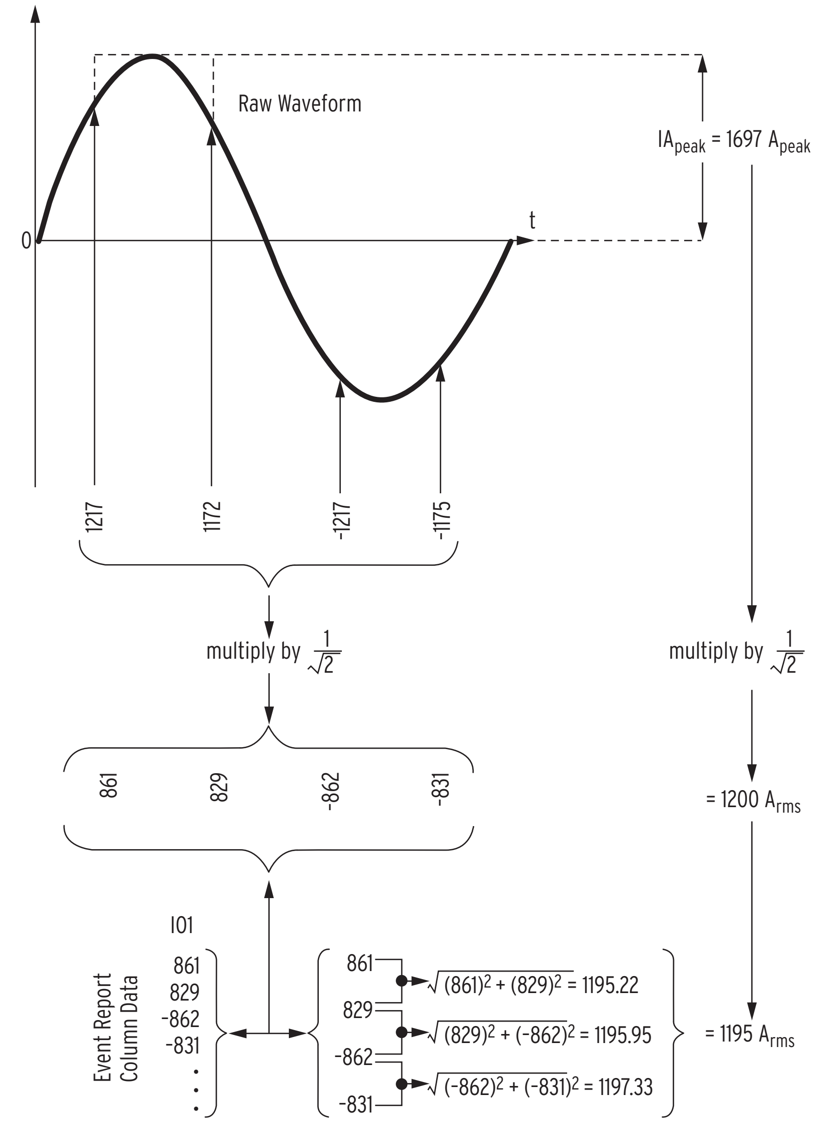


Figure 3.6 Event Report Current Column Data and RMS Current Magnitude

NOTE: The arctan function of many calculators and computing programs does not return the correct angle for the second and third quadrants (when X is negative). When in doubt, graph the X and Y quantities to confirm that the angle that your calculator reports is correct.

Step 5. Calculate the immediate phase angle.

a. Select the same cycle of data from the I01 column of the event report as you did when finding the magnitude (Cycle [1] data for this example).

b. Compute phasor angle using *Equation 3.2*:

$$\theta = \arctan\left(\frac{Y}{X}\right) = \angle \text{Phasor}$$

Equation 3.2

In *Equation 3.2*, Y is the first (or previous value) I01 column current of a data pair, and X is the present value of the pair. For this example, the computation shown in *Figure 3.7* yields 46.1 degrees.

c. Compute phasor angles from the remaining data pairs for Cycle [1].

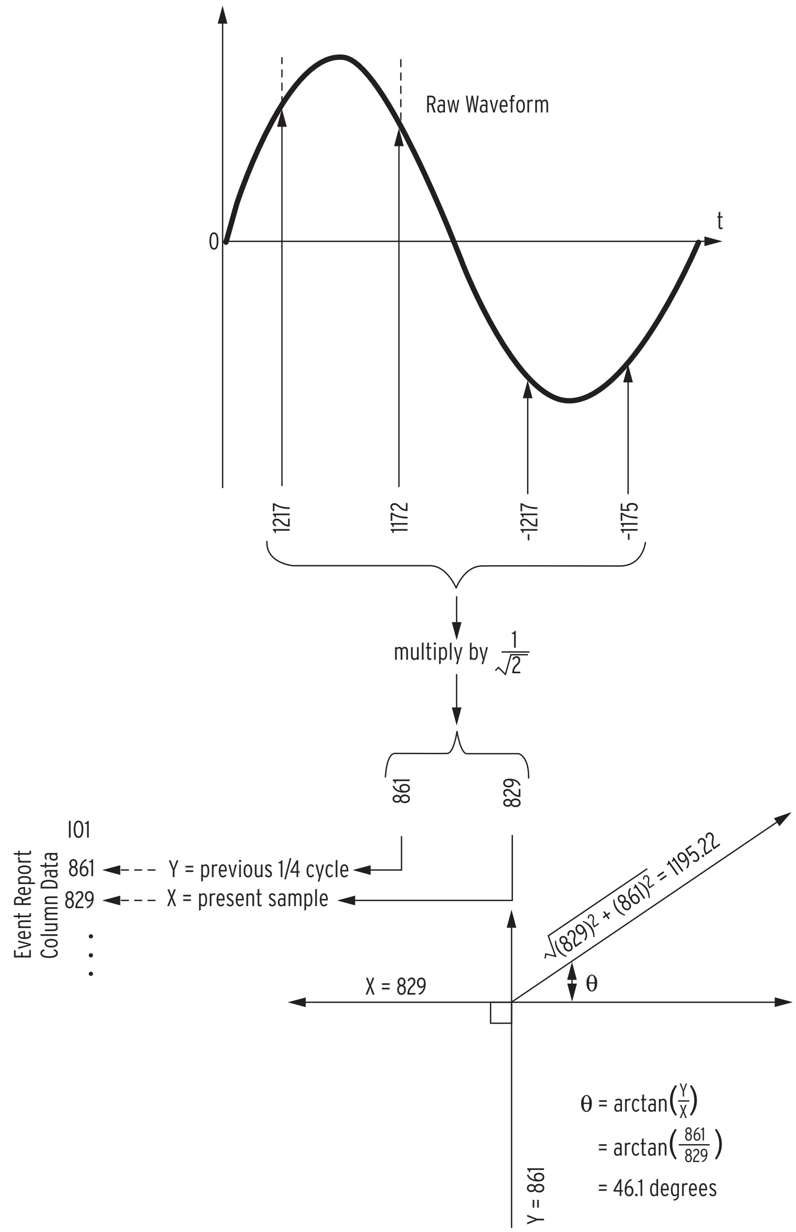


Figure 3.7 Event Report Current Column Data and RMS Current Angle

Step 6. Calculate the reference phase angle.

a. Usually, you compare power system angles to a reference phasor (A-phase voltage, for example).

b. Repeat *Step 5 on page A.3.14* for the row data in the V01 column that correspond to the I01 column data values you used in *Step 5*. Use *Equation 3.3* to calculate the angle for the V01 data:

$$\theta = \arctan\frac{Y}{X} = \angle\text{Phasor}$$

$$= \arctan\left(\frac{99.4}{89.3}\right)$$

$$= 48.1°$$

Equation 3.3

Step 7. Calculate the absolute phase angle.

a. Subtract the I01 angle from the V01 angle to obtain the A-phase-referenced phasor angle for I01.

$$\angle V01 - \angle I01 = 48.1 - 46.1 = 2.0° \quad \textbf{Equation 3.4}$$

Therefore, the rms phasor for current I01 at the present sample is 1195.22 A $\angle 46.1°$, lagging reference voltage V01 by 2.0 degrees.

In the procedure above, you use two rows of current data from the event report to calculate an rms phasor current. At the first sample pair of Cycle [1], the rms phasor is I01 = 1195.22 A $\angle 46.1°$. The present sample of the sample pair (X = 829) is a scaled instantaneous current value (not an rms quantity) that relates to the rms phasor current value by the expression

$$X = 829 = 1195.22 \bullet \cos(46.1°) \quad \textbf{Equation 3.5}$$

Polar Calculator Method. A method for finding the phasor magnitude and angle from event report quarter-cycle data pairs is to use a polar-capable calculator or computer program. Many calculators and computer programs convert Cartesian (X and Y) coordinate data to polar data.

Step 1. Key or enter the X value (present value or lower value of a column pair) and the Y value (later value or upper value in a column pair) as Cartesian (rectangular) coordinates.

Step 2. Perform the keystrokes necessary for your calculator or computing program to convert to polar coordinates. This is the phasor value for the data pair.

Digital Section of the Event Report

The second portion of an event report is the digital section.

Step 1. Inspect the digital data to evaluate relay element response during an event.

a. See *Figure 3.8* for the locations of items in a sample event report digital section.

Step 2. If you want to view only the digital portion of an event report, use the **EVE D** command.

See *Table 3.5* or *Section 7: ASCII Command Reference in the Reference Manual* for details.

In the digital portion of the event report, the relay indicates deasserted elements with a period (.) and asserted elements with an asterisk (*) character.

The element and digital information labels are single-character columns. Read these columns from top to bottom. The trigger row includes a > character following immediately after the last digital element column to indicate the trigger point. The relay marks the row used to report the maximum fault current with an asterisk * character at the right of the last digital element column. Event reports that are 4-samples/cycle reports show the OR combination of digital elements in the 12-samples/cycle rows to make the quarter-cycle entry.

The digital report arranges the event report digital settings into 79 column pages. For every 79 columns, the relay generates a new report that follows the previous report.

The report displays the digital label header for each column in a vertical fashion, aligned on the last character. If the Relay Word bits included in the header were assigned aliases, the alias names appear in the report. For example, the first six Relay Word bits in the event report are 87Z1, 87Z2, 87Z3, 87Z4, 87Z5, and 87Z6. Each Relay Word bit has an alias name as shown in *Table 3.8*.

Table 3.8 Primitive and Alias Names of the First Four Digital Label Headers in the Default Event Report

Primitive Name	Alias Name
87Z1	WEST_A
87Z2	WEST_B
87Z3	WEST_C
87Z4	EAST_A
87Z5	EAST_B
87Z6	EAST_C

Figure 3.8 shows the digital section of the event report for fault F1.

```
=>>EVE D <Enter>

Relay 1                                     Date: 07/24/2003  Time: 18:02:37.099
Station A                                   Serial Number: 2003004005
FID=SEL-487B-R102-V0-Z001001-D20030724 Event Number = 10057     CID=0xBF4D

            D
WWWEEE LNCS I   LLLSSSNNNSSSCCC
EEEAAA OEAE FB  OOOEEEEEEEEEAAA
SSSSSS NWNC FF  NNNCCCWWWCCCNNN          Digital Column Labels
TTTTTT ____ __T DDD222YYY111BBB
______ BBBB EEN _______________
ABCABC FFFF NNS ABCABCABCABCABC

[1]
...... .... **. ...............
...... .... **. ...............          One Cycle of Data
...... .... **. ...............
...... .... **. ...............
.
.
.

[5]
...... .... **. ...............
...... .... **. ...............
...... .... **. ...............
...... .... **. ...............
[6]
...*** .... **. ......*********>         Trigger
...*** .... **. ......*********          Trip outputs
...*** .... **. ......*********          assert for the
...*** .... **. ......*********          tie breaker and FDR_1
[7]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[8]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[9]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********          Differential element resets
[10]
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
...*** .... **. ......*********
[11]
...*** .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********
.
.
.

[15]
...... .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********
...... .... **. ......*********

=>>
```

Figure 3.8 Digital Section of the Event Report

Figure 3.9 shows the first six digital label headers in the default event report and the same information in a horizontal format.

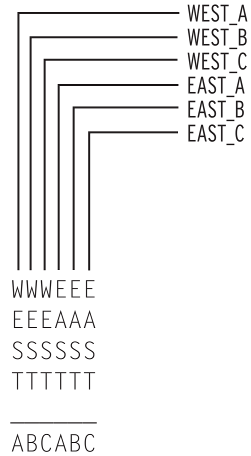


Figure 3.9 Sample Digital Portion of the Event Report

EXAMPLE 3.3 Reading the Digital Portion of the Event Report

This example shows how to read the digital event report shown in Figure 3.9. The sample digital event report shows nine cycles of 4-samples/cycle data for a three-phase fault.

Relay Word bit DIFF_EN in the 13th column from the left is picked up, enabling the differential elements. In this particular report, the three differential elements, EAST_A, EAST_B, and EAST_C, pick up in the first sample of Cycle [6]. The relay asserts the tripping Relay Word bits when the differential elements operate.

Selecting Event Digital Elements

Specify the digital elements in the digital section of the event report by using the Event Reporting Digital Elements settings found in the Report settings (the **SET R** command from a terminal or the Report branch of the Settings tree view of the ACSELERATOR software). You can enter at least 647 Relay Word bits from at least 73 Relay Word bit rows in the event report. The **#** symbol places a blank column in the digital report. Use the **#** symbol to organize the digital section of the event report. See *Report Settings on page R.8.29* for a list of the default programmed digital elements.

Event Summary Section of the Event Report

The third portion of an event report is the summary section. See *Figure 3.10* for the location of items included in a sample summary section of an event report. If you want to exclude the summary portion from an event report, use the **EVE NSUM** command. See *EVENT on page R.7.14* for details.

The information in the summary portion of the event report is the same information in the event summary, except that the report header does not appear immediately before the event information when you view a summary in the event report. See *Event Summary on page A.3.24* for a description of the items in the summary portion of the event report.

```
=>>SUM <Enter>

Relay 1                                     Date: 03/02/2003  Time: 12:33:51.078
                                            Serial Number: 2003030400
Event: 87BTR                                                  Time Source: OTHER
Event Number: 10057                                                     Group: 1
Targets: TLED_1 TLED_6 TLED_7 TLED_8

Fault:       I01   I02   I03   I04   I05   I06   I07   I08   I09   I10   I11
MAG(A)     14964 14966 14968 14969 14957 14966 22146 22138 22135 14960 14959
ANG(DEG)     178    59   -61   179    59   -61     0  -120   120  -179    61
             I12   I13   I14   I15   I16   I17   I18   V01   V02   V03
MAG(A/kV)  14973 14967 14964 14968 22140 22134 22136  67.8  67.8  67.8
ANG(DEG)     -59  -178    62   -58     2  -117   123     0  -120   121

Tripped Terminals
    I07         I08         I09         I10         I11         I12
    I16         I17         I18

Bus-Zones in Protection Zone 4
    BZ4

Bus-Zones in Protection Zone 5
    BZ5

Bus-Zones in Protection Zone 6
    BZ6

=>>
```

Figure 3.10 Summary Section of the Event Report

Settings Section of the Event Report

The final portion of an event report is the settings section. See *Figure 3.11* for the locations of items included in a sample settings section of an event report. If you want to exclude the settings portion from an event report, use the **EVE NSET** command. See *EVENT on page R.7.14* for details.

The settings portion of the event report lists important relay settings at the time the relay event triggered. The event report shows group, zone configuration settings, global, output, protection SELOGIC control equation settings, and alias settings. For the group settings, zone configuration, and protection SELOGIC control equation settings, the relay reports only the active group. The settings order in the event report is the same order as when you issue a **SHOW** command from a terminal. See *SHOW on page R.7.37* for information on the **SHOW** command, and *Making Simple Settings Changes on page U.4.12* for information on relay settings.

```
Group 1

Relay Configuration

E87SSUP := N       ECSL    := N       ETOS    := 5       EBFL    := 6
E50     := N       E51     := N       EVOLT   := Y       EADVS   := N

.
.
.
Trip Logic

TR01    := 87BTR01 OR 87BTR04
ULTR01  := NA
.
.
.
```

Active Group Settings

```
Zone Config Group 1

Potential Transformer Ratio

PTR1    := 2000     PTR2    := 2000     PTR3    := 2000

Current Transformer Ratio

CTR01   := 600      CTR02   := 600      CTR03   := 600      CTR04   := 600
.
.
.
```

Active Zone Configuration Settings

```
Global

General Global Settings

SID     := "Station A"
RID     := "Relay 1"
.
.
.
```

Global Settings

```
Output

Main Board

OUT101  := LOND_A OR LOND_B OR LOND_C
.
.
.
```

Output Settings

```
Protection 1

1: PLT01S := PCT02Q AND NOT DIFF_EN # DIFFERENTIAL ENABLED
.
.
.
```

Protection Logic Settings

```
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: 87Z1,"WEST_A"
.
.
.
28: TRIP18,"CANB_C"
```

Alias Settings

Figure 3.11 Settings Section of the Event Report

CEVENT

The relay provides a Compressed ASCII event report for SCADA and other automation applications. The ACSELERATOR software uses Compressed ASCII commands to gather event report data. If you want to view the Compressed ASCII event report data, use a terminal to issue the **CEV** command. A sample of the report appears in *Figure 3.12*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII event report are similar to the event, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order. Contact your local Technical Service Center or the SEL factory for the latest inventory of the items and item order in the Compressed ASCII event report.

See *SEL Compressed ASCII Commands on page R.4.4* and *Section 7: ASCII Command Reference in the Reference Manual* for more information on the Compressed ASCII command set.

```
=>>CEV <Enter>
"FID","RID","SID","03E2"
"FID=SEL-487B-R102-V0-Z001001-D20030724","Relay 1","Station A","0F5F"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","0C6A"
4,21,2003,6,57,13,441,960,"04FA"
```

Report Header

```
"EVENT_NUM","FREQ","NFREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","SER_NUM","PRIM_
VAL","CTR_I01","CTR_I02","CTR_I03","CTR_I04","CTR_I05","CTR_I06","CTR_I07","CTR_
I08","CTR_I09","CTR_I10","CTR_I11","CTR_I12","CTR_I13","CTR_I14","CTR_I15","CTR_
I16","CTR_I17","CTR_I18","PTR_V01","PTR_V02","PTR_V03","EVENT","TIME_SOURCE","GR
OUP","TARGETS","MB_TRIGGER","MB_TRIP","TRIP_TERM","BZ_IN_ZONE1","BZ_IN_ZONE2","B
Z_IN_ZONE3","BZ_IN_ZONE4","BZ_IN_ZONE5","BZ_IN_ZONE6","I01","I01_DEG","I02","I02
_DEG","I03","I03_DEG","I04","I04_DEG","I05","I05_DEG","I06","I06_DEG","I07","I07
_DEG","I08","I08_DEG","I09","I09_DEG","I10","I10_DEG","I11","I11_DEG","I12","I12
_DEG","I13","I13_DEG","I14","I14_DEG","I15","I15_DEG","I16","I16_DEG","I17","I17
_DEG","I18","I18_DEG","V01","V01_DEG","V02","V02_DEG","V03","V03_DEG","BB17"
```

Summary Labels

```
10057,60.00,60,4,4,15,"0000000000","YES",600,600,600,600,600,600,600,600,600,600
,600,600,600,600,600,600,600,600,2000,2000,2000,"87BTR","OTHER",1,"TLED_1 TLED_6
 TLED_7 TLED_8","0000000000","0000000000","I07 I08 I09 I10 I11 I12 I16 I17 I18",
" "," "," ","BZ4","BZ5","BZ6",14964,178,14966,59,14968,-61,14969,179,14957,59,14
966,-61,22146,0,22138,-120,22135,120,14960,-179,14959,61,14973,-59,14967,-178,14
964,62,14968,-58,22140,2,22134,-117,22136,123,67.8,0,67.8,-120,67.8,121,"5D61"
```

Summary Data

```
"I01(A)","I02(A)","I03(A)","I04(A)","I05(A)","I06(A)","I07(A)","I08(A)","I09(A)"
,"I10(A)","I11(A)","I12(A)","I13(A)","I14(A)","I15(A)","I16(A)","I17(A)","I18(A)
","V01(kV)","V02(kV)","V03(kV)","IOP1","IRT1","IOP2","IRT2","IOP3","IRT3","IOP4"
,"IRT4","IOP5","IRT5","IOP6","IRT6","VDC1","TRIG","WEST_A WEST_B WEST_C EAST_A E
AST_B EAST_C LON_BF NEW_BF CAN_BF SEC_BF DIFF_EN BF_EN TNS LOND_A LOND_B LOND_C
SEC2_A SEC2_B SEC2_C NEWY_A NEWY_B NEWY_C SEC1_A SEC1_B SEC1_C CANB_A CANB_B CAN
B_C","37E6"
```

Column Labels

```
861,-1146,277,872,-1142,266,439,-568,124,901,-1127,216,907,-1122,206,455,-558,94
,99.4,-126.8,26.2,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.79,0.00,0.80,0.00,0.79,28
.33, ,"0030000","2180"
829,339,-1162,820,352,-1159,401,185,-580,789,393,-1174,775,411,-1174,380,211,-58
4,89.3,42.2,-131.0,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.79,0.00,0.80,0.00,0.79,2
8.33, ,"0030000","21A5"
-862,1147,-276,-873,1142,-265,-438,568,-125,-902,1127,-216,-910,1122,-206,-459,5
58,-95,-99.4,126.8,-26.2,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.80,0.00,0.80,0.00,
0.79,28.32, ,"0030000","22B3"
-831,-342,1164,-818,-352,1161,-401,-185,582,-786,-394,1175,-771,-410,1177,-378,-
211,584,-89.3,-42.2,131.0,0.01,0.80,0.00,0.80,0.00,0.80,0.00,0.79,0.00,0.80,0.00
,0.79,28.33, ,"0030000","22D4"
.
.
.

2792,-5466,2663,93.0,-112.3,18.1,0.01,0.75,0.01,1.56,0.00,1.35,2.04,2.17,4.40,4.
41,2.35,2.52,28.32,">","1C301FF","2529"
```

Trigger

```
-3399,301,3096,-3381,252,3142,5933,478,-6428,-3304,-47,3354,-3282,-131,3424,5721
,1056,-6813,72.3,41.1,-112.9,0.01,2.30,0.02,2.18,0.02,2.35,5.39,5.41,4.43,4.44,6
.01,6.02,28.32, ,"1C301FF","23E8"
6481,-10043,3496,6572,-10045,3431,-10565,15503,-4900,6862,-10098,3164,6956,-1011
5,3078,-11115,15543,-4341,-68.5,81.0,-11.7,0.03,4.90,0.02,6.70,0.03,3.60,10.74,1
0.74,13.72,13.73,6.91,6.92,28.32, ,"1C301FF","2784"
8983,2019,-10965,8901,2120,-11025,-13155,-3801,16970,8601,2731,-11307,8511,2906,
-11390,-12565,-4856,17455,-50.3,-30.7,80.7,0.04,7.55,0.03,6.84,0.03,7.69,14.88,1
4.88,14.23,14.24,15.79,15.80,28.32, ,"1C301FF","2815"
-10822,14336,-3423,-10940,14297,-3287,16439,-21057,4554,-11304,14107,-2692,-1141
7,14053,-2510,17099,-20708,3453,50.5,-64.3,13.1,0.05,9.39,0.04,9.64,0.05,7.66,18
.82,18.83,19.01,19.01,15.66,15.66,28.33, ,"1C301FF","28FE"
-10335,-4297,14572,-10217,-4394,14600,14840,6832,-21661,-9800,-4977,14729,-9677,
-5140,14756,14065,7815,-21866,45.2,21.5,-66.5,0.06,9.98,0.03,9.97,0.05,9.98,19.7
5,19.75,19.74,19.74,19.74,19.75,28.33,"*","1C301FF","2955"
```

Largest Current

```
10824,-14331,3424,10940,-14295,3285,-16437,21055,-4552,11304,-14104,2690,11413,-
```

Event Data

```
.
.
.
"SETTINGS","02E1"
"
Group 1

Relay Configuration

E87SSUP := N       ECSL    := N       ETOS    := 5       EBFL    := 6
E50     := N       E51     := N       EVOLT   := Y       EADVS   := N

.
.
.
Trip Logic

TR01    := 87BTR01 OR 87BTR04
ULTR01  := NA
.
.
.
Zone Config Group 1

Potential Transformer Ratio

PTR1    := 2000     PTR2    := 2000     PTR3    := 2000

Current Transformer Ratio

CTR01   := 600      CTR02   := 600      CTR03   := 600      CTR04   := 600
CTR05   := 600      CTR06   := 600      CTR07   := 600      CTR08   := 600
.
.
.
Global

General Global Settings

SID     := Station A
RID     := Relay 1
.
.
.
Output

Main Board

OUT101  := LOND_A OR LOND_B OR LOND_C
.
.
.
Protection 1

1: PLT01S := PCT02Q AND NOT DIFF_EN # DIFFERENTIAL ENABLED
.
.
.
Alias

Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])

1: 87Z1,WEST_A
.
.
.

28: TRIP18,CANB_C
","98DA"

=>>
```

Active Group Settings

Active Group Zone Configuration Settings

Global Settings

Output Settings

Active Protection Logic Settings

Alias Settings

Figure 3.12 Sample Compressed ASCII Event Report

The order of the labels in the Column Labels data group matches the order of the Relay Word bits in the event report when read from left to right. For example, refer to the Column Labels data group and find the label TRIG. Look lower on the page at the Trigger data group, and identify the > symbol. The TRIG label in the Column Labels data group corresponds to the > symbol in the Event Data group. Next to the > symbol appears a hexadecimal number

(1C301FF). Each numeral of this hexadecimal number reports the status of four Relay Word bits in the event report. The first numeral (1) of the hexadecimal number 1C301FF reports the status of the first four Relay Word bits in the event report, i.e., WEST_A, WEST_B, WEST_C, and EAST_A. Because each hexadecimal numeral represents four Relay Word bits, the binary number is 0001. Binary number 0001 tells us that of the four Relay Word bits in this group, only the fourth Relay Word bit (EAST_A) asserted, i.e., WEST_A = 0, WEST_B = 0, WEST_C = 0, and EAST_A = 1.

The next group of four Relay Word bits in the event report comprises EAST_B, EAST_C, LON_BF, and NEW_BF, represented by C in 1C301FF. The binary equivalent of C is 1100, telling us that only the first two Relay Word bits (EAST_B and EAST_C) of the four Relay Word bits in the group asserted.

The first sample of Cycle [6] (see *Figure 3.8*) shows that elements EAST_A, EAST_B, and EAST_C (as well as other elements) are picked up.

Event Files Download

You can download the event file from the relay and save these files to a PC to keep it as a record or examine it later. Use a terminal emulation program with file transfer capability. For example:

Step 1. Type **FILE READ EVENTS E24_10007.TXT <Enter>** at an Access Level 1 prompt or higher to download a 24-samples/cycle event report with serial number 10007.

Step 2. Start the terminal download routine to store the file on your computer.

Use Y modem protocol.

Step 3. If you want the Compressed ASCII file, type **FILE READ EVENTS C24_10007.TXT <Enter>**.

In addition, you can use the ACSELERATOR software to download event files. See *Retrieving Event Report Data Files: Terminal Emulation Software on page U.4.36* and *Section 3: PC Software in the User's Guide* for more information on event report file download procedures.

Event Summary

You can retrieve a shortened version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event in response to power system faults and other trigger events (see *Triggering Data Captures and Event Reports on page A.3.3*). See *Figure 3.13* for a sample event summary.

```
Relay 1                                        Date: 03/30/2003  Time: 18:02:37.099
Station A                                      Serial Number: 2003004005

Event: 87BTR                                                 Time Source: OTHER
Event Number: 10057                                                     Group: 1
Targets: TLED_1 TLED_6 TLED_7 TLED_8

Fault:        I01   I02   I03   I04   I05   I06   I07   I08   I09   I10   I11
MAG(A)      14964 14966 14968 14969 14957 14966 22146 22138 22135 14960 14959
ANG(DEG)      178    59   -61   179    59   -61     0  -120   120  -179    61
              I12   I13   I14   I15   I16   I17   I18   V01   V02   V03
MAG(A/kV)   14973 14967 14964 14968 22140 22134 22136  67.8  67.8  67.8
ANG(DEG)      -59  -178    62   -58     2  -117   123     0  -120   121

Tripped Terminals
    I07         I08         I09         I10         I11         I12
    I16         I17         I18

Bus-Zones in Protection Zone 4
    BZ4

Bus-Zones in Protection Zone 5
    BZ5

Bus-Zones in Protection Zone 6
    BZ6
```

Report Header

Event Information

Fault Data

Terminals Tripped

Bus-Zones in the Protection Zone

Figure 3.13 Sample Event Summary Report

The event summary contains the following:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- Time source
- Event number
- Active settings group at trigger time
- Targets
- Fault currents and voltages
- Tripped terminals
- Bus-Zones in protection zone

Targets are displayed only if a rising edge of Relay Word bits 87BTR, SBFTR, or TRIP asserted before the end of the event report. When a trip occurs, the relay displays the aliases of the latched targeting bits asserted on the last row of the event. Current and voltage analog quantities in the summary are the values 1.25 cycles after the event trigger.

Table 3.9 defines the various event types in fault reporting priority. Fault event type 87BTR (busbar protection trip) has reporting priority over event type SBFTR (breaker failure). If more than one event type asserts, the relay reports only the highest priority event type. For example, you can trigger an event when there is no fault condition on the power system by using the **TRI** command. In this case, when there is no fault, the relay reports the event type as TRIG.

Table 3.9 Event Types

Event Type	Event Trigger
87BTR	Rising edge of Relay Word Bit 87BTR, the OR combination of a busbar protection trip output to any Terminal.
SBFTR	Rising edge of Relay Word Bit SBFTR, the OR combination of a breaker failure trip output to any Terminal.
TRIP	Rising edge of Relay Word Bit TRIP.
ER	The relay generates the event with elements in the SELOGIC control equation ER.
TRIG	The relay generates the event in response to the **TRI** command.

Viewing the Event Summary

Access the event summary from the communications ports or from the communications card. View and download history reports from Access Level 1 and higher. You can independently acknowledge a summary (with the **SUM ACK** command) at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve a complete set of summary reports.

To acknowledge and remove a summary, first use the **SUM N(EXT)** command to view that summary. Use the **SUM** command to retrieve event summaries by date or date range and by event number. (The relay labels each new event with a unique number as reported in the **HIS** command history report; see *Event History on page A.3.27*.)

Table 3.10 lists the **SUM** commands. See *SUMMARY on page R.7.41* for complete information on the **SUM** command.

Table 3.10 SUM Command

Command	Description
SUM	Return the most recent event summary.
SUM *n*	Return an event summary for event n[a].
SUM ACK	Acknowledge the oldest unacknowledged event summary on at the present communications port.
SUM NEXT	View the oldest unacknowledged event summary at the present communications port.

[a] Parameter n indicates event order or serial number; see Event Numbering on page A.3.7 for more information.

You can retrieve event summaries with the ACSELERATOR software. See *Analyze Events on page U.3.15* for information and examples.

CSUMMARY

The relay outputs a Compressed ASCII summary report for SCADA and other automation applications. Issue the **CSU** command to view the Compressed ASCII summary report. A sample of the summary report appears in *Figure 3.14*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII summary report are similar to those included in the summary report, although the relay reports the items in a special order.

See *SEL Compressed ASCII Commands on page R.4.4* and *Section 7: ASCII Command Reference in the Reference Manual* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03E2"
"Relay 1","Station A","FID=SEL-487B-R102-V0-Z001001-D20030724","0F59"
"EVENT_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","TIME_
SOURCE","GROUP","TARGETS","MB_TRIGGER","MB_TRIP","TRIP_TERM","BZ_IN_ZONE1","BZ_I
N_ZONE2","BZ_IN_ZONE3","BZ_IN_ZONE4","BZ_IN_ZONE5","BZ_IN_ZONE6","I01","I01_DEG"
,"I02","I02_DEG","I03","I03_DEG","I04","I04_DEG","I05","I05_DEG","I06","I06_DEG"
,"I07","I07_DEG","I08","I08_DEG","I09","I09_DEG","I10","I10_DEG","I11","I11_DEG"
,"I12","I12_DEG","I13","I13_DEG","I14","I14_DEG","I15","I15_DEG","I16","I16_DEG"
,"I17","I17_DEG","I18","I18_DEG","V01","V01_DEG","V02","V02_DEG","V03","V03_DEG"
,"822E"
10057,3,30,2003,18,2,37,99,600,"87BTR","OTHER",1,"TLED_1 TLED_6 TLED_7 TLED_8","
0000000000","0000000000","I07 I08 I09 I10 I11 I12 I16 I17 I18"," "," "," ","BZ4"
,"BZ5","BZ6",14964,178,14966,59,14968,-61,14969,179,14957,59,14966,-61,22146,0,2
2138,-120,22135,120,14960,-179,14959,61,14973,-59,14967,-178,14964,62,14968,-58,
22140,2,22134,-117,22136,123,67.8,0,67.8,-120,67.8,121,"4B06"
```

Report Header

Report Labels

Report Data

Figure 3.14 Sample Compressed ASCII Summary

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767, the top of the numbering range, the relay returns to 10000 for the next event number and then continues to increment.) See *Figure 3.15* for a sample event history.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- Time source
- Event number
- Active settings group at trigger time
- Targets
- Fault currents and voltages
- Tripped terminals
- Bus-Zones in protection zones

Figure 3.15 is a sample event history from a computer terminal.

```
=>>HIS <Enter>

Relay 1                                      Date: 05/06/2003  Time: 06:53:08.568
Station A                                    Serial Number: 2003004005

#       DATE        TIME       EVENT  GRP  TARGETS
10050 05/06/2003 06:52:59.807  87BTR   2   87_DIFF ZONE_2
.
.
.
10004 05/06/2003 06:51:20.646  ER      2
10003 05/06/2003 06:51:15.648  87BTR   1   87_DIFF ZONE_1
10002 05/06/2003 06:50:22.751  ER      1

10001 05/06/2003 06:50:17.758  87BTR   1   87_DIFF ZONE_1
10000 05/06/2003 06:46:22.656  TRIG    1
```

Event Number | Event Type | Active Group

Figure 3.15 Sample Event History

The event types in the event history are the same as the event types in the event summary. See *Table 3.5* for event types.

The event history report indicates events stored in relay nonvolatile memory. The relay places a blank row in the history report output; items that are above the blank row are available for viewing (use the **EVE** and **CEV** commands). Items that are below the blank row are no longer in relay memory; these events appear in the history report to indicate past power system performance. The relay does not ordinarily modify the numerical or time order in the history report. However, if an event report is corrupted (power was lost during storage, for example), the relay lists the history report line for this event after the blank row.

Viewing the Event History

Access the history report from the communications ports and communications cards.

Step 1. View and download history reports from Access Level 1 and higher.

Step 2. You can also clear or reset history data from Access Levels 1 and higher.

a. You can independently clear/reset history data at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete history reports.

b. You can also clear all history data from all ports (with the **HIS CA** and **HIS RA** commands).

Step 3. Use the **HIS** command from a terminal to obtain the event history.

Step 4. You can view event histories by date or by date range, or you can specify the number of the most recent events that the relay returns.

See *HISTORY on page R.7.17* for information on the **HIS** command. *Table 3.11* lists the **HIS** commands.

Table 3.11 HIS Command

Command	Description
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *k*	Return the *k* most recent event summaries with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *date1*	Return the event summaries on date *date1*.
HIS *date1 date2*	Return the event summaries from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.
HIS C	Clear/reset all event data on the present port only.
HIS R	Clear/reset all event data on the present port only.
HIS CA	Clear event data for all ports.
HIS RA	Clear event data for all ports.

Step 5. You can use the ACSELERATOR software to retrieve the relay event history. See *Analyze Events on page U.3.15* for information and examples.

CHISTORY

NOTE: The **CHI A** option outputs compressed summary (**CSU**) information. This format displays the **CSU** labels, followed by **CSU** data for each record.

The relay outputs a Compressed ASCII history report for SCADA and other automation applications. Issue the **CHI** command to view the Compressed ASCII history report. A sample of the report appears in *Figure 3.16*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of each history in the Compressed ASCII history report. Items included in the Compressed ASCII history report are similar to those included in the history report.

See *SEL Compressed ASCII Commands on page R.4.4* and *Section 7: ASCII Command Reference in the Reference Manual* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03E2"
"Relay 1","Station A","FID=SEL-487B-R102-V0-Z001001-D20030724","0F59"
"REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT
","GROUP","TARGETS","1818"
10057,1,3,30,2003,18,2,37,99,600,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","1038"
10056,2,3,30,2003,18,2,3,209,300,"TRIG",1," ","08D0"
10055,3,3,30,2003,18,0,36,494,0,"TRIG",1," ","08A7"
10054,4,3,30,2003,17,49,16,588,500,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","10A1
"
10053,5,3,30,2003,17,45,2,151,0,"TRIG",1," ","089E"
10052,6,3,30,2003,17,44,14,332,900,"ER",1," ","089B"
10051,7,3,30,2003,17,44,9,334,300,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","1061"
10050,8,3,30,2003,17,43,21,957,900,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","109B
"
10049,9,3,30,2003,17,36,29,576,700,"87BTR",1,"TLED_1 TLED_6 TLED_7 TLED_8","10A9
"
10048,10,3,30,2003,17,29,16,320,400,"87BTR",1," ","0988"
10047,11,3,30,2003,17,23,18,689,900,"87BTR",1," ","099B"
```

Report Header
Report Labels
Report Data

Figure 3.16 Sample Compressed ASCII History Report

History File Download

You can also download the history report file from the relay.

Step 1. Use a terminal emulation program with file transfer capability.

Step 2. At an Access Level 1 prompt or higher type **FILE READ REPORTS HISTORY.TXT <Enter>**.

Step 3. Start the terminal download routine to store the file on your computer.

Step 4. If you want the Compressed ASCII file, type **FILE READ REPORTS CHISTORY.TXT <Enter>**.

In addition, you can use the ACSELERATOR software to download history files. See *Retrieving Event Report Data Files: Terminal Emulation Software on page U.4.36* for file download procedures.

Combined Event Report

Each SEL-487B provides event reports for analysis with software such as the SEL-5601 Analytic Assistant product. For stations with more than six terminals, the busbar protection requires three SEL-487B relays. Except for single-phase faults, all other faults involve at least two SEL-487B relays. For example, an A-phase to B-phase fault operates the differential element in the A-phase relay, as well as the differential element in the B-phase relay. For post-fault analysis, you need to consider two different event reports from two different relays.

With the SEL-5601 Analytic Assistant, you can display events from three different relays in one window to make the fault analysis easier and more meaningful. Because the three different relays time-stamp the events with values from their individual clocks, first you need to time-synchronize the three SEL-487B relays.

Time Synchronization

Each SEL-487B relay provides two IRIG-B connectors, labeled IN and OUT. Referring to the external source connections in *Figure 3.17*, connect the IRIG-B signals to the IN connection of Relay A to update the clock of Relay A. Connect the OUT connection of Relay A to the IN connector of Relay B to update the clock in Relay B. A similar connection between Relay B and Relay C updates the time in Relay C.

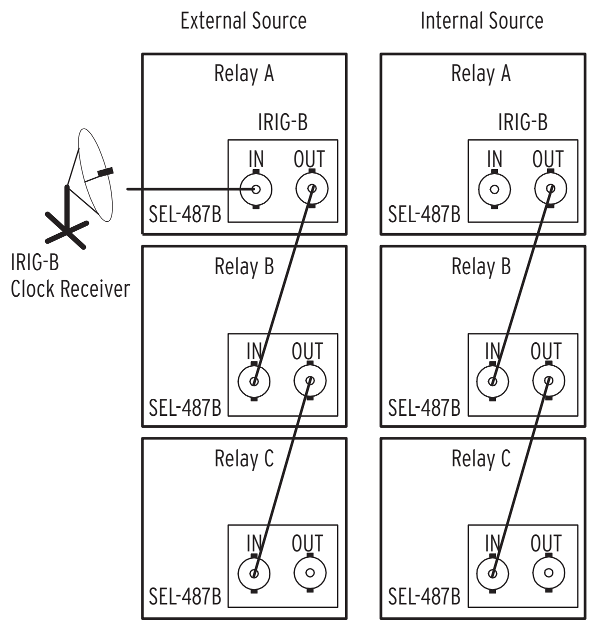


Figure 3.17 Time Synchronization Connections Between Three Relays

In the absence of an external IRIG-B signal, connect the relays as shown by the internal source connections in *Figure 3.17*. Connected this way, Relay B uses the clock of Relay A as time reference, and Relay C uses the clock of Relay B as time reference.

SEL-5601 Analytic Assistant

See *Section 3: PC Software in the User's Guide* for a full description of the use of the SEL-5601 Analytic Assistant.

SER (Sequential Events Recorder)

The SEL-487B SER (Sequential Events Recorder) gives you detailed information on relay states and relay element operation. The SER captures and time tags state changes of Relay Word bit elements and relay conditions. These conditions include power up, relay enable and disable, group changes, settings changes, memory overflow, diagnostic restarts, and SER automatic removal and reinsertion. The SEL-487B stores the latest 1000 SER entries to nonvolatile memory. *Figure 3.18* is a sample SEL-487B SER report.

The SER report contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- SER number
- SER date and time
- Relay element or condition
- Element state

```
Relay 1                                      Date: 07/24/2003  Time: 18:39:05.882
Station A                                    Serial Number: 2003004005

FID=SEL-487B-R102-V0-Z001001-D20030724

#      DATE        TIME          ELEMENT            STATE
20   03/30/2003  18:00:34.277   Settings changed     Class T 1
.
.
.
1    03/30/2003  18:02:37.185   87BTR18              Deasserted
```

SER Number

Relay Element or Condition

Element State

Figure 3.18 Sample SER Report

In the SER report, the oldest information has the highest number. The newest information is always #1. When using a computer terminal you can order the positions of the SER records in the SER report. See *Table 3.12* or *SER on page R.7.30*.

Viewing the SER Report

The relay displays the SER records in ASCII and binary formats. For more information on binary SER messaging, see *Section 4: SEL Communications Protocols in the Reference Manual*.

Access the SER report from the communications ports and communications cards in Access Level 1 and higher. Clear or reset SER data from Access Levels 1, B, P, A, O, and 2. You can independently clear/reset SER data at each communications port (with the **SER CV** and **SER RV** commands) so that you and users at other ports (SCADA, Engineering, for example) can retrieve complete SER reports. You can also clear all SER data from all ports (with the **SER CA** command).

Use an ASCII terminal or the ACSELERATOR software to examine SER records. You can use the **SER** command to view the SER report by date, date range, SER number, or SER number range.

The relay labels each new SER record with a unique number. See *Table 3.12* or *Section 7: ASCII Command Reference in the Reference Manual* for more information on the **SER** command.

Table 3.12 SER Commands (Sheet 1 of 2)

Command	Description
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *m n*	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.

Table 3.12 SER Commands (Sheet 2 of 2)

Command	Description
SER *date1*	Return the SER records on date *date1*.
SER *date1 date2*	Return the SER records from *date1* at the top of the list to *date2* at the bottom of the list.
SER C and **SER R**	Clear SER records on the present port.
SER CA and **SER RA**	Clear SER data for all ports.
SER CV and **SER RV**	Clear viewed SER records on the present port.
SER D	List chattering SER elements that the relay has removed from the SER records.

You can retrieve SER records with the ACSELERATOR software. See *Viewing SER Records on page U.4.37* for information and examples. The latest 200 SER events are viewable on the front-panel display through the front-panel EVENTS MENU (see *Front-Panel Operations on page U.5.1 in the User's Guide*).

CSER

The relay outputs a Compressed ASCII SER report for SCADA and other automation applications. Issue the **CSE** command to view the Compressed ASCII SER report. A sample of the SER report appears in *Figure 3.19*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

See *SEL Compressed ASCII Commands on page R.4.4* and *CSER on page R.7.9* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-487B-R102-V0-Z001001-D20030724","0e49"
"#","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","ELEMENT","STATE","0FC8"
1,3,30,2003,18,2,37,185,"87BTR18","Deasserted","0B33"
2,3,30,2003,18,2,37,185,"87BTR17","Deasserted","0B33"
3,3,30,2003,18,2,37,185,"87BTR12","Deasserted","0B2F"
4,3,30,2003,18,2,37,185,"87BTR11","Deasserted","0B2F"
```

Report Header

SER Data

Figure 3.19 Sample Compressed ASCII SER Report

SER File Download

You can also download the SER data as a file from the relay.

Step 1. Use a terminal emulation program with file transfer capability.

Step 2. At an Access Level 1 prompt or higher type **FILE READ REPORTS SER.TXT <Enter>**.

Step 3. Start the terminal download routine to store the file on your computer.

Step 4. If you want the Compressed ASCII file, type **FILE READ REPORTS CSER.TXT <Enter>**.

See *Downloading an SER Report File on page U.4.39* for SER file download procedures.

Setting SER Points and Reporting Names

You program the relay elements that trigger an SER record. You can select from as many as 250 elements. These triggers, or points, can include control input and control output state changes, element pickups and dropouts, and so on. You can also change the names of the elements and set reporting names for the element clear and set states.

Use the **SET R** command from a terminal, or use the ACSELERATOR software Report branch of the Settings tree view to enter SER Points.

Step 1. Use the text-edit line mode settings method to enter or delete SER elements (see *Text-Edit Mode Line Editing on page U.4.18*).

Step 2. To set an SER element, enter the five items of this comma-delimited string (all but the first parameter are optional):

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Reporting names can contain any printable ASCII character. See *Viewing SER Records on page U.4.37* for examples of entering SER data.

The relay defaults to the element name when you do not provide a reporting name. The defaults for the set and clear states are Asserted and Deasserted, respectively. By default, SER Points are not configured for HMI alarm display. The relay always creates an SER record for power-up, relay enable and relay disable, any group change and settings change, diagnostic restart, and memory overflow. For a setting example, see *Viewing SER Records*.

Automatic Deletion and Reinsertion

The SER also includes an automatic deletion and reinsertion function. The relay automatically deletes oscillating SER items from SER recording. This function prevents overfilling the SER buffer with chattering information. To use the automatic deletion and reinsertion function, proceed with the following steps:

Step 1. Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function.

Step 2. Select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element.

The relay removes an item from all SER recordings once a point has changed state more than SRDLCNT times in an SRDLTIM period. Once deleted from SER recording, the relay ignores the item for a 10 • SRDLTIM period.

At the end of this period, the relay checks the chatter criteria and, if the point does not exceed the criteria, the relay automatically reinserts the item into SER recording.

Use the **SER D** command to see a list of deleted SER points (see *SER on page R.7.30*).

Section 4
SEL Communications Processor Applications

Overview

This section describes applications where the SEL-487B Relay is applied in a system integration architecture that includes the SEL-20xx family (SEL-2020, SEL-2030, SEL-2032) of communications processors. This section contains the following topics:

- ➤ Introduction to the SEL communications processor family
- ➤ SEL-487B and SEL communications processor architecture
- ➤ Example SEL-487B with SEL communications processor Application

For detailed application examples using the SEL Communications Processors, see the SEL library of Application Guides on our website at www.selinc.com.

SEL Communications Processor

SEL offers the SEL-2020, SEL-2030, and SEL-2032 Communications Processors, powerful tools for system integration and automation.

The SEL-2020, SEL-2030, and SEL-2032 hardware are similar, except that the SEL-2020 does not support network protocol cards. Both the SEL-2030 and SEL-2032 support as many as two network protocol cards. The SEL-2032 supports relay SER time tagging of data used for DNP; the SEL-2020 and the SEL-2030 do not. The SEL-20xx family provides a single point of contact for integration networks with a star topology as shown in *Figure 4.1*.

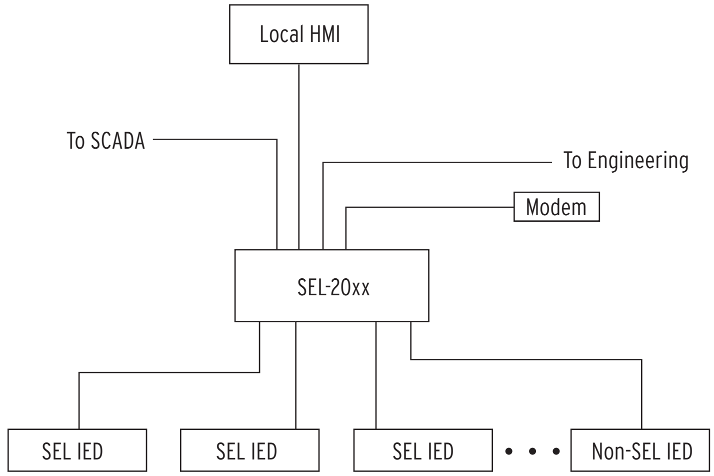


Figure 4.1 SEL-20xx Star Integration Network

In the star topology network in *Figure 4.1* the SEL communications processors offer the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Distribution of IRIG-B time synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Automated dial-out on alarms

The SEL communications processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure 4.2*. In this multitiered system, the lower-tier SEL communications processors forward data to the upper-tier SEL communications processor that serves as the central point of access to substation data and station IEDs.

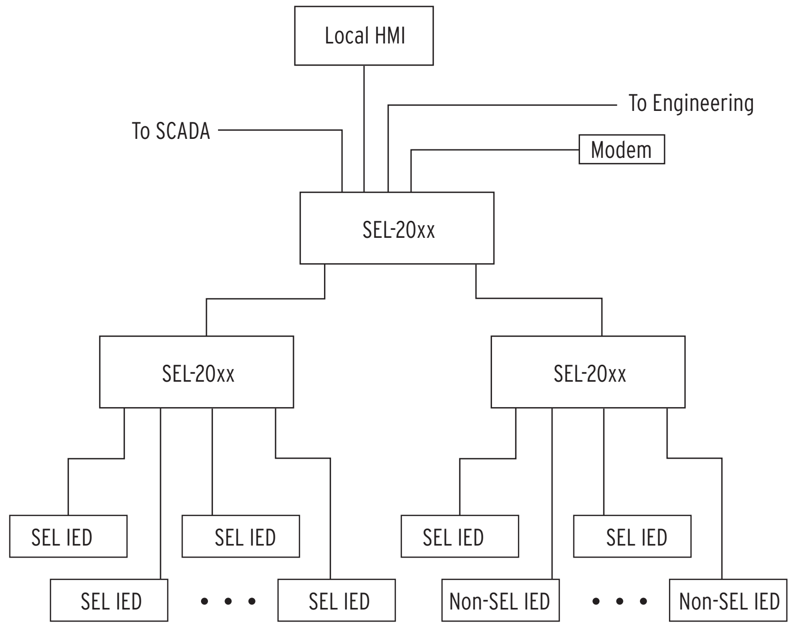


Figure 4.2 Multitiered SEL-20xx Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. The SEL-20xx family of communications processors provides an integration solution with MTBF (mean time between failures) that is 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure the SEL-20xx family with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. The SEL communications processors offer the protocol interfaces listed in *Table 4.1*.

Table 4.1 SEL-2020, SEL-2030, and SEL-2032 Communications Processor Protocol Interfaces

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters (serial)
Modbus® RTU Protocol	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus®[a]	Modbus Plus peers with global data and Modbus Plus masters
DNP3 Level 2 Slave (Ethernet)[b]	DNP3 masters (Ethernet)
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol peers

[a] SEL-2030 and SEL-2032 only, requires SEL-2711 Modbus Plus protocol card.
[b] SEL-2030 and SEL-2032 only, requires SEL-2701 Ethernet Processor.

SEL Communications Processors and SEL-487B Architecture

You can apply the SEL Communications Processors and the SEL-487B in a limitless variety of applications that integrate, automate, and improve station operation. Most of the system integration architectures utilizing the SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-487B and an SEL-20xx is shown in *Figure 4.1*. In this architecture, the SEL communications processor collects data from the SEL-487B and other station IEDs. The SEL-20xx acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The SEL communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses the SEL communications processor to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting the SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface; so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

NOTE: The communications processor Ethernet card supports components of UCA2 as a subset of IEC 61850.

The SEL communications processor equipped with an SEL-2701 can provide a UCA2 interface to SEL-487B relays and other serial IEDs. The SEL-2701 and SEL communications processor offer a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 and SEL communications processor see the *SEL-2701 Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software, including the ACSELERATOR QuickSet® SEL-5030 Software Program, can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use the SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure 4.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI (Human Machine Interface).

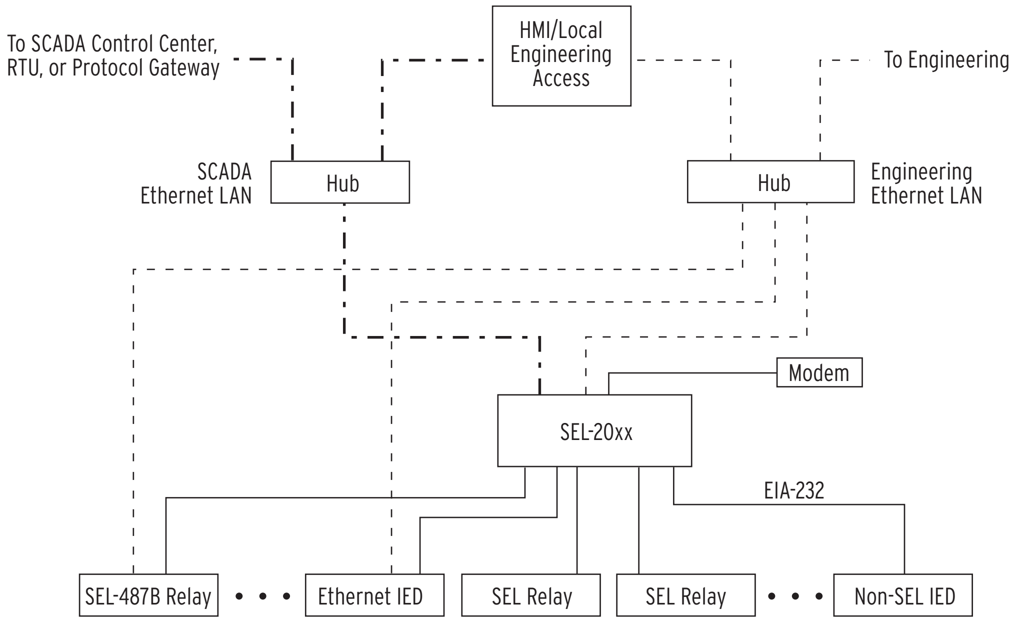


Figure 4.3 Enhancing Multidrop Networks With the SEL-20xx

In this example, the SEL-20xx provides the following enhancements when compared to a system that employs only the multidrop network:

- ➤ Ethernet access for IEDs with serial ports
- ➤ Backup engineering access through the dial-in modem
- ➤ IRIG-B time signal distribution to all station IEDs
- ➤ Integration of IEDs without Ethernet
- ➤ Single point of access for real-time data for SCADA, HMI, and other uses
- ➤ Significant cost savings by use of existing IEDs with serial ports
- ➤ Cost savings by installing Ethernet network interfaces in the SEL communications processor rather than in each relay

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-487B. The station layout is shown in *Figure 4.5*. The busbar voltage is 230 kV, and the highest expected current on any feeder is 2000 A. The physical configuration used in this example is shown in *Figure 4.4*.

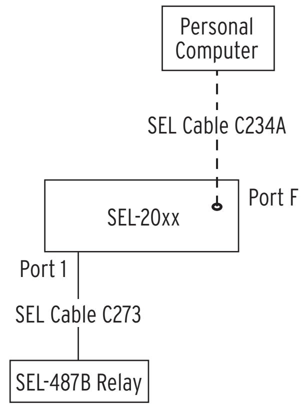


Figure 4.4 Example SEL-487B and SEL-20xx Configuration

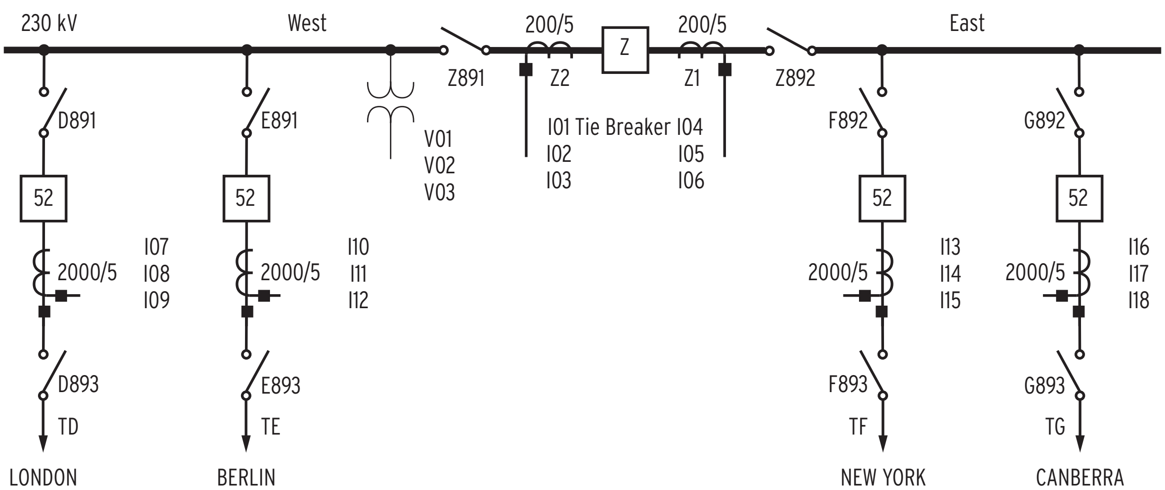


Figure 4.5 Substation Layout Showing Four Feeders and a Tie Breaker

Table 4.2 shows the port settings for Port 1 of the SEL communications processor.

Table 4.2 SEL Communications Processor Port 1 Settings (Sheet 1 of 2)

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	Relay 1	Name of connected relay[a]
BAUD	19200	Channel speed of 19200 bits per second[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit

Table 4.2 SEL Communications Processor Port 1 Settings (Sheet 2 of 2)

Setting Name	Setting	Description
PARITY	N	No parity
RTS_CTS	Y	Hardware flow control enabled
TIMEOUT	5	Idle timeout that terminates transparent connections of 5 minutes

[a] Automatically collected by the SEL Communications Processor during autoconfiguration.

Data Collection

The SEL communications processor is configured to collect data from the SEL-487B using the list in *Table 4.3*.

Table 4.3 SEL Communications Processor Data Collection Automessages

Message	Data Collected
20METER	Selected SEL-487B automation math variables (AMVs)
20METER2	Binary METER database region[a]
20TARGET	Selected Relay Word bit elements
20TARGET2	Binary TARGET database region[a]
20STATUS	Relay status similar to the **CST** command
20STATUS2	Binary STATUS database region[a]
20HISTORY	History data similar to the **CHI** command
20HISTORY2	Binary HISTORY database region[a]
20EVENTL	Event data similar to the **CEV L** command
20LOCAL2	Binary LOCAL database region[a]
20ANALOGS2	Binary ANALOGS database region[a]
20STATE2	Binary STATE database region[a]
20D12	Binary D1 270x DNP database region[a]

[a] For detailed information regarding the database regions, see Communications Card Database on page R.3.23.

In this example, we only consider the 20METER and 20TARGET functions. *Table 4.4* shows the automessage (SET A) settings for the SEL communications processor.

Table 4.4 SEL Communications Processor Port 1 Automatic Messaging Settings (Sheet 1 of 2)

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	ACC*n*OTTER*n*	Automatically log on at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker bit control
REC_SER	N	Automatic Sequential Event Recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	2	Two automessages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data

Table 4.4 SEL Communications Processor Port 1 Automatic Messaging Settings (Sheet 2 of 2)

Setting Name	Setting	Description
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Relay Word bit data
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table 4.5 shows the map of regions in the SEL communications processor for data collected from the SEL-487B.

Table 4.5 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Relay metering data
D2	Binary	TARGET	Relay Word bit data
D3–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

Table 4.6 shows the list of meter data available in the SEL-20xx and the location and data type for the memory areas within D1 (Data Region 1). The type field indicates the data type and size. The type “int” is a 16-bit integer. The type “float” is a 32-bit IEEE® floating point number. Because the number of terminals differs from substation to substation, the SEL-487B provides 21 automation math variables (AMV001 through AMV021) instead of dedicated meter values. This flexibility makes it possible to assign meter values to suit the substation. The communications processor treats these as vector quantities.

Table 4.6 SEL Communications Processor METER Region Map (Sheet 1 of 2)

Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME(ms)	2002h	int
MONTH	2003h	char
DATE	2004h	char
YEAR	2005h	char
HOUR	2006h	char
MIN	2007h	char
SECONDS	2008h	char
MSEC	2009h	int
AMV001	200Ah	float
AMV002	200Ch	float
AMV003	200Eh	float
AMV004	2010h	float
AMV005	2012h	float

Table 4.6 SEL Communications Processor METER Region Map (Sheet 2 of 2)

Item	Starting Address	Type
AMV006	2014h	float
AMV007	2016h	float
AMV008	2018h	float
AMV009	201Ah	float
AMV010	201Ch	float
AMV011	201Eh	float
AMV012	2020h	float
AMV013	2022h	float
AMV014	2024h	float
AMV015	2026h	float
AMV016	2028h	float
AMV017	202Ah	float
AMV018	202Ch	float
AMV019	202Eh	float
AMV020	2030h	float
AMV021	2032h	float

In the example, we assign the current from one phase in each terminal, one phase voltage from the PT, and the differential currents from each differential zone to eight automation math variables in the SEL-487B. *Figure 4.5* shows the analog channel assignment of each terminal. For example, current channels I07, I08, and I09 are assigned to Terminal LONDON. Assuming balanced conditions, we measure one phase from each terminal and one phase from the potential transformer. *Figure 4.6* shows the assignment of alias names to analog quantities (see *Appendix B: Analog Quantities in the Reference Manual* for a list of the available analog quantities).

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?  > <Enter>
62:
?  I01FM,TIE_BKR <Enter>
63:
?  I07FM,LONDON <Enter>
64:
?  I10FM,BERLIN <Enter>
65:
?  I13FM,NEW_YRK <Enter>
66:
?  I16FM,CANBERRA <Enter>
67:
?  V01FM,VOLTAGE <Enter>
68:
?  IOP1F,DIFF_W <Enter>
69:
?  IOP4F,DIFF_E <Enter>
70:
?  END <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.6 Assigning Alias Names to the Analog Quantities

Figure 4.7 shows the assigning of the selected analog quantities to the automation math variables.

```
=>>SET A <Enter>
Automation 1

1:
?  AMV001:=LONDON <Enter>
2:
?  AMV002:=BERLIN <Enter>
3:
?  AMV003:=TIE_BKR <Enter>
4:
?  AMV004:=NEW_YRK <Enter>
5:
?  AMV005:=CANBERRA <Enter>
6:
?  AMV006:=VOLTAGE <Enter>
7:
?  AMV007:=DIFF_W <Enter>
8:
?  AMV008:=DIFF_E <Enter>
9:
?  END <Enter>
Automation 1

1: AMV001 := LONDON
2: AMV002 := BERLIN
3: AMV003 := TIE_BKR
4: AMV004 := NEW_YRK
5: AMV005 := CANBERRA
6: AMV006 := VOLTAGE
7: AMV007 := DIFF_W
8: AMV008 := DIFF_E

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 4.7 Assigning Selected Analog Quantities to the Automation Math Variables

Table 4.7 lists the Relay Word bit data available in the SEL-20xx TARGET region.

Table 4.7 SEL Communications Processor TARGET Region (Sheet 1 of 3)

Relay Word Bits (in Bits 7–0)								
Address	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
2804h	TEST	FMTEST	STEST	STCSET	STFAIL	STWARN	STRSET	STGSET
2805h	EN	TRIPLED	*	*	*	*	*	*
2806h	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
2807h	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
2808h	52AL03	52A03	52CL02	52AL02	52A02	52CL01	52AL01	52A01
2809h	52A06	52CL05	52AL05	52A05	52CL04	52AL04	52A04	52CL03
280Ah	*	*	ZONE6	ZONE5	ZONE4	ZONE3	ZONE2	ZONE1
280Bh	*	*	*	*	ZSWOAL	ZSWOIP	ZSWO	RZSWOAL
280Ch	*	87ST	87ST6	87ST5	87ST4	87ST3	87ST2	87ST1
280Dh	*	CSL1	ACTRPT1	ACTRP1	CBCLST1	CBCLS1	CB52T1	CB52A1
280Eh	*	CSL2	ACTRPT2	ACTRP2	CBCLST2	CBCLS2	CB52T2	CB52A2
280Fh	TOS08	TOS07	TOS06	TOS05	TOS04	TOS03	TOS02	TOS01
2810h	TOS16	TOS15	TOS14	TOS13	TOS12	TOS11	TOS10	TOS09
2811h	*	*	*	*	*	*	TOS18	TOS17
2812h	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
2813h	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
2814h	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
2815h	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
2816h	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
2817h	*	IN107	1N106	IN105	IN104	IN103	IN102	IN101
2818h	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
2819h	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
281Ah	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
281Bh	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
281Ch	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
281Dh	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
281Eh	IN408	IN407	IN406	IN405	IN404	IN403	IN402	IN401
281Fh	IN416	IN415	IN414	IN413	IN412	IN411	IN410	IN409
2820h	IN424	IN423	IN422	IN421	IN420	IN419	IN418	IN417
2821h	IN508	IN507	IN506	IN505	IN504	IN503	IN502	IN501
2822h	IN516	IN515	IN514	IN513	IN512	IN511	IN510	IN509
2823h	IN524	IN523	IN522	IN521	IN520	IN519	IN518	IN517
2824h	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
2825h	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
2826h	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
2827h	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
2828h	PSV40	PSV39	PSV38	PSV37	PSV36	PSV35	PSV34	PSV33

Table 4.7 SEL Communications Processor TARGET Region (Sheet 2 of 3)

	Relay Word Bits (in Bits 7–0)							
Address	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
2829h	PSV48	PSV47	PSV46	PSV45	PSV44	PSV43	PSV42	PSV41
282Ah	PSV56	PSV55	PSV54	PSV53	PSV52	PSV51	PSV50	PSV49
282Bh	PSV64	PSV63	PSV62	PSV61	PSV60	PSV59	PSV58	PSV57
282Ch	PLT08	PLT07	PLT06	PLT05	PLT04	PLT03	PLT02	PLT01
282Dh	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
282Eh	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
282Fh	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
2830h	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
2831h	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
2832h	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
2833h	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
2834h	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV001
2835h	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
2836h	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
2837h	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
2838h	ASV040	ASV039	ASV038	ASV037	ASV036	ASV035	ASV034	ASV033
2839h	ASV048	ASV047	ASV046	ASV045	ASV044	ASV043	ASV042	ASV041
283Ah	ASV056	ASV055	ASV054	ASV053	ASV052	ASV051	ASV050	ASV049
283Bh	ASV064	ASV063	ASV062	ASV061	ASV060	ASV059	ASV058	ASV057
283Ch	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
283Dh	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
283Eh	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
283Fh	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
2840h	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
2841h	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
2842h	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
2843h	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
2844h	SALARM	HALARM	BADPASS	CCALARM	CCOK	*	*	*
2845h	*	*	TIRIG	TUPDH	*	*	*	*
2846h	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
2847h	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
2848h	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
2849h	OUT408	OUT407	OUT406	OUT405	OUT404	OUT403	OUT402	OUT401
284Ah	OUT508	OUT507	OUT506	OUT505	OUT504	OUT503	OUT502	OUT501
284Bh	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
284Ch	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
284Dh	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
284Eh	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
284Fh	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
2850h	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*

Table 4.7 SEL Communications Processor TARGET Region (Sheet 3 of 3)

	Relay Word Bits (in Bits 7–0)							
Address	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
2851h	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
2852h	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
2853h	CCIN25	CCIN26	CCIN27	CCIN28	CCIN29	CCIN30	CCIN31	CCIN32
2854h	CCIN17	CCIN18	CCIN19	CCIN20	CCIN21	CCIN22	CCIN23	CCIN24
2855h	CCIN09	CCIN10	CCIN11	CCIN12	CCIN13	CCIN14	CCIN15	CCIN16
2856h	CCIN01	CCIN02	CCIN03	CCIN04	CCIN05	CCIN06	CCIN07	CCIN08
2857h	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
2858h	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
2859h	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
285Ah	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
285Bh	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
285Ch	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
285Dh	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
285Eh	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
285Fh	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*

NOTE: An asterisk (*) indicates reserved for future use.

Control Points

The SEL communications processor can automatically pass control messages, called Fast Operate messages, to the SEL-487B. You must enable Fast Operate messages using the FASTOP setting in the SEL-487B port settings for the port connected to the communications processor. You must also enable Fast Operate messages in the communications processor by setting the automessage setting SEND_OPER equal to Y.

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the relay for changes in remote bits RB1–RB16 or breaker bits BR1 and BR2 on the corresponding SEL communications processor port. In this example, if you set RB1 on Port 1 in the communications processor, it automatically sets RB01 in the SEL-487B.

Breaker bits BR1 through BR16 operate differently than remote bits. There are no breaker bits in the SEL-487B. For Circuit Breaker 1, when you set BR1, the SEL communications processor sends a message to the SEL-487B that asserts the manual open command bit OC1 for one processing interval. If you clear BR1, the communications processor sends a message to the connected relay that asserts the close command bit CC1 for one processing interval. Because there is no breaker close functionality (no CC*nn* bits) bits in the SEL-487B, breakers cannot be closed using the clear breaker function. If you are using the default settings, OC1 opens Circuit Breaker 1.

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Section 5
Direct Network Communications

Overview

This section describes applications in which the SEL-487B Relay connects directly to a communications network via an optional Ethernet card or a serial port connection. This section contains the following topics:

- ➤ Serial Port Networking
- ➤ Protocol Card Networking
- ➤ Direct Networking Example

Direct Network Communication

You can establish direct network communication with the SEL-487B either by serial port or through an optional protocol card. The protocols available on the serial ports are DNP3 and the SEL suite of ASCII and binary protocols. The protocol card presently available for the SEL-487B is an Ethernet card with FTP, Telnet, DNP3, and IEC 61850 protocols. This is a factory-installed option available at the time of purchase of a new SEL-487B or as a factory-installed conversion to an existing relay.

The SEL-487B includes a protocol card slot. This slot supports an SEL standard interface for network protocol cards. Communication between the SEL-487B and an installed protocol card is automatic; you do not need any configuration or driver software. You can access any configuration settings you need for protocol parameters or network operation through the SEL-487B. Each protocol card contains a processor responsible for network interface operation.

Unlike a protocol card installed in a computer, a protocol card installed in the SEL-487B is responsible for all network message and protocol processing. This means that network traffic volumes and network failures do not affect protection processing.

Because SEL relays have more than one port, you can establish direct networking and a communications processor star network simultaneously. Combine a member of the SEL-20xx family of communications processors (SEL-2020, SEL-2030, or SEL-2032) with a direct networking application to add the following system capabilities:

- ➤ Distribution of IRIG-B time synchronization signal
- ➤ Single point of access for IEDs through an Ethernet network or serial connection
- ➤ Nonvolatile logging of data collected from several IEDs

- Single point for central substation database access
- Single point of access for Fast SER (Sequential Events Recorder) data

See *Section 4: SEL Communications Processor Applications* for more information regarding use of the SEL communications processors with the SEL-487B.

Serial Networking

The protocols available on the SEL-487B serial ports are either SEL protocols or standard protocols. While the standard protocols offer connectivity without a specific SEL support in other integration products, the SEL protocols offer features not included in standard protocols. These features provide additional capabilities that can significantly enhance your application.

SEL Protocols

SEL protocols are described in detail in *Section 4: SEL Communications Protocols in the Reference Manual*. SEL protocols include Fast Meter, Fast Operate, Fast SER, MIRRORED BITS® communications, and SEL ASCII.

DNP3

This section describes the serial networking features of DNP3. The DNP3 Ethernet interface is discussed briefly in *Ethernet Card on page A.5.4*

DNP3 is a protocol that provides an interface for retrieving SCADA data. The DNP User's Group is responsible for maintaining and distributing the DNP3 specifications.

NOTE: In order to use DNP3 features, including virtual terminal connections, your DNP3 master device must support the required standard DNP3 objects and operations.

The serial DNP3 settings and operation are described in *Section 5: DNP3 Communications in the Reference Manual*. The serial DNP3 interface has the capabilities summarized in *Table 5.1*.

Table 5.1 DNP3 Feature Summary

Feature	Application
DNP event data reporting	More efficient polling through event collection or unsolicited data
Time tagged events	Time-stamped SER data
Control output relay blocks	Operator-initiated control through remote bits
Write analog output	Change the active protection settings group
Time synchronization	Set the relay time from the master station or automatically request time synchronization from the master
Custom mapping	Increase communication efficiency by organizing data and reducing available data to what you need for your application
Modem support	Reduce the cost of the communications channel by either master dialing to relay or relay dialing to master
Virtual terminal	Establish an engineering connection across a DNP3 network
TEST DNP command	Test DNP3 interface without disturbing protection

You can build a DNP3 network using either a multidrop or star topology. Each DNP3 network has a DNP3 master and DNP3 remotes or slaves. *Figure 5.1* shows the DNP3 multidrop network topology while *Figure 5.2* shows the DNP3 star network topology.

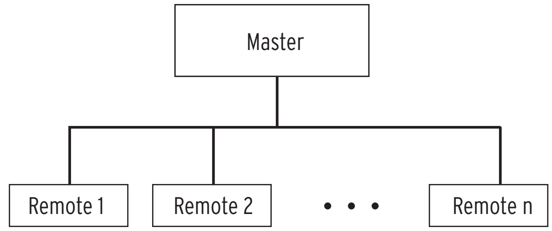

Figure 5.1 DNP3 Multidrop Network Topology

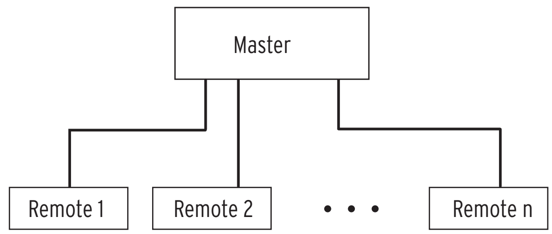

Figure 5.2 DNP3 Star Network Topology

DNP3 multidrop networks that are used within substations often use an EIA-485 physical layer. The multidrop network is vulnerable to the failure of a single transmitter. If any one transmitter fails in a state that disrupts signals on the network, the network will fail. The DNP3 star network topology eliminates the network transmitters and other single points of failure related to the physical medium.

If you are planning either a DNP3 star or network topology, you should consider the benefits of including an SEL Communications Processor in your design. A network with a communications processor is shown in *Figure 5.3*. A DNP3 network that includes a communications processor has a lower data latency and shorter scan time than comparable networks through two primary mechanisms. First, the communications processor collects data from all remotes in parallel rather than one-by-one. Second, the master can collect all data with one message and response, drastically reducing message overhead.

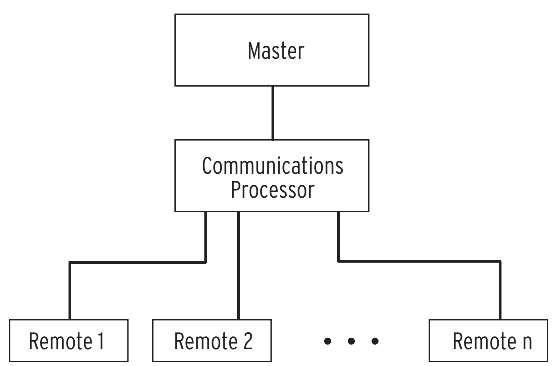

Figure 5.3 DNP3 Network With Communications Processor

In the communications processor DNP3 network you can also collect data from devices that do not have DNP3 protocol. The communications processor can collect data and present it to the master as DNP3 data regardless of the protocol between the communications processor and the remote device.

Ethernet Card

The SEL-487B Ethernet card is an optional protocol card that you can add to the SEL-487B in the field or purchase as a factory-installed option. In order to exchange data over this interface, you must choose a data exchange protocol that operates over the Ethernet network link. The Ethernet card supports FTP, Telnet, HTTP, DNP LAN/WAN, FTP, and IEC 61850 data exchange protocols.

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. Work with a networking professional to design your substation Ethernet network.

Ethernet

The SEL-487B Ethernet card provides Ethernet networking with the popular physical and data-link standards listed in *Table 5.2*.

Table 5.2 Ethernet Connection Options

Name	Connector	Media
10BASE-T/100BASE-TX selectable	RJ-45	CAT 5 cable (Category 5 twisted pair)
10BASE-F	Standard ST	Multimode fiber-optic cable
100BASE-FX	Standard ST	Multimode fiber-optic cable

FTP

Use FTP (File Transfer Protocol) to access data stored in files in the SEL-487B. FTP is a standard TCP/IP protocol for exchanging files. A free FTP application is included with most web browser software. You can also obtain a free or inexpensive FTP application from the Internet.

When you connect to the SEL-487B Ethernet card, you will find files stored in directories. At the root or top level, you will find three directories, one for the Ethernet card and two for the SEL-487B. One SEL-487B directory contains snapshots of data regions within the SEL-487B database. The other SEL-487B directory contains the files and subdirectories included in the virtual file interface described in *Section 4: SEL Communications Protocols in the Reference Manual*.

Files associated with the Ethernet card are in the SEL-2702 directory. This directory contains the file DIAGNOSTICS.TXT, which contains a log of Ethernet card system failures. The time and date of the diagnostics file correspond to the time and date of the last system failure event. The SEL-2702 directory may also contain custom mapping files for the DNP LAN/WAN protocol.

The relay generates certain files at the time that they are requested, so that the file you retrieve contains the latest information. For example, when you request the file SER.TXT, the SEL-487B creates and sends to you a file that contains SER information up until the moment that you requested the file.

If the IEC 61850 protocol is installed and enabled, the following files will be found in the root directory:

- CID (Configured IED Description) file—contains the IEC 61850 SCL configuration for the SEL-487B
- ERR.TXT file—contains any errors encountered during the CID file download
- CFG.XML file—contains the Ethernet card and SEL-487B configuration information

Telnet

Use Telnet to connect to the SEL-487B ASCII interface and work with the relay. Telnet is a terminal connection across a TCP/IP network that operates in a manner very similar to a direct serial port connection to one of the relay ports. As with FTP, Telnet is a part of TCP/IP. A free Telnet application is included with most computer operating systems, or you can obtain low-cost or free Telnet applications on the Internet.

When you connect with Telnet and log on to the relay, you can use all of the ASCII and Compressed ASCII commands described in *Section 7: ASCII Command Reference in the Reference Manual* to configure and interact with the relay. You can also use the SEL binary Fast Meter and Fast Operate commands described in *Section 4: SEL Communications Protocols in the Reference Manual*.

HTTP

The SEL-2702 Ethernet Card supports HTML web pages when used with the SEL-487B. These web pages allow you to view relay read-only data, including settings, metering, event history, event reports, relay status, and relay configuration. This is enabled via the EHTTP settings (see *Table 8.75 on page R.8.39*). Up to four simultaneous connections are allowed. No data is allowed to be written to the relay via the HTML web page interface.

To connect to the web server, use a web browser and go to the configured IP address (IPADDR) and port number (HPNUM setting). This will initially display a login screen, as shown in *Figure 5.4*. The Username is always ACC. The password is the relay's access level one password.

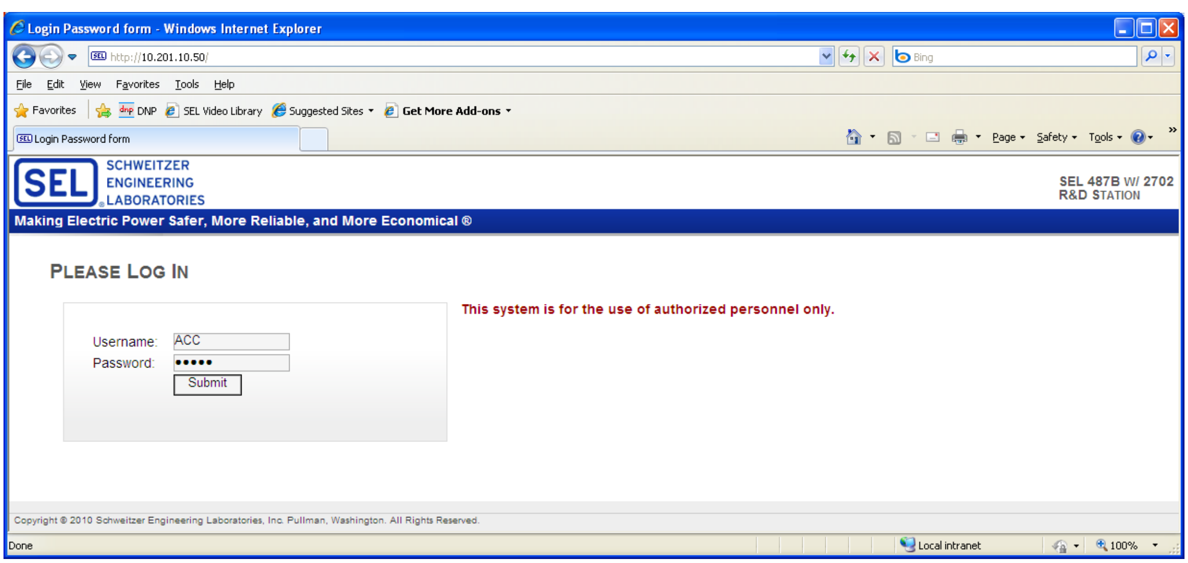

Figure 5.4 Web Server Login Screen

Once you are logged in to the relay, you will see a menu of choices, as shown in *Figure 5.5*. Select items from the menu to see the respective data displayed on the screen.

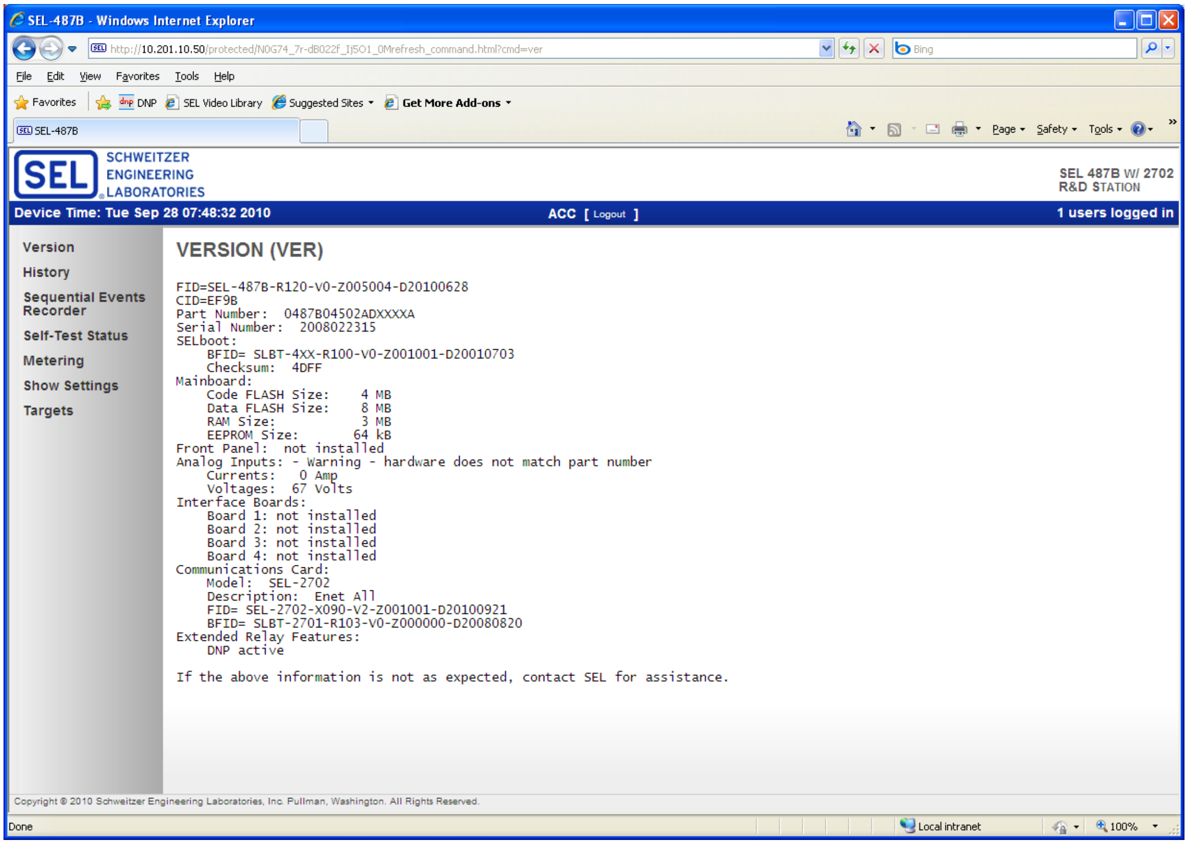

Figure 5.5 Web Server Default Menu Screen

Event reports are accessed from the history screen. Each listed event that has an event report will contain a link to that event report. An example of this is shown in *Figure 5.6*.

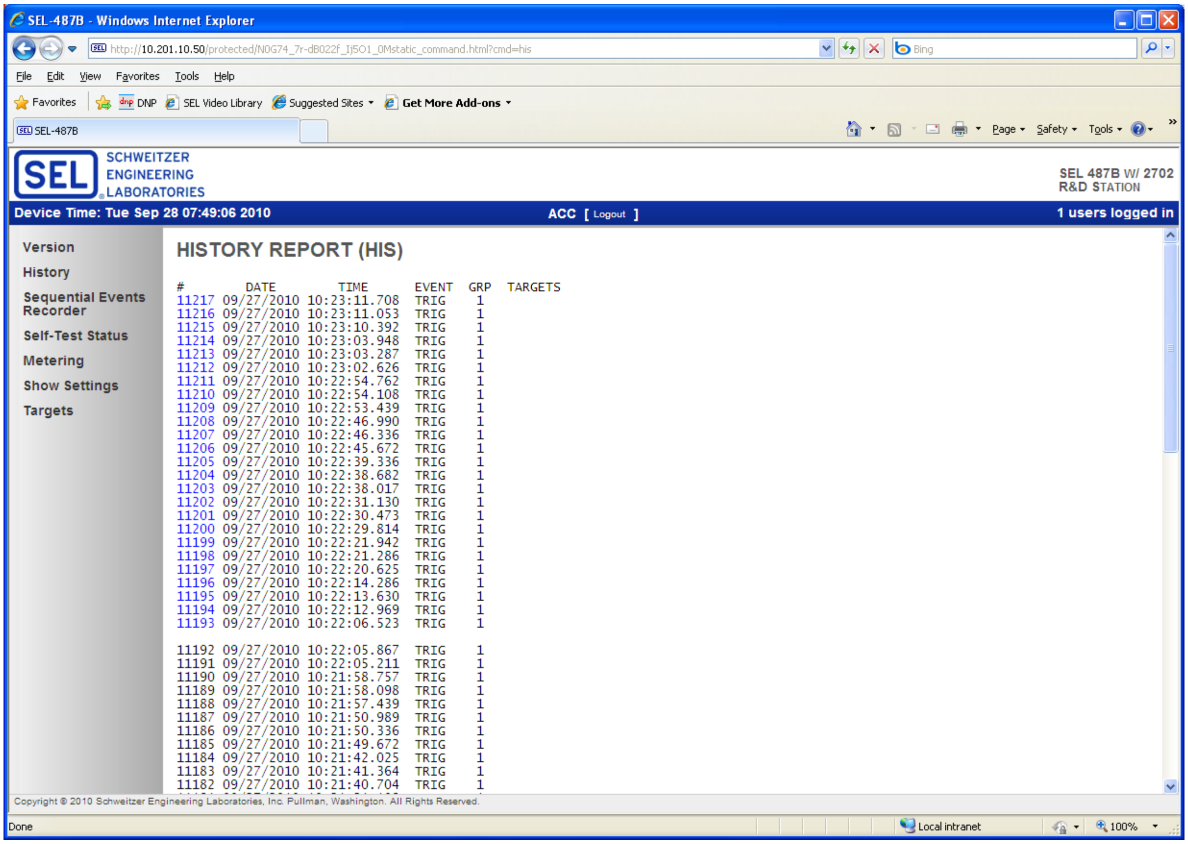

Figure 5.6 Event History Screen With Links to Event Reports

IEC 61850

The IEC 61850 standard is a superset of UCA2 and contains most of the UCA2 specification plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards.

UCA2 utilized GOMSFE to present data from station IEDs as a series of objects called models or bricks. The IEC working group incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

The GOOSE object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network.

MMS provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506. MMS supports complex named objects and flexible services that enable the mapping to IEC 61850 in a straightforward manner. It was for this reason that the UCA users group utilized MMS for UCA from the start, and why the IEC chose to keep it for IEC 61850.

See *Section 6: IEC 61850 Communications in the Reference Manual* for important information regarding IEC 61850.

DNP3

Installation of the Ethernet card in an SEL-487B relay provides a high performance DNP3 Level 2 slave network interface designed for operation in a substation environment.

The DNP LAN/WAN interface has the capabilities summarized in *Table 5.3*.

Table 5.3 DNP LAN/WAN Feature Summary

Feature	Key Features
DNP Event data reporting	More efficient polling through event collection or unsolicited data
Time tagged events	Time-stamped SER data directly from the SEL-487B, not an intermediate device
Control output relay blocks	Operator-initiated control through remote bits
Custom mapping	Increase communication efficiency by organizing and/or reducing available data to what is needed with 5 custom data maps for up to 10 different sessions
Analog deadband settings per session	Deadbands may be set to different values per session depending on desired application

Customized DNP3 data within the SEL-487B relay is available to any of ten DNP3 master sessions configured in the Ethernet card. Configuration and implementation of DNP LAN/WAN is entirely independent of any serial DNP3 settings that might exist in the SEL-487B relay.

See *Section 5: DNP3 Communications* in the Reference Manual for information on configuring and using DNP LAN/WAN for the SEL-487B.

SEL Software

The SEL-487B configuration software, ACSELERATOR QuickSet® SEL-5030 software, can connect to, configure, and control an SEL-487B with an Ethernet card. You can use ACSELERATOR QuickSet to choose a connection type and provide the required information for a network connection. With this capability, you can configure and control SEL-487B relays from a local substation LAN (local area network) or from an engineering workstation across a WAN (wide area network). The ACSELERATOR Architect® software will be included with your purchase of the IEC 61850 option. The ACSELERATOR Architect SEL-5032 software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Other SEL software includes Ethernet network connection capabilities, so you can use an Ethernet network for engineering connections to SEL protection and integration products. Check the documentation of your specific software for more information on Ethernet network connection capabilities.

Direct Networking Example

This direct networking example demonstrates direct networking to the SEL-487B using the Ethernet card. *Figure 5.7* shows the Ethernet network topology.

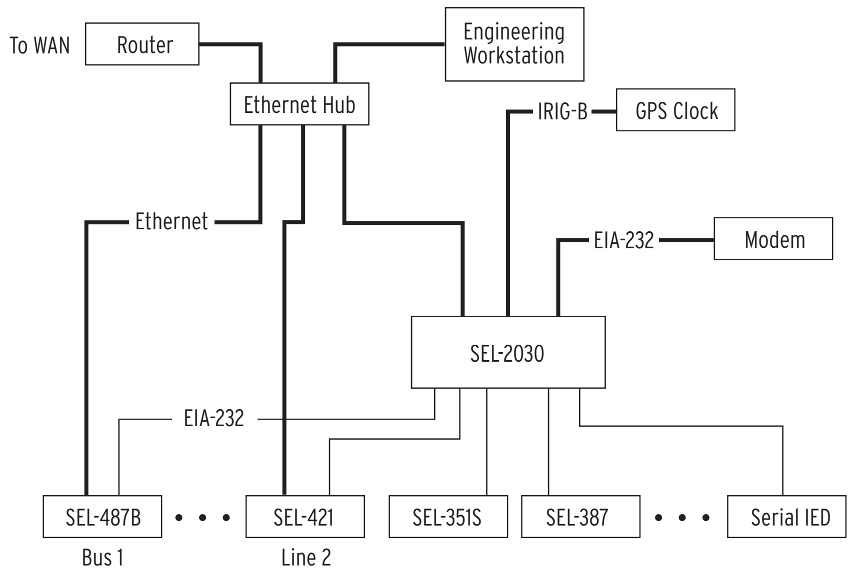

Figure 5.7 Example Direct Networking Topology

Application

In this application, all IEDs connect to the Ethernet network. The SEL-487B and SEL-421 relays and the SEL-2030 each have an Ethernet card installed. In this example, the Ethernet network is used primarily for an engineering connection to the devices in the substation either across the WAN or from the local computer. The engineer can use FTP to collect settings, oscillography, and other file data directly from the SEL-487B and SEL-421 relays. The engineer can also use Telnet to establish a terminal connection to the SEL-487B and SEL-421 relays or through the SEL-2030 to one of the serial IEDs in order to configure these devices or obtain diagnostic information.

There is a serial cable from the SEL-2030 to the SEL-487B and SEL-421 relays. This cable provides IRIG-B time synchronization from the SEL-2030 that is synchronized by the GPS clock attached to the SEL-2030. The SEL-2030 provides its output synchronization signal from its internal clock, so that loss of the signal from the GPS will not result in a loss of synchronization between substation devices as they will all be synchronized to the SEL-2030 clock. During long periods of loss of synchronization, the SEL-2030 clock drift will become noticeable, but all substation devices will remain synchronized relative to each other and the SEL-2030 clock. The serial cables also allow the SEL-2030 to provide a single point for dial-in communications with the substation IEDs avoiding the high cost of high bandwidth connections (for example, ISDN or DSL) for this backup to the Ethernet network engineering connection.

Settings

This example focuses on the relay labeled Bus 1 shown in *Figure 5.7*. Port 5 settings for the SEL-487B configure the Ethernet card. Port 5 settings for this example are shown in *Table 5.4*.

Table 5.4 SEL-487B Port 5 Direct Networking Settings (Sheet 1 of 2)

Setting Name	Setting	Description
TIMEOUT	5	Port inactivity time-out in minutes (drops to Access Level 0 on Telnet connections when this expires)
AUTO	N	Automessage disabled because engineering connection will not require unsolicited messages from SEL-2030
FASTOP	N	Fast Operate messages disabled because they are not required on engineering connection
TERTIM1	1	Length of time the channel must be idle before checking for the termination string in seconds
TERSTRN	\005	Transparent communication termination string default of **<Ctrl+E>**
TERTIM2	0	Length of time the channel must be idle before accepting the termination string in seconds
IPADDR	10.201.0.112	IP network address
SUBNETM	255.255.0.0	IP network subnet mask
DEFRTR	10.201.0.1	Default router
ETCPKA	N	Disable TCP keep-alive functionality (IEC 61850 only)
KAIDLE	10	Length of time to wait with no detected activity before sending a keep-alive packet (must be greater than or equal to KAINTV)
KAINTV	1	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet (must be less than or equal to KAIDLE)
KACNT	6	Maximum number of keep-alive packets to send
NETPORT	A	Primary network port selected to Port A
FAILOVR	N	Automatic fail-over disabled, forcing network operation on Port A only
FTIME	5	Fail over time-out; not used in this application
NETASPD	A	Automatically detect network speed on Port A
NETBSPD	A	Automatically detect network speed on Port B; not used in this application
FTPSERV	Y	FTP sessions enabled
FTPCBAN	FTP SERVER:	FTP connect banner
FTPIDLE	5	FTP connection time-out in minutes
FTPANMS	N	Anonymous log on disabled so that passwords are required for all FTP users
FTPAUSR	“”	Host user from which anonymous FTP client inherits access rights; not used in this application
T1CBAN	HOST TERMINAL SERVER:	Host Telnet connect banner
T1INIT	N	Telnet session from Ethernet card enable; not used in this application
T1RECV	Y	Telnet session to SEL-487B enable
T1PNUM	23	Host Telnet TCP/IP port

Table 5.4 SEL-487B Port 5 Direct Networking Settings (Sheet 2 of 2)

Setting Name	Setting	Description
T2CBAN	CARD TERMINAL SERVER:	Ethernet card Telnet connect banner
T2RECV	Y	Telnet session to Ethernet card enable
T2PNUM	1024	Ethernet card Telnet TCP/IP port
TIDLE	5	Telnet connection time-out in minutes

FTP Session

Figure 5.9 is a screen capture of an FTP session with the relay. The FTP client used for this example is included with the Windows NT® operating system and accessible through a command prompt window. The operator connects to the relay, moves to the SETTINGS directory, and collects the Port 5 settings. *Figure 5.10* shows a portion of the Port 5 settings in the SET_P5.TXT file.

Telnet Session

This section contains screen captures of a Telnet session with the Bus 1 SEL-487B. The Telnet application shown is included with the Windows NT operating system. *Figure 5.8* shows the log on dialog box and the entries required to connect to the SEL-487B.

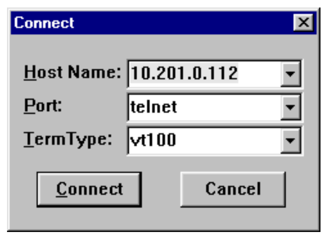

Figure 5.8 Telnet Connection Dialog Box

Figure 5.11 is a screen capture of a Telnet session with the relay. The operator connects to the relay and displays the Port 5 settings. Only a portion of the Port 5 settings are shown.

```
C:\>ftp 10.201.0.112 <Enter>

Connected to 10.201.0.112.
220 FTP SERVER:
User (10.201.0.112:(none)): 2AC <Enter>
331 User name okay, need password.
Password:
230 User logged in, proceed.

ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
SEL-487B
SEL-2702
DD01_SEL_487B
CFG.TXT
226 Closing data connection.
42 bytes received in 0.00 seconds (42000.00 Kbytes/sec)

ftp> cd SEL-487B <Enter>
250 CWD  requested file action okay, completed.

ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
CFG.TXT
EVENTS
REPORTS
SETTINGS
226 Closing data connection.
36 bytes received in 0.08 seconds (0.45 Kbytes/sec)
ftp> cd SETTINGS <Enter>
250 CWD  requested file action okay, completed.
```

```
ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
ERR.TXT
SET_A1.TXT
SET_A10.TXT
SET_A2.TXT
SET_A3.TXT
SET_A4.TXT
SET_A5.TXT
SET_A6.TXT
SET_A7.TXT
SET_A8.TXT
SET_A9.TXT
SET_ALL.TXT
SET_D1.TXT
SET_F1.TXT
SET_G1.TXT
SET_L1.TXT
SET_L2.TXT
SET_L3.TXT
SET_L4.TXT
SET_L5.TXT
SET_L6.TXT
SET_O1.TXT
SET_P1.TXT
SET_P2.TXT
SET_P3.TXT
SET_PF.TXT
SET_R1.TXT
SET_S1.TXT
SET_S2.TXT
SET_S3.TXT
SET_S4.TXT
SET_S5.TXT
SET_S6.TXT
SET_T1.TXT
SET_Z1.TXT
SET_Z2.TXT
SET_Z3.TXT
SET_Z4.TXT
SET_Z5.TXT
SET_Z6.TXT
226 Closing data connection.
419 bytes received in 0.73 seconds (0.57 Kbytes/sec)

ftp> get SET_P5.TXT <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
2392 bytes received in 1.58 seconds (1.51 Kbytes/sec)

ftp> QUIT <Enter>
221 Goodbye.
C:\>
```

Figure 5.9 Example FTP Session

```
[INFO]
RELAYTYPE=487B
FID=SEL-487B-R102-V0-Z001001-D20030724
BFID=SLBT-4XX-R100-V0-Z001001-D20010703
PARTNO=0487B061X2XBDXXXH
[IOBOARDS]
IO1, , , 24, 8, 0, 0, 1
[COMCARDS]
SEL-2702, SEL-2702-R100-V0-Z000000-D20060501, SLBT-2702-R100-V0-Z000000-D20060425, 1
[P5]
"TIMEOUT",5
"AUTO",Y
"FASTOP",N
"TERTIM1",1
"TERSTRN","\005"
"TERTIM2",0
"IPADDR","10.200.90.10"
"SUBNETM","255.255.0.0"
"DEFRTR","10.200.0.1"
"NETPORT","B"
"FAILOVR","Y"
"FTIME",5
"NETASPD","A"
"NETBSPD","A"
"FTPSERV","Y"
"FTPCBAN","SEL-2701 FTP SERVER:"
"FTPIDLE",5
"FTPANMS","Y"
"FTPAUSR","2AC"
"T1CBAN","HOST TERMINAL SERVER:"
"T1INIT","Y"
"T1RECV","Y"
"T1PNUM",23
"T2CBAN","SEL-2702 TERMINAL SERVER:"
"T2RECV","Y"
"T2PNUM",1024
"TIDLE",5
```

Remaining settings not shown

Figure 5.10 Partial Contents of SET_P5.TXT

```
HOST TERMINAL SERVER:

Bus 1                                    Date: 01/19/2001  Time: 15:35:57.644
Station A                                  Serial Number: 00000001

=ACC <Enter>

Password: ?***** <Enter>

Relay 1                                    Date: 01/19/2001  Time: 15:36:12.856
Station A                                  Serial Number: 00000001

Level 1

=>2AC <Enter>

Password: ?**** <Enter>

Bus 1                                    Date: 01/19/2001  Time: 15:36:16.887
Station A                                  Serial Number: 00000001

Level 2

=>>SHO P 5 <Enter>

Port 5

SEL Protocol Settings

TIMEOUT := 5        AUTO    := N        FASTOP  := N        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0

Protocol Card Settings

IPADDR  := "10.201.0.112"
SUBNETM := "255.255.0.0"
DEFRTR  := "10.201.0.1"
NETPORT := "A"
FAILOVR := "N"
FTIME   := 5
NETASPD := "A"
NETBSPD := "A"
FTPSERV := "Y"
FTPCBAN := "SEL-2702 FTP SERVER:"
FTPIDLE := 5
FTPANMS := "N"
FTPAUSR := ""
T1CBAN  := "HOST TERMINAL SERVER:"
T1INIT  := "N"
T1RECV  := "Y"
T1PNUM  := 23
T2CBAN  := "SEL-2702 TERMINAL SERVER:"
T2RECV  := "Y"
T2PNUM  := 1024     TIDLE   := 5
Settings HOST1-CTRLB64 Not Shown

=>>QUIT <Enter>

Host connection terminated, terminating Network connection.
```

Figure 5.11 Example Telnet Session

Section 1
Protection Functions

Overview

This section provides a detailed explanation of the SEL-487B Relay protection functions. Each subsection provides an explanation of the function, along with a list of the corresponding settings and Relay Word bits. Logic diagrams and other figures are included.

Functions discussed in this section are listed below.

- Busbar protection elements
- Sensitive differential element
- Zone supervision logic
- Dynamic zone selection logic
- Instantaneous/delayed overcurrent elements
- Time-overcurrent elements
- Instantaneous voltage elements
- Open phase detector logic
- Open CT detector logic
- Circuit breaker failure protection
- Circuit Breaker failure trip logic
- Buscoupler/bus sectionalizer configurations
- Coupler security logic
- Disconnect monitor
- Zone-switching supervision logic
- Differential trip logic
- Breaker trip logic
- Circuit breaker status logic

Busbar Protection Elements

Busbar protection philosophy traditionally calls for two-out-of-two trip criteria, where two separate measuring elements must agree before protection issues a trip signal. Realization of the two-out-of-two trip criteria can occur by using one of the combinations of measuring elements listed below:

- Dual differential element combination (main zone and check zone)
- Differential element and directional element combination (main zone and directional element)

Each combination has an advantage over the other; the weakness of one being the strength of the other. In particular, differential elements (amplitude comparators) are more vulnerable to CT saturation than directional elements (phase comparators), but directional elements (phase comparators) are more vulnerable to high-impedance faults.

CT saturation is a concern in networks with high fault currents. Poor CT selection increases the potential for CT saturation. In networks with impedance grounding, all ground faults are high-impedance faults. Although relays may have been correctly selected in the initial network design, changes in the network may adversely influence the network parameters. For example, network extensions or reduced source impedance result in higher fault current, and deterioration of the substation grounding mat at the substation may result in higher fault impedance for ground faults.

Modern busbar protection relays should not only include protection elements to allow for diverse network parameters, but the implementation of these elements in the relays must ensure continual, uncompromising relay performance, despite changes in network parameters. In general, busbar protection must comply with the following performance requirements:

- Fast operating times for all busbar faults
- Security for external faults with heavy CT saturation
- Minimum delay for evolving faults

The SEL-487B meets the above performance requirements during all system operating conditions. The relay includes six busbar protection elements for the protection of up to six zones. Each of the six busbar protection elements consists of the following three elements (see *Figure 1.1*):

- Differential element using phasor values
- Directional element using phasor values
- Fault detection logic using instantaneous values

Figure 1.1 shows a block diagram of one of the six busbar protection elements, with only two (I01 and I02) of the available 18 current inputs connected. Because the relay accepts current inputs from CTs with a 10:1 ratio mismatch, the calculations for the differential elements are performed on per unit values. The relay uses the highest CT ratio (CTR_{MAX}) of the installed CT ratios as a reference value in converting the input currents from ampere to per unit values. Using *Equation 1.1*, the relay calculates a normalization factor value (TAP) for each terminal:

$$\mathrm{TAPnn} = \frac{\mathrm{CTR_{MAX}} \cdot \mathrm{I_{NOM}}}{\mathrm{CTRnn}}$$ **Equation 1.1**

where:

TAP*nn* =	TAP value for each terminal to convert current from ampere to per unit (*nn* = 01 through 18)
$\mathrm{CTR_{MAX}}$ =	Highest CT ratio of the terminals used in the terminal-to-bus-zone settings
$\mathrm{I_{NOM}}$ =	Nominal CT secondary current (1 A or 5 A)
CTR*nn* =	CT ratio of the specific terminal

Using the TAP*nn* values, the relay calculates the current in per unit values for each terminal as follows:

$$\mathrm{InnCR} = \frac{\mathrm{Inn}}{\mathrm{TAPnn}}\mathrm{pu}$$ **Equation 1.2**

where:

I*nn*CR =	Per unit current for Terminals I01 through I18
I*nn* =	Current in amperes for Terminals I01 through I18
pu =	per unit

Figure 1.1 shows the block diagram for Busbar Protection Element 1, one of six busbar protection elements available in the relay. Throughout the following element descriptions, the numerical part of the Relay Word bits refers either to elements from a specific busbar protection element (1 through 6) or the specific terminal number (01 through 18). In most cases, the protection element descriptions refer to elements from Busbar Protection Element 1. For example, FDIF1 in *Figure 1.1* refers to the output from the filtered differential element of Busbar Protection Element 1. I01 and I02 refer to current inputs from Terminal I01 and Terminal I02.

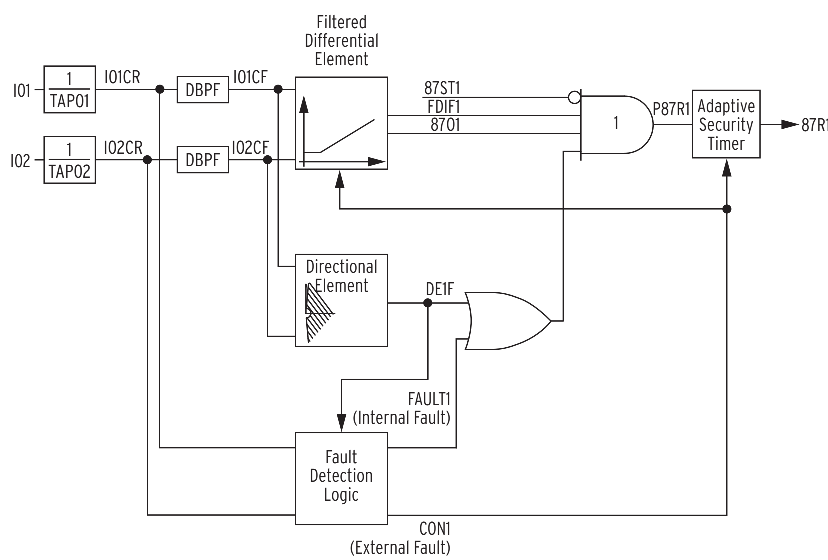

Figure 1.1 Block Diagram Showing the Logic for Busbar Protection Element 1

Referring to *Figure 1.1*, after the per unit conversion, the data (I01CR and I02CR) follow two separate paths. One path is through a digital band-pass filter (DBPF) to the filtered differential element and the directional element; the other path brings the instantaneous values to the fault detection logic.

The filtered differential element uses the input currents from each terminal in a protection zone to calculate the operate and restraint currents. The directional element compares the direction of current at a reference terminal to the direction of current at all other terminals in a protection zone to calculate fault direction. Several elements combine in the fault detection logic to distinguish between internal or busbar faults (FAULT1) and external faults (CON1).

AND Gate 1 combines the OR combination of the directional element (DE1F) and internal fault element (FAULT1) with the sensitive differential element (87ST1) to supervise the filtered differential element. P87R1, the output from Gate 1, drives a security timer that controls the final output (87R1) of the busbar protection element.

The logic includes a dedicated check zone (see *Check Zone Protection Elements on page R.1.10*). This flexibility provides the opportunity to configure the dual differential (main zone and check zone) element combination.

Filtered Differential Element

The following discussion refers to the Filtered Differential Element 1, (with only Terminals 01 and 02 connected to the element) but applies equally well to the remaining five filtered differential elements. Using the output quantities from the digital band-pass filter (cosine filter), the filtered differential element calculates a restraint quantity, IRT1, and an operating quantity, IOP1, according to *Equation 1.3* and *Equation 1.4*:

$$\mathrm{IRT1} = |\mathrm{I01CF}| + |\mathrm{I02CF}| \qquad \textbf{Equation 1.3}$$

and

$$\mathrm{IOP1} = |\mathrm{I01CF} + \mathrm{I02CF}| \qquad \textbf{Equation 1.4}$$

where:

I01CF and I02CF = Filtered per unit current values from Terminals I01 and I02

Figure 1.2 shows a block diagram of the elements necessary for obtaining the differential and restraint quantities used in the filtered differential elements. Relay Word bit FDIF1 is the output from the differential calculation. Relay Word bit 87O1 asserts when the differential current exceeds the O87P threshold. Together these two Relay Word bits form the filtered differential element characteristic.

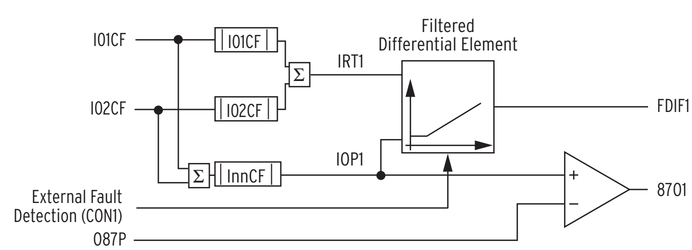

Figure 1.2 Filtered Differential Element 1

Figure 1.3 shows the characteristic of the differential element as a straight line through the origin of the form:

$$\mathrm{IOP1(IRT1)} = \mathrm{SLP1} \bullet \mathrm{IRT1} \qquad \textbf{Equation 1.5}$$

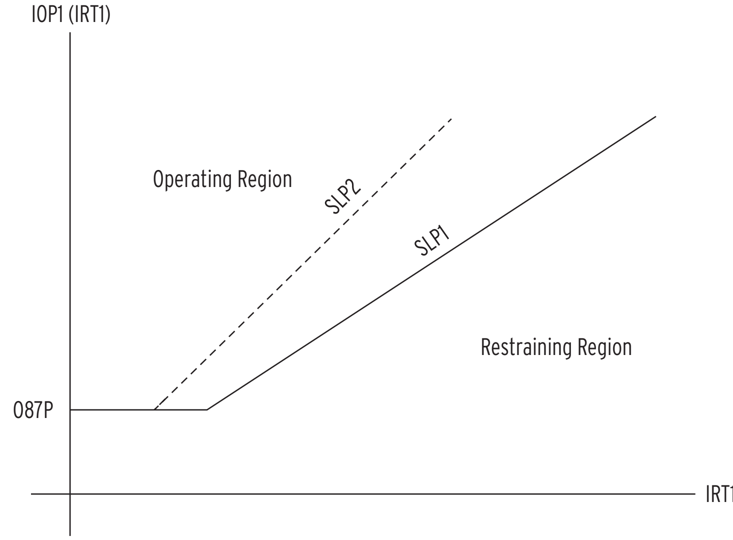

Figure 1.3 Filtered Differential Element Characteristic

For operating quantities (IOP1) exceeding the threshold level O87P and falling in the operate region of *Figure 1.3*, the filtered differential element issues an output. There are two slope settings. Slope 1 (SLP1) is effective for internal faults, and Slope 2 (SLP2) is effective for external faults. To change the slope values, first enable the advance settings by setting EADVS := Y in Group Settings and then proceed to change the slope values. Otherwise, the default settings in *Table 1.1* apply. When the fault detection logic detects an external fault condition, Relay Word bit CON1 asserts. CON1 switches the slope of the differential characteristic from Slope 1 to Slope 2 to add security to the filtered differential element (see *Fault Detection Logic on page R.1.7*).

Table 1.1 shows default settings for the filtered differential element.

Table 1.1 Restraint Filtered Differential Element Default Settings

Setting	Restrained Differential Element	Range	Default
O87P	Restrained Diff Element Pickup	0.1–4 pu	1.00 pu
SLP1	Restrained Slope 1 Percentage	15–90%	60%
SLP2	Restrained Slope 2 Percentage	15–90%	80%

Directional Element

The relay includes directional elements that supervise the filtered differential elements. In particular, the directional elements provide additional security to the filtered differential elements during external faults with heavy CT saturation conditions. Each of the six busbar protection elements has a directional element specific to that differential element.

The directional element compares the direction of current at the reference terminal to the direction of current at all other qualifying terminals in each zone. A qualifying terminal is a terminal with current value greater than the 50DSP threshold setting; the relay selects one of these currents as a reference. For each calculation, the relay uses the real part of the product of the terminal current and the conjugate of the current at the reference terminal, as depicted in *Figure 1.4*.

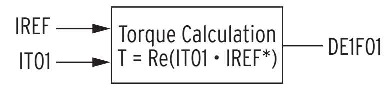

Figure 1.4 Torque Calculation Used in the Directional Element to Determine Fault Direction

The relay declares an internal fault condition when the direction of current at all the remaining terminals coincides with the direction of current at the reference terminal. For the directional element to begin processing, the current values of at least two terminals within the zone must exceed the 50DSP threshold. *Figure 1.5* shows the directional element characteristic, the shaded area indicating an internal fault.

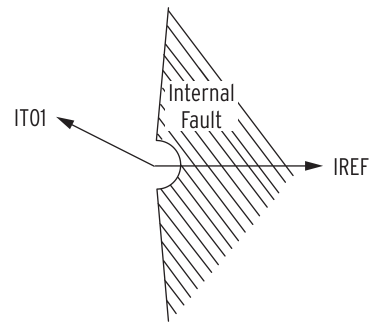

Figure 1.5 Directional Element Characteristic, the Shaded Area Indicating an Internal Fault

The relay acquires the terminals within each specific protection zone from the zone selection logic. The relay determines the terminals with phase current greater than the 50DSP threshold and selects one of the currents greater than the 50DSP threshold as a reference. The relay establishes fault direction by comparing the direction of current at the reference terminal to that at the remaining terminals in the zone with phase current greater than the 50DSP threshold.

Referring to *Figure 1.6*, consider the case of four terminals in Zone 1, with inputs labeled I01CF, I02CF, I03CF, and I04CF. Further assume that the current magnitude in terminal I04CF is below the 50DSP threshold.

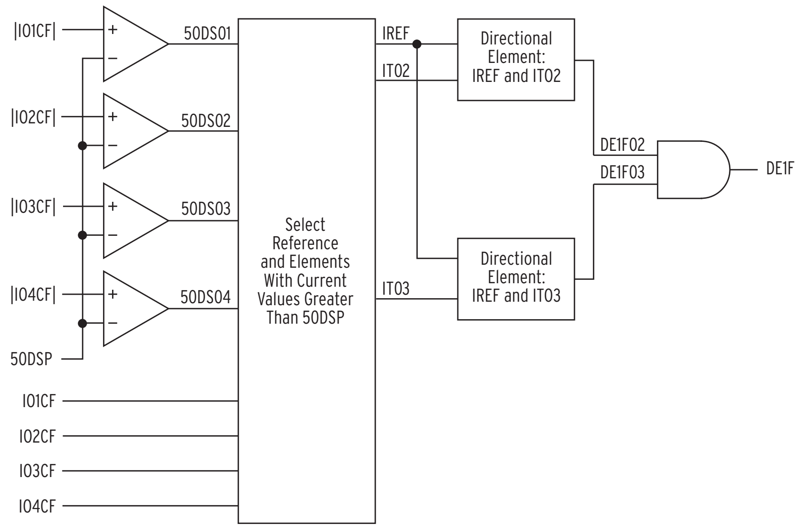

Figure 1.6 Directional Element Logic

First, the directional element determines which terminals have phase current magnitude greater than the 50DSP threshold. Because the current magnitude of input I04CF is below the 50DSP threshold, the relay selects only inputs I01CF, I02CF, and I03CF for further processing. The relay selects input I01CF as the reference (IREF) and compares the direction of current I02CF (IT02) and current I03CF (IT03) to this reference. DE1F asserts only if the direction of current at both IT02 and IT03 coincides with the direction of current at the reference terminal according to the directional element characteristic shown in *Figure 1.5*. *Table 1.2* shows default settings for the directional element.

Table 1.2 Default Settings for the Directional Element

Setting	Directional Element	Range	Default
50DSP	Dir Element O/C Supervision Pickup	0.05–3.0 pu	0.05 pu

Fault Detection Logic

The fault detection logic distinguishes between external faults (external fault detection logic) and internal faults (internal fault detection logic), as shown in *Figure 1.7*. When the fault detection logic detects an external fault, Relay Word bit CON1 asserts, and when the fault detection logic detects an internal fault, Relay Word bit FAULT1 asserts.

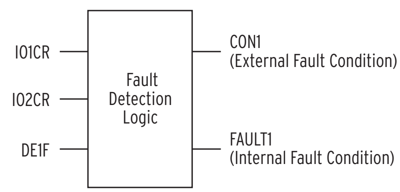

Figure 1.7 Fault Detection Logic That Distinguishes Between External and Internal Faults

Elements in the fault detection logic use instantaneous per unit currents to calculate a restraint quantity, IRT1R, and an operating quantity, IOP1R, according to *Equation 1.6* and *Equation 1.7*:

$$IRT1R = abs(I01CR) + abs(I02CR) \qquad \textbf{Equation 1.6}$$

and

$$IOP1R = abs(I01CR + I02CR) \qquad \textbf{Equation 1.7}$$

where:

I01CR and I02CR = Instantaneous per unit current from Terminals 01 and 02.

Figure 1.8 shows a block diagram of how the fault detection logic obtains restraint quantity IRT1R and operating quantity IOP1R.

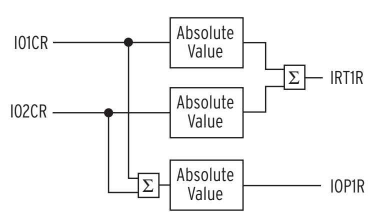

Figure 1.8 Fault Detection Logic Obtaining Restraint and Operating Quantities

External Fault Detection Logic

In general, operating and restraint currents increase simultaneously for internal faults; for external faults, only the restraint current increases if there is no CT saturation. By comparing the change in operating current (ΔIOP1R) to the change in restraint current (ΔIRT1R), the relay detects external fault conditions. Because CTs can saturate during external faults, the relay asserts the external fault condition (Relay Word bit CON1) for 60 cycles after detecting an external fault. *Figure 1.9* shows the logic for detecting external fault conditions.

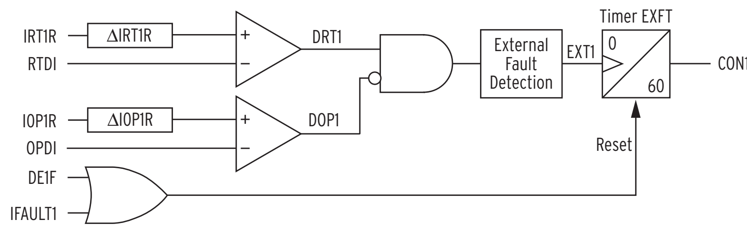

Figure 1.9 External Fault Detection Logic

Asserting CON1 for 60 cycles can slow relay operation for evolving faults (where the fault starts as an external fault and then develops into an internal fault). To prevent delayed tripping, CON1 resets when either the directional element (DE1F) detects an evolving fault or the internal fault detection logic (IFAULT1) confirms an internal fault condition.

Relay Word bit CON1 controls the operating mode of the relay by asserting when the relay detects an external fault. The relay operates normally with CON1 deasserted but switches to a high-security mode when CON1 asserts. High security causes the following in the relay:

- Slope 1 changes to Slope 2.
- Delay time of the adaptive security timer increases.

Resetting CON1 releases the relay from the high-security mode, and the relay operates with the normal settings.

Table 1.3 shows the settings for the external fault detection logic. To change the threshold values, first enable the advanced settings (see *Section 8: Settings* for more information on setting the relay) by setting EADVS := Y in Group Settings.

Table 1.3 External Fault Detection Logic Default Settings

Setting	Restrained Differential Element	Range	Default
RTDI	Incr Restrained Current Threshold	0.1–10 pu	1.2 pu
OPDI	Incr Operating Current Threshold	0.1–10 pu	1.2 pu

Internal Fault Detection Logic

For the internal fault detection logic, the relay uses a characteristic similar to the filtered differential element characteristic.

Figure 1.10 shows the internal fault detection logic consisting of the instantaneous differential element, the consecutive measurement fault detection logic, and the fast fault detection logic. RDIF1, the output from the instantaneous differential element, forms the input into the consecutive measurement fault detection logic and the fast fault detection logic.

The consecutive measurement fault detection logic declares an internal fault when differential current still exists on a consecutive measurement one-half cycle after the instantaneous differential element asserted. When this logic detects an internal fault, the IFAULT1 Relay Word bit asserts.

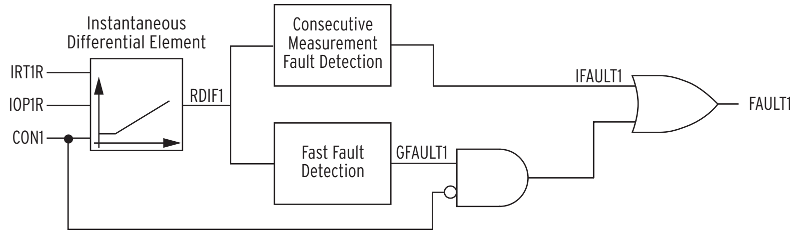

Figure 1.10 Internal Fault Detection, Instantaneous Differential Element, Consecutive Measurement Fault Detection, and Fast Fault Detection Logics

If surge (lightning) arrestors are installed on busbars, a path to ground exists when these devices conduct, resulting in operating current in the differential elements. The fast fault detection logic qualifies the operating current with a time delay to differentiate between operating current resulting from surge arrestor conduction and operating current because of internal faults. If the fast fault detection logic detects an internal fault, Relay Word bit GFAULT1 asserts.

Protection Element Output Logic

Figure 1.11 shows the four conditions from the relay measuring and control logic that must be fulfilled to start the security timer (the final stage in asserting the protection element output, Relay Word bit 87R1):

- An output from the filtered differential element, FDIF1
- An output from the filtered differential element threshold, 87O1
- An output from either the directional element (DE1F) or the internal fault detection logic (FAULT1)
- No output from the sensitive differential element (87ST1) with E87SSUP := Y

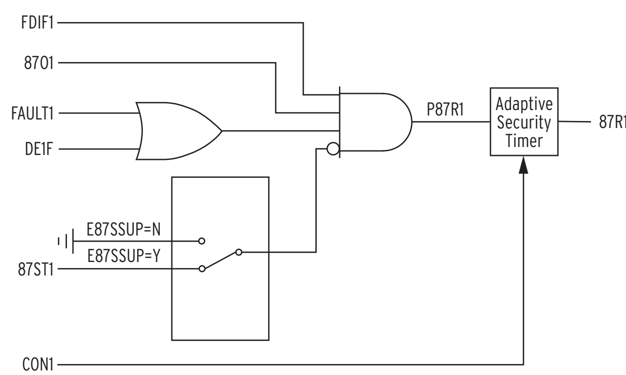

Figure 1.11 Differential Element Output: Final Conditions and Adaptive Security Timer

When the four differential element output logic conditions are met, the output P87R1 starts the adaptive security timer. CON1 also controls the security timer time setting; when CON1 asserts, the relay increases the time delay by 0.4 cycles to increase security for the protection element.

Check Zone Protection Elements

The SEL-487B logic includes a dedicated check zone, providing the flexibility and opportunity to configure the dual differential (main zone and check zone) element combination.

Figure 1.12 shows the block diagram for the Check Zone Protection Element. Throughout the following element descriptions, the numerical part of the Relay Word bits refers to the specific terminal number (01 through 18). I01 and I02 refer to current inputs from Terminal I01 and Terminal I02.

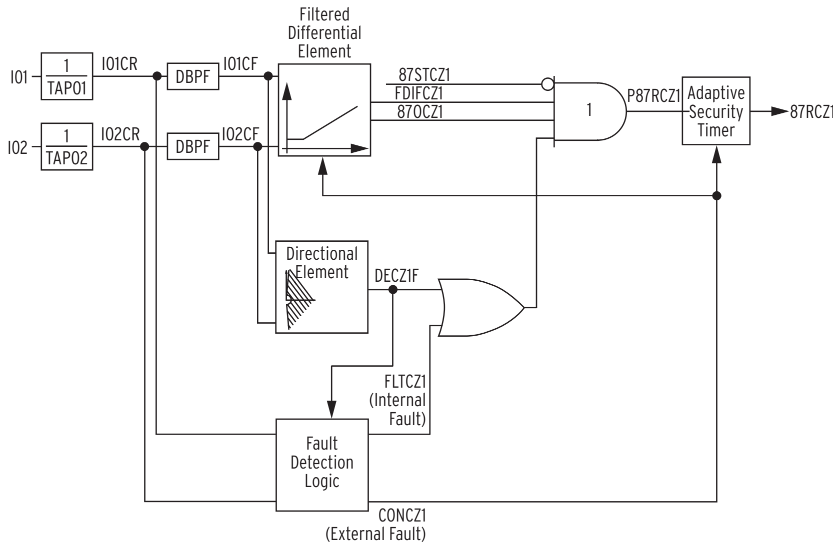

Figure 1.12 Block Diagram Showing Logic for Check Zone Protection Element 1

Check Zone Filtered Differential Element

Figure 1.13 shows a block diagram of the elements necessary for obtaining the differential and restraint quantities used in the filtered differential elements. Relay Word bit FDIFCZ1 is the output from the differential calculation. Relay Word bit 87OCZ1 asserts when the differential current exceeds the CZO87P threshold. Together these two Relay Word bits form the filtered differential element characteristic.

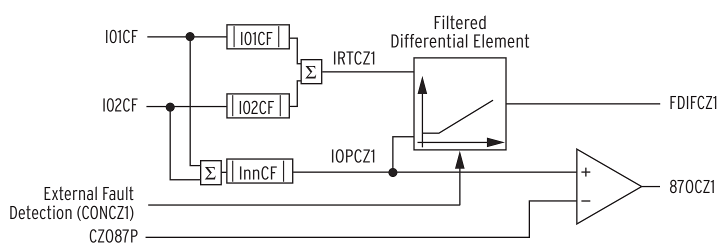

Figure 1.13 Check Zone Filtered Differential Element 1

Table 1.4 shows default settings for the filtered Check Zone Differential Element.

Table 1.4 Check Zone Restraint Filtered Element Default Settings

Setting	Check Zone Restrained Differential Element	Range	Default
CZO87P	CZ Restrained Diff Element Pickup	0.1–4 pu	1.00 pu
CZSLP1	CZ Restrained Slope 1 Percentage	15–90%	60%
CZSLP2	CZ Restrained Slope 2 Percentage	15–90%	80%

Check Zone External Fault Detection Logic

Figure 1.14 shows the logic for detecting external fault conditions.

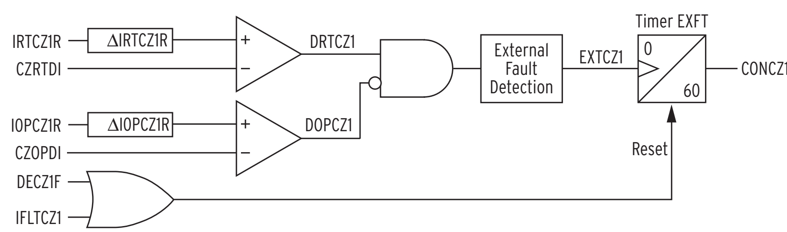

Figure 1.14 Check Zone External Fault Detection Logic

Table 1.5 shows the settings for the external fault detection logic. To change the threshold values, first enable the advanced settings (see *Section 8: Settings* for more information on setting the relay) by setting EADVS := Y in Group Settings.

Table 1.5 Check Zone External Fault Detection Logic Default Settings

Setting	Check Zone Restrained Differential Element	Range	Default
CZRTDI	CZ Incr Restrained Current Threshold	0.1–1- pu	1.2 pu
CZOPDI	CZ Incr Operating Current Threshold	0.1–1- pu	1.2 pu

Check Zone Internal Fault Detection Logic

For the internal fault detection logic, the relay uses a characteristic similar to the filtered differential element characteristic.

Figure 1.15 shows the internal fault detection logic consisting of the instantaneous differential element, the consecutive measurement fault detection logic, and the fast fault detection logic. RDIFCZ1, the output from the instantaneous differential element, forms the input into the consecutive measurement fault detection logic and the fast fault detection logic.

The consecutive measurement fault detection logic declares an internal fault when differential current still exists on a consecutive measurement one-half cycle after the instantaneous differential element asserted. When this logic detects an internal fault, the Relay Word bit IFLTCZ1 asserts.

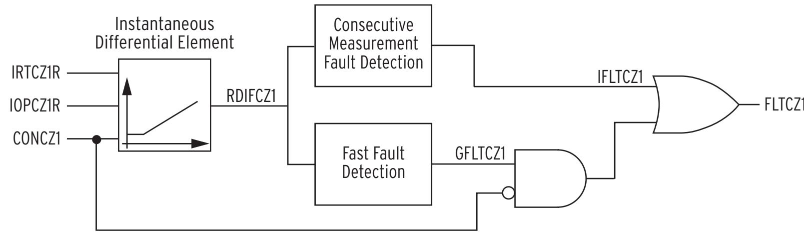

Figure 1.15 Check Zone Internal Fault Detection, Instantaneous Differential Element, Consecutive Measurements Fault Detection, and Fast Fault Detection Logics

Check Zone Protection Element Output Logic

Figure 1.16 shows the four conditions from the relay measuring and control logic that must be fulfilled to start the security timer (the final stage in asserting the Check Zone Protection Element output, Relay Word bit 87RCZ1):

- ➤ An output from the filtered differential element (FDIFCZ1)
- ➤ An output from the filtered differential element threshold (87OCZ1)
- ➤ An output from either the directional element (DECZ1F) or the internal fault detection logic (FLTCZ1)
- ➤ No output from the sensitive differential element (87STCZ1) with E87SSUP := Y

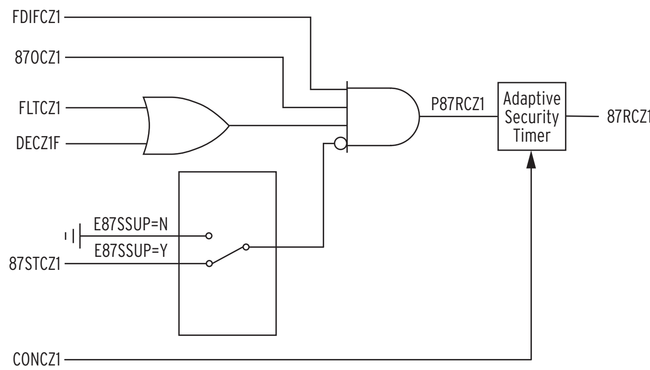

Figure 1.16 Check Zone Differential Element Output: Final Conditions and Adaptive Security Timer

When the four differential element output logic conditions are met, the output P87RCZ1 starts the adaptive security timer. CONCZ1 also controls the security timer time setting; when CONCZ1 asserts, the relay increases the time delay by 0.4 cycles to increase security for the protection element.

Sensitive Differential Element

For each zone, sensitive differential elements detect differential current resulting from CT open or short circuits conditions. If such a condition exceeds a settable delay, the element asserts an alarm. There are two Relay Word bits per zone: an instantaneous Relay Word bit, 87S1, and a time-delayed Relay Word bit, 87ST1. Use 87ST1, the time-delayed output, for alarming and supervision. Each sensitive differential element compares the sensitive differential element operating quantity, IOP1, against the S87P threshold.

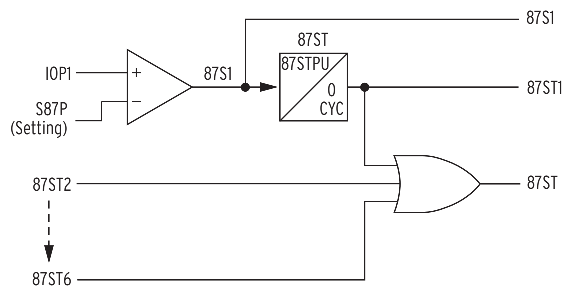

Figure 1.17 Sensitive Differential Element (87S)

The status of the sensitive differential element is one of the four conditions considered in the final output logic of the differential protection element (see *Figure 1.11*). With E87SSUP := Y, the output 87ST*n* supervises the differential protection element. When E87SSUP := N the sensitive differential (87ST*n*) element does not supervise the differential protection elements (87R*n*). Setting E87SSUP := N only removes the supervision function from the differential element, but does not disable the sensitive differential elements. The sensitive differential elements are still running and available for other functions such as asserting an alarm.

The sensitive differential elements may assert under load conditions if not set properly. To prevent these elements from asserting under load conditions, set the differential threshold setting 50 percent higher than the natural out-of-balance current at the station. Be sure to measure the worst natural out-of-balance current at the station. For example, in a double busbar layout with bus-zone-to-bus-zone connections, first merge the bus-zones before making the measurement (see *Dynamic Zone Selection Logic on page R.1.15* and *Bus-Zone-to-Bus-Zone Connections on page A.1.34* for more information). Use the **MET DIF** command to read the per unit operating current values from each protection zone.

Check Zone Sensitive Differential Element

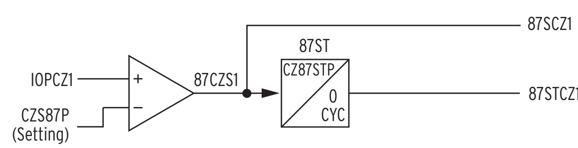

Figure 1.18 Check Zone Sensitive Differential Element (87S)

The check zone has an independent sensitive differential element. There are two Relay Word bits: an instantaneous Relay Word bit, 87SCZ1, and a time-delayed Relay Word bit, 87STCZ1. Use 87STCZ1, the time-delayed output, for alarming and supervision. The sensitive differential element compares the sensitive differential element operating quantity, IOPCZ1, against the CZS87P threshold.

Zone Supervision Logic

This logic provides final supervision criteria before a trip signal is issued. *Figure 1.19* shows the logic for Differential Element 1, but similar logic is available for all six differential elements. Relay Word bit 87R1 is the output from the differential element, and Z1S is a SELOGIC® control equation in the zone configuration settings. The differential trip logic uses Relay Word bit 87Z1, the output from this logic, to determine which terminals to trip. See *Differential Trip Logic on page R.1.53* for more detail.

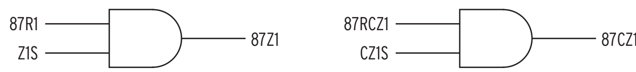

Figure 1.19 Zone and Check Zone Supervision Logic

NOTE: Setting E87ZSUP := N sets ZnS to logical 1. This setting prevents the inadvertent blocking of the differential elements.

⚠CAUTION
Setting E87ZSUP := Y enables the zone supervision in all six zones. If you do not enter any supervision conditions for a particular zone, be sure to enter a 1 at the SELOGIC control equation prompt.

Setting Z1S is a SELOGIC control equation in which you can program the conditions for supervising the differential element (87R1). For example, this is the setting in which you enter the output from the check zone differential element during check zone configuration. Consider the case where a check zone is configured and 87CZ1 is the check zone element output. Both the check zone and the sensitive differential elements must supervise the 87R1 element. With E87SSUP := Y, 87ST1 is already included in the differential element supervision (one of the four final conditions; see *Figure 1.11*). Only the check zone information is required:

Z1S := **87CZ1**

Table 1.6 shows the default values for the six zone supervision settings.

Table 1.6 Default Values for the Zone Supervision Settings

Setting	Setting Description	Range	Default Value
E87ZSUP	Differential Element Zone Supervision	Y or N	Y
Z1S	Zone 1 Supervision (SELOGIC control equation)	SV[a]	1
Z2S	Zone 2 Supervision (SELOGIC control equation)	SV[a]	1
Z3S	Zone 3 Supervision (SELOGIC control equation)	SV[a]	1
Z4S	Zone 4 Supervision (SELOGIC control equation)	SV[a]	1
Z5S	Zone 5 Supervision (SELOGIC control equation)	SV[a]	1
Z6S	Zone 6 Supervision (SELOGIC control equation)	SV[a]	1

[a] SV = SELOGIC control equation variable.

NOTE: Setting E87CZSP := N sets CZ1S to logical 1. This setting prevents the inadvertent blocking of the check zone differential element.

Table 1.7 Default Values for the Check Zone Supervision Settings

Setting	Setting Description	Range	Default Value
E87CZSP	Check Zone Supervision	Y or N	N
CZ1S	Check Zone 1 Supervision (SELOGIC control equation)	SV[a]	1

[a] SV = SELOGIC control equation variable.

Dynamic Zone Selection Logic

Busbar protection involves assigning the appropriate input current values to the corresponding differential elements for calculation of per zone operating and restraint quantities and determining the breakers to trip for differential and breaker failure protection operation. To allow flexible substation configuration without compromising busbar protection, the relay dynamically reassigns input currents to the appropriate differential elements when the station configuration changes.

Disconnect and breaker auxiliary contacts typically provide station configuration information in the form of control inputs, entered into the relay as SELOGIC control equations. By evaluating these SELOGIC control equations, the zone selection logic assigns the currents to the appropriate differential elements. When disconnects are closed in such a way that a solid connection exists between two (or more) zones, the zones merge, and only one zone is active. The active zone after a merge is always the zone with the lowest number. For example, if Zone 3 and Zone 4 merge, Zone 3 encompasses Zone 4.

When the SELOGIC control equation representing the Terminal-to-Bus-Zone becomes a logical 1, the zone selection algorithm processes the current values associated with that particular terminal. See *Table 1.8*. When the equation is logical 0, the current values are neither processed nor considered in the differential calculations. This is also true for the trip output. When the SELOGIC control equation of a terminal is a logical 0, the differential element issues no trip signals to that terminal.

Table 1.8 Current Values Assigned to the Differential Element as a Function of the Disconnect Status

SELOGIC Control Equation	Status	Meaning in the Differential Calculation
I01BZ1V := D891	D891 = 1 (closed)	I01 is part of differential Bus-Zone 1
I01BZ1V := D891	D891 = 0 (open)	I01 is not part of differential Bus-Zone 1

where:

I01BZ1V = SELOGIC control equation declaring the conditions when Terminal 1 connects to Bus-Zone 1

D891 = input from Terminal 1 disconnect auxiliary contact that changes state when the disconnect switch changes state

To properly configure the station, the zone selection algorithm requires the following information:

- Terminals to bus-zones connections, I*qq*BZ*p*V.
- Interconnections between bus-zones, BZ*p*BZ*p*V.

where:

qq = 01–18 (Terminal 1 to Terminal 18)

p = 1–6 (Bus-Zone 1 to 6)

Both I*qq*BZ*p*V and BZ*p*BZ*p*V are SELOGIC control equation variables that you enter in the relay when using the **SET Z** command to set the relay.

Selecting the Zones

The relay runs the zone selection algorithm every protection processing interval and sets the appropriate zone switching operation (ZSWOP*p*) Relay Word bits for one cycle when there is a status change in either I*qq*BZ*p*V (terminal is connected to or disconnected from a bus-zone) or BZ*p*BZ*p*V (two or more bus-zones are connected together).

Based on the SELOGIC control equations I*qq*BZ*p*V and BZ*p*BZ*p*V, the zone selection logic determines the following:

- ➤ The bus-zone(s) to be included in each protection zone
- ➤ The active terminals to be included in each protection zone
- ➤ The terminals to trip for differential and breaker failure protection operations

Table 1.9 shows the Relay Word bits available in the zone selection logic with their descriptions.

Table 1.9 Relay Word Bits in the Zone Selection Logic

Quantity	Description
ZSWOP*p*	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone *p*
ZONE*p*	Differential Zone *p* is active
I*qq*BZ*p*V	Terminal *qq* connected to BZ*p*
BZ*p*BZ*p*V	A connection exists between *BZp* and BZ*p*
ZN*p*I*qq*	Terminal *qq* connected to Zone *p*
ZN*p*I*qq*T	Terminal *qq* connected to Zone *p* and will be tripped
BZ*p*BZ*p*R	A connection exists between BZ*p* and BZ*p* and the coupler is removed
Z*p*BZ*p*	Bus-Zone *p* is part of Protective Zone *p*

Check Zone Selection

When the SELOGIC control equation representing the Terminal-to-Check-Zone becomes a logical 1, the check zone selection algorithm processes the current values associated with that particular terminal. When the equation is logical 0, the current values are neither processed nor considered in the differential calculations.

To properly configure the station, the zone selection algorithm requires the following information:

Terminal-to-Check-Zone connections, I*qq*CZ1V

where:

qq = 01–18 (Terminal 1 to Terminal 18)

I*qq*CZ1V are SELOGIC control equation variables that you enter in the relay when using the **SET Z** command to set the relay.

The relay asserts the active check zone bit CZONE1 when the Check Zone is active according to the zone configuration settings. CZONE1 is deasserted if Zone Configuration Setting ECHKZN := N or if there are no active terminals in a check zone. CZONE1 is asserted when Zone Configuration Setting ECHKZN := Y and there are active terminals in a check zone.

Table 1.10 shows the Relay Word bits available in the Check Zone selection logic with their descriptions.

Table 1.10 Relay Word Bits in the Check Zone Selection Logic

Quantity	Description
CZONE1	Differential Check Zone 1 is active.
I*qq*CZ1V	Terminal *qq* connected to CZ1.

Instantaneous/Delayed Overcurrent Elements

Each of the 18 terminals includes a single level of phase instantaneous and time-delayed overcurrent elements. *Figure 1.20* shows the logic for the 50P*nn* element. Labels FIM (Filtered, Instantaneous, Magnitude) are included for informational purposes and indicate specific processes used in the relay (see *Appendix B: Analog Quantities* for more information about analog quantities).

The logic compares the magnitudes of phase input current I*nn*FIM to a pickup setting 50P*nn*P. If the current magnitude exceeds the pickup level, Relay Word bit 50P*nn* asserts and the timer starts timing. After the time specified by the delay setting 50P*nn*D expires, a second Relay Word bit, 50P*nn*T, asserts. Relay Word bit 50P*nn*T only asserts if Relay Word bit 50P*nn* remains asserted for the duration of the 50P*nn*D time setting. When Relay Word bit 50P*nn* deasserts, the timer resets without delay, along with 50P*nn*T if it has asserted.

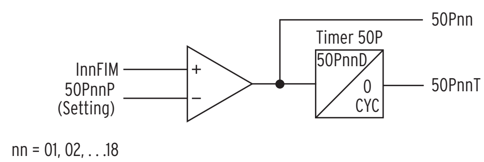

Figure 1.20 Phase Instantaneous and Time-Delayed Overcurrent Elements

Table 1.11 and *Table 1.12* show the setting information for Terminal I01 phase instantaneous and time-delayed overcurrent elements; Terminals I02 through I18 have the same settings.

Table 1.11 Settings for the Phase Instantaneous and Time-Delayed Overcurrent Elements (5 A Relay)

Setting	Setting Description	Range	Default Value (5 A)
50P01P	Terminal 01 Pickup (amps, sec)	OFF, 0.25–100	OFF
50P01D	Terminal 01 Pickup Delay (cyc)	0.00 –99999	10

Table 1.12 Settings for the Phase Instantaneous and Time-Delayed Overcurrent Elements (1 A Relay)

Setting	Setting Description	Range	Default Value (1 A)
50P01P	Terminal 01 Pickup (amps, sec)	OFF, 0.05–20	OFF
50P01D	Terminal 01 Pickup Delay (cyc)	0.00 –99999	10

The definite-time overcurrent elements are not enabled in the default settings. Enable the elements by setting E50 := *nn* (*nn* = 01 through 18). After enabling the elements, the definite-time overcurrent elements of all 18 terminals are available but are still set to OFF. For example, assume we want definite-time overcurrent protection for Terminal 05. Set E50 := 5, making the definite-time overcurrent elements of Terminal 01 through Terminal 05 available. Because the default settings for the definite-time overcurrent elements are OFF, the elements are not active. Only enter settings at the definite-time overcurrent protection prompt of Terminal 05. Terminal 05 is the only terminal with definite-time overcurrent protection; the definite-time overcurrent protection for Terminal 01 through Terminal 04 remains switched OFF.

Inverse Time-Overcurrent Elements

Each of the 18 terminals includes time overcurrent (TOC) characteristics of 10 different operating curves (5 U.S. curves and 5 IEC curves).

Time-Current Operating Characteristics

The following information describes curve timing for time-overcurrent element curve and time-dial settings. The time-overcurrent relay curves in *Figure 1.21* through *Figure 1.30* conform to *IEEE® C37.112–1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays*.

where:

T_p = operating time in seconds
T_r = electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)
TD = time-dial setting
M = applied multiples of pickup current [for operating time (T_p), M > 1; for reset time (T_r), M ≤ 1]

Table 1.13 Equations Associated With U.S. Curves (Sheet 1 of 2)

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$T_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_r = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 1.21*
U2 (Inverse)	$T_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 1.22*
U3 (Very Inverse)	$T_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 1.23*

Table 1.13 Equations Associated With U.S. Curves (Sheet 2 of 2)

Curve Type	Operating Time	Reset Time	Figure
U4 (Extremely Inverse)	$T_p = TD \bullet \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{5.64}{1 - M^2}\right)$	*Figure 1.24*
U5 (Short-Time Inverse)	$T_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_r = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 1.25*

Table 1.14 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$T_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$T_r = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 1.26*
C2 (Very Inverse)	$T_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$T_r = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 1.27*
C3 (Extremely Inverse)	$T_p = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 1.28*
C4 (Long-Time Inverse)	$T_p = TD \bullet \left(\frac{120}{M - 1}\right)$	$T_r = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 1.29*
C5 (Short-Time Inverse)	$T_p = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$T_r = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 1.30*

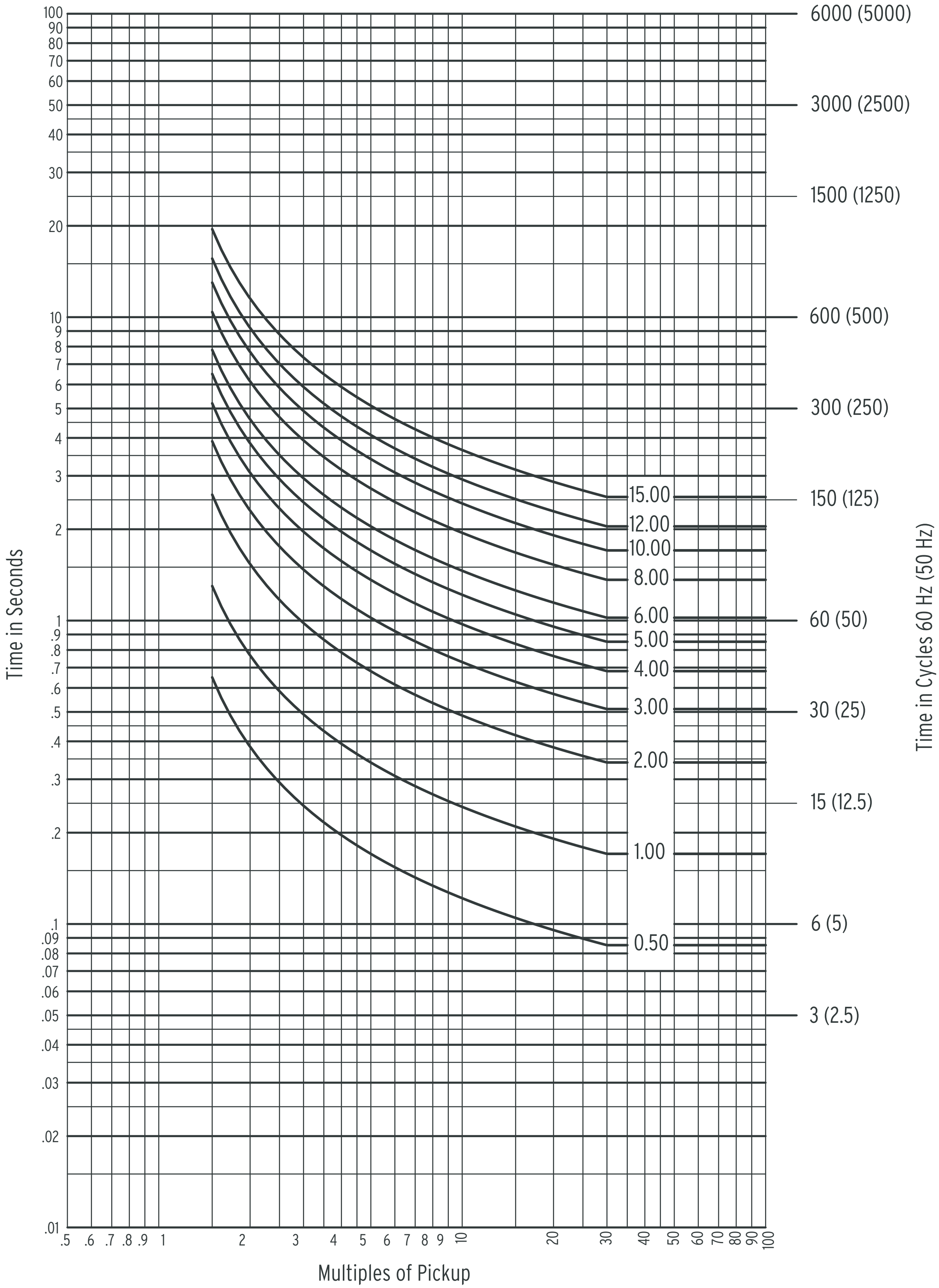

Figure 1.21 U.S. Moderately Inverse—U1

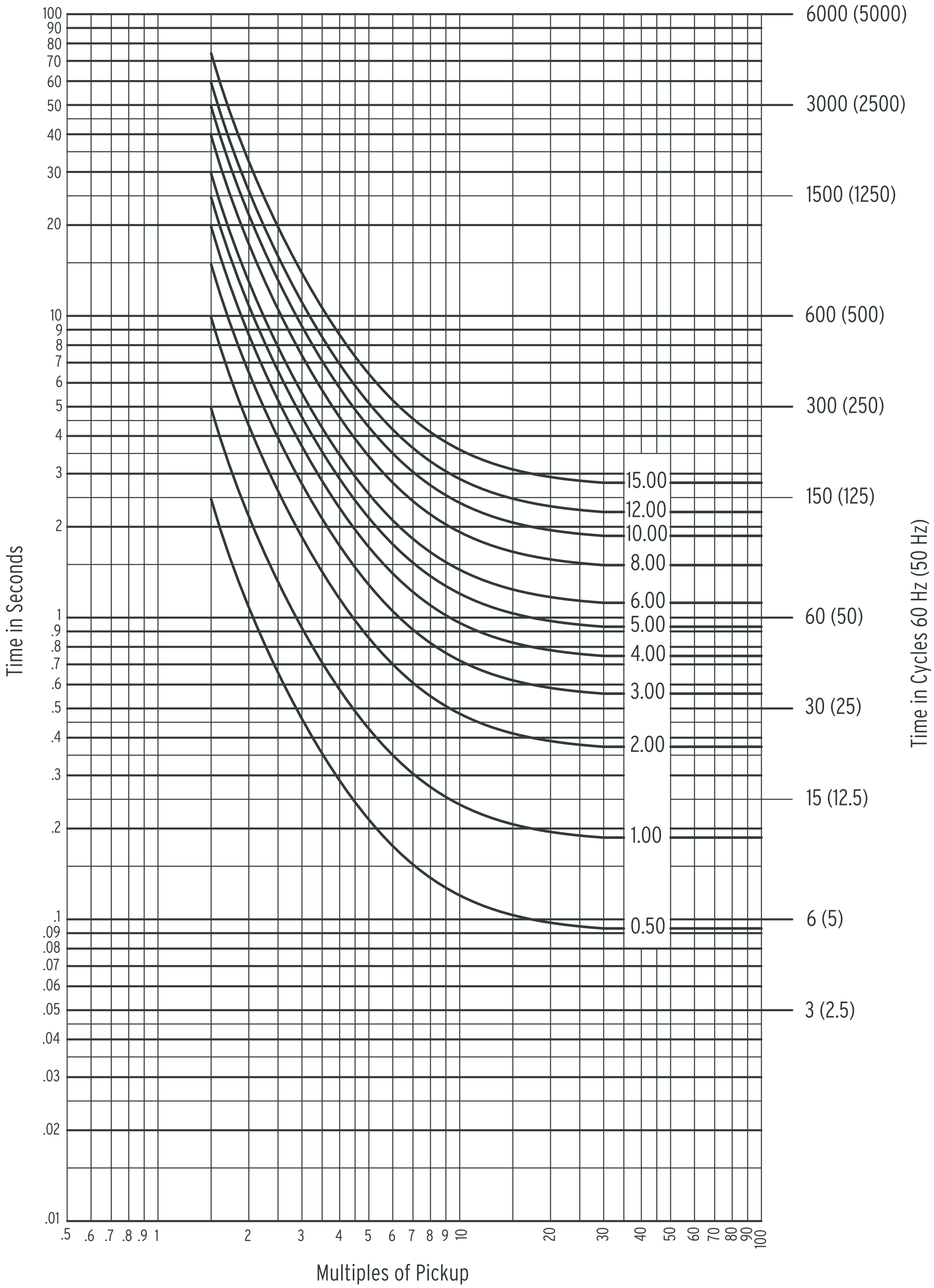

Figure 1.22 U.S. Inverse—U2

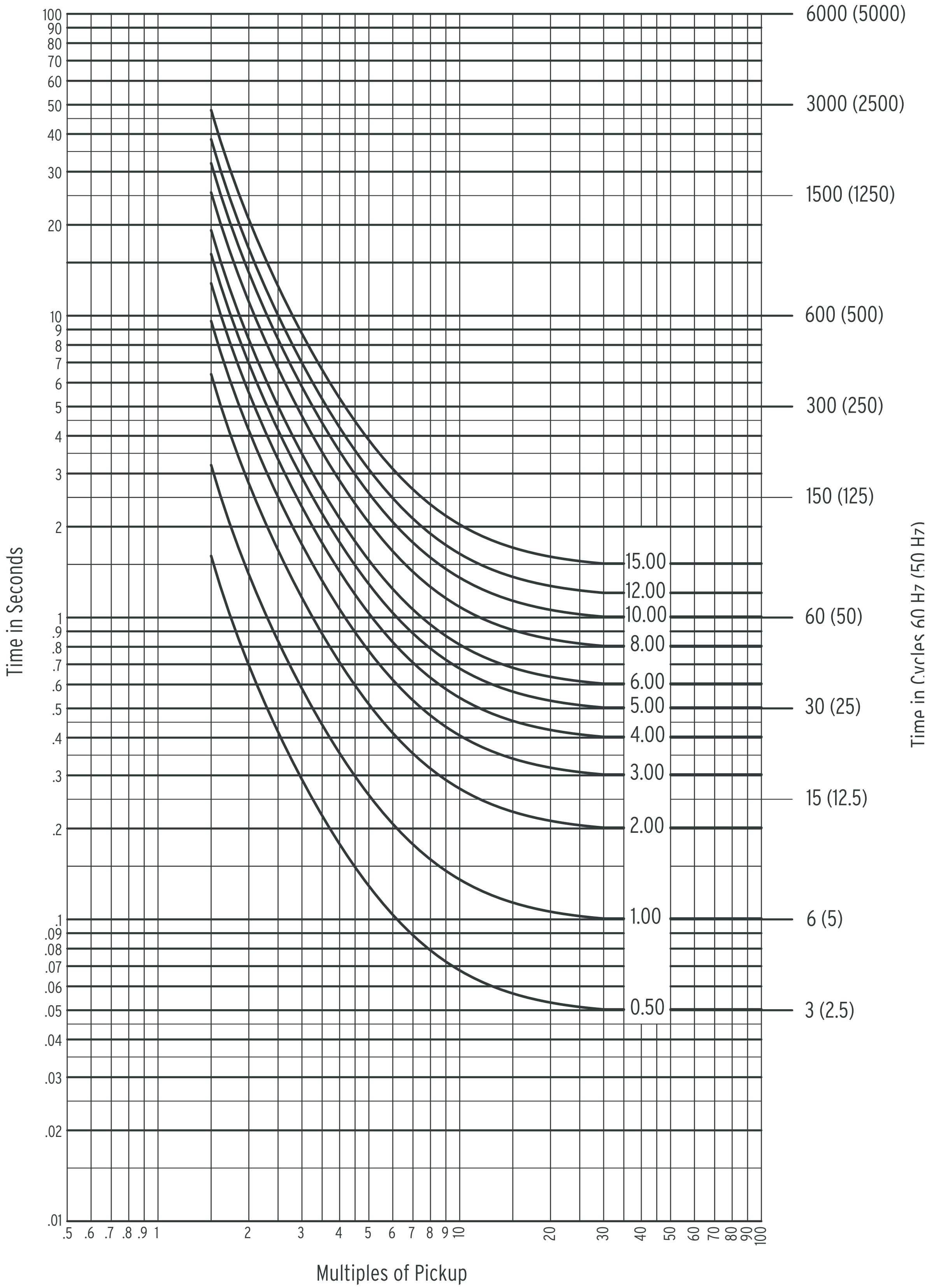

Figure 1.23 U.S. Very Inverse—U3

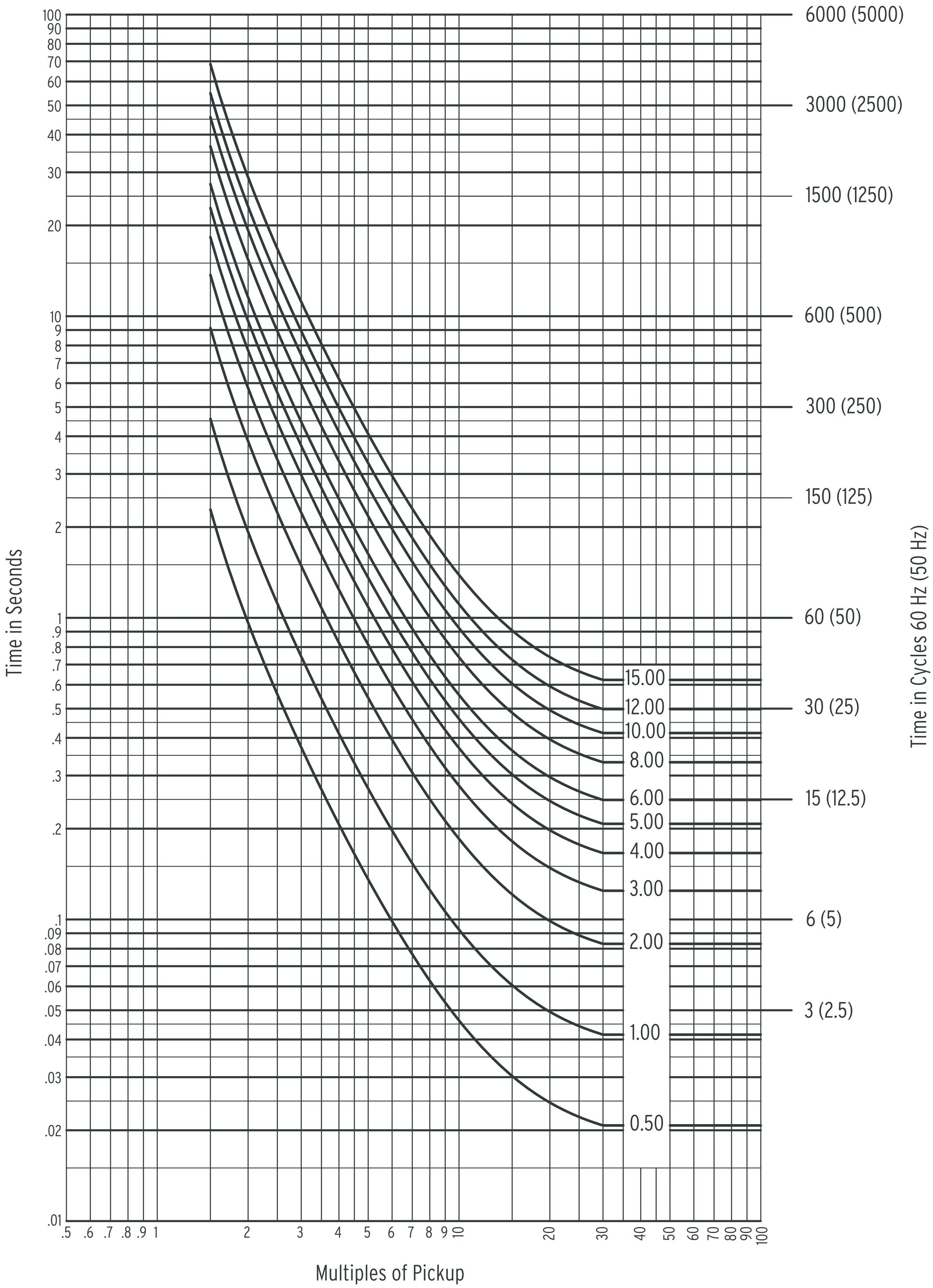

Figure 1.24 U.S. Extremely Inverse—U4

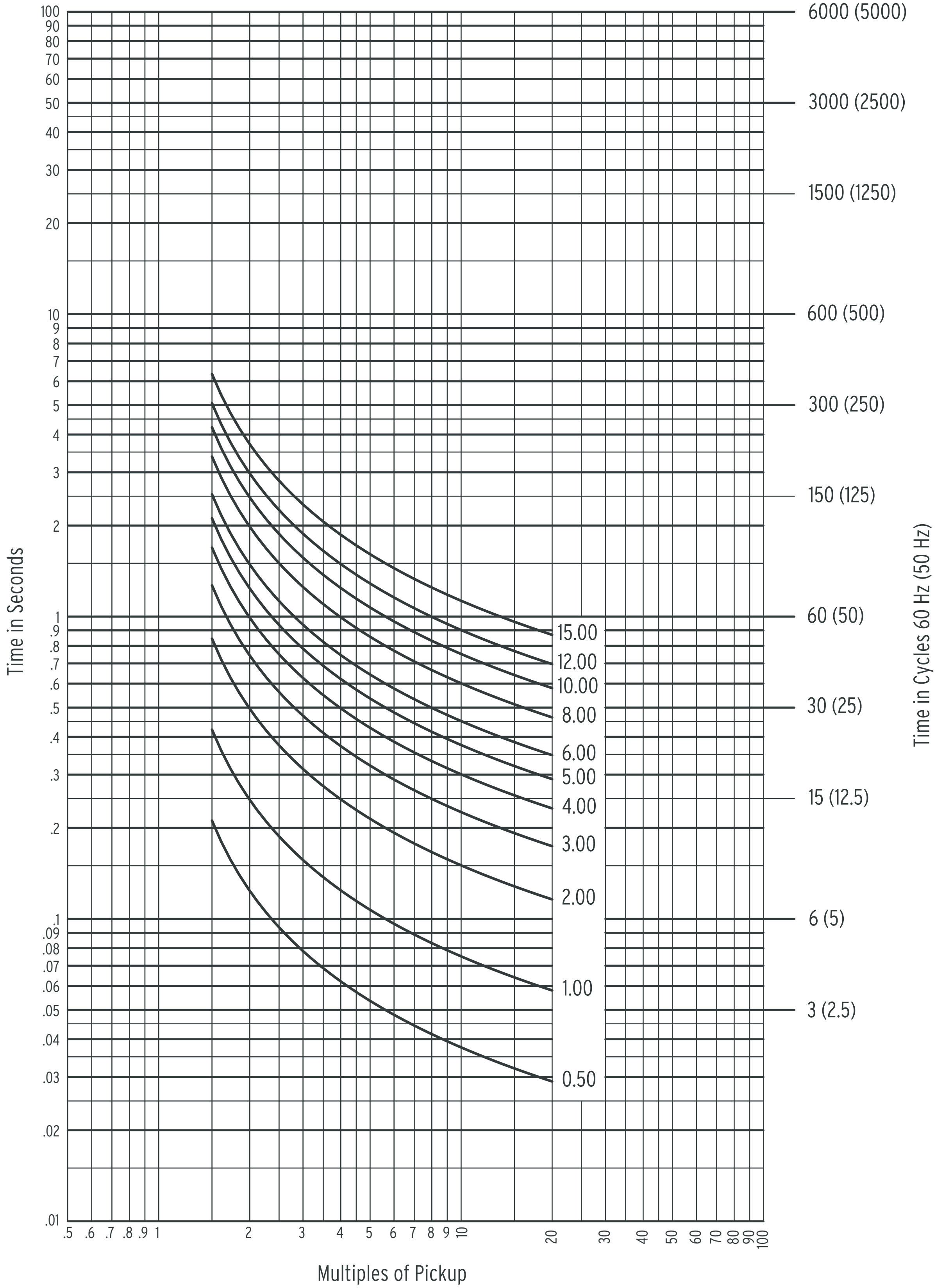

Figure 1.25 U.S. Short-Time Inverse—U5

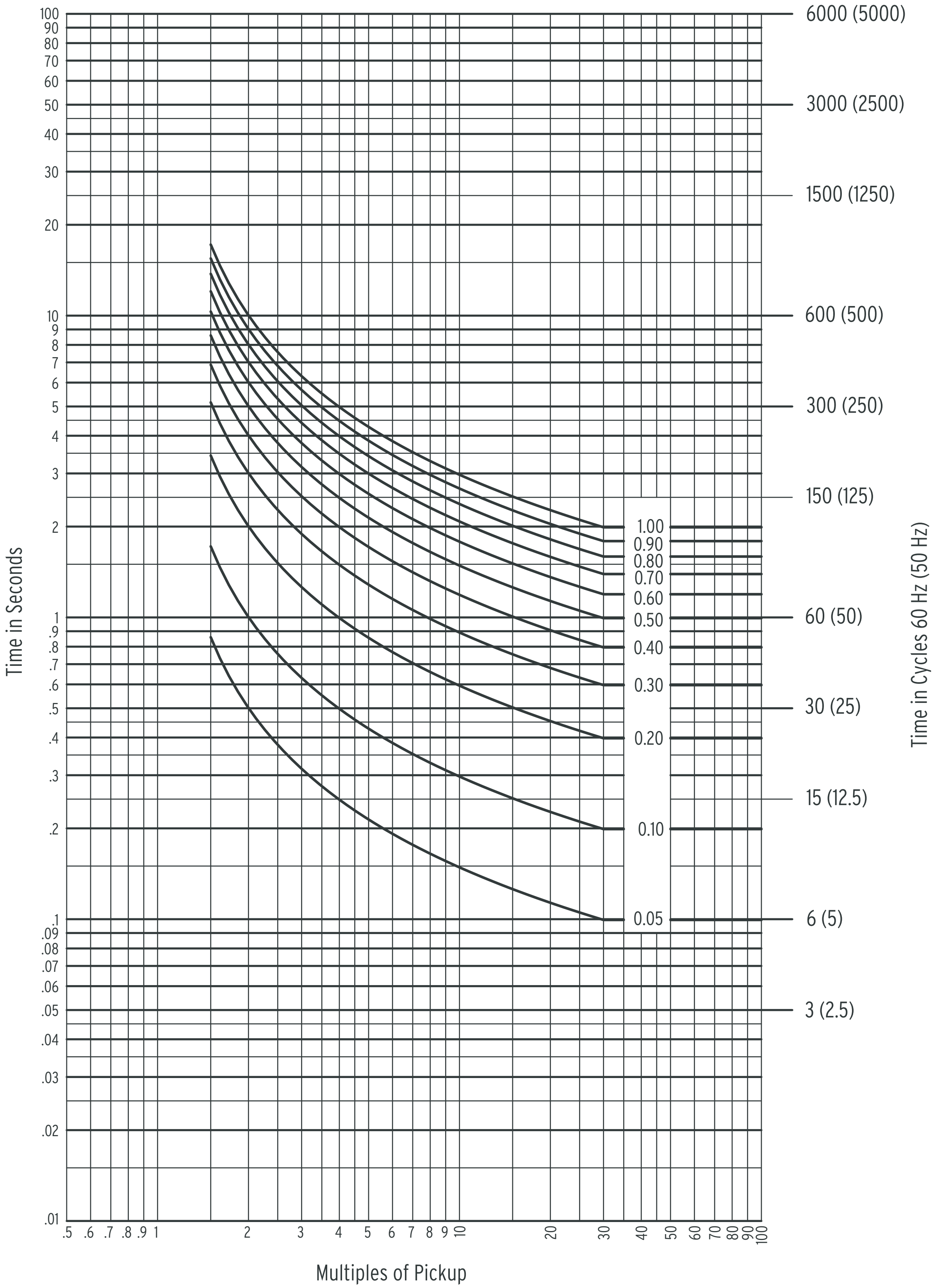

Figure 1.26 IEC Standard Inverse—C1

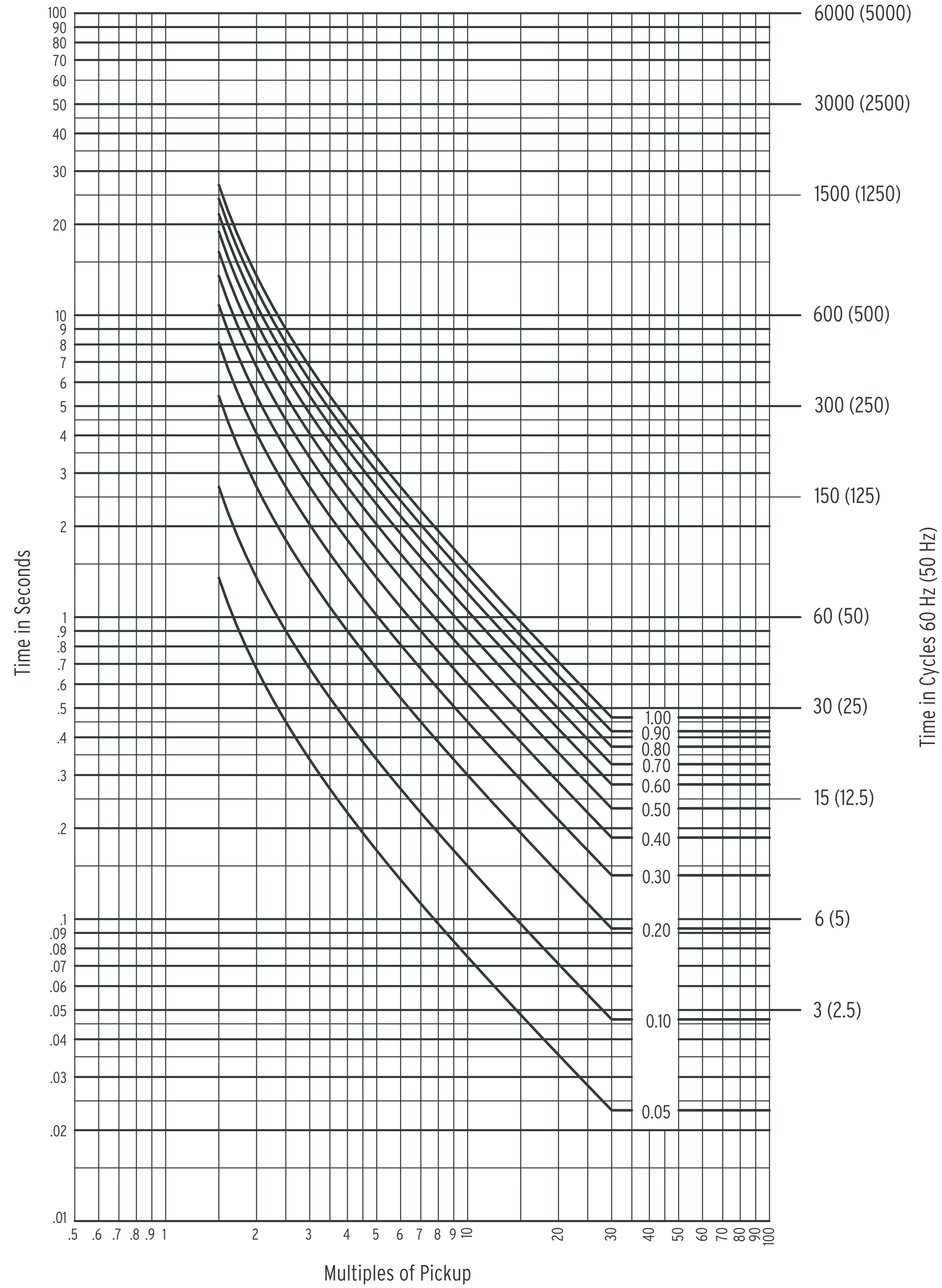

Figure 1.27 IEC Very Inverse—C2

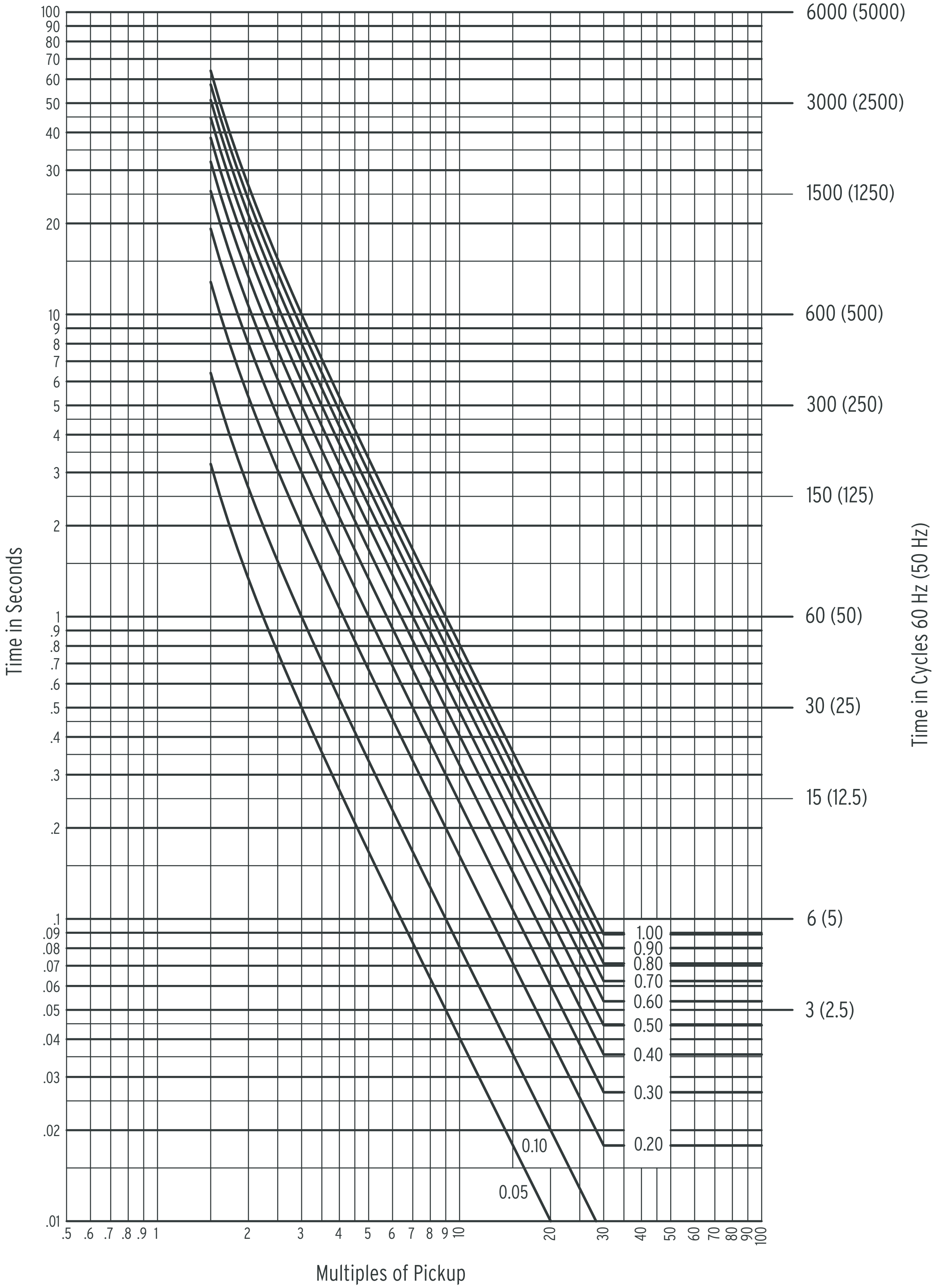

Figure 1.28 IEC Extremely Inverse—C3

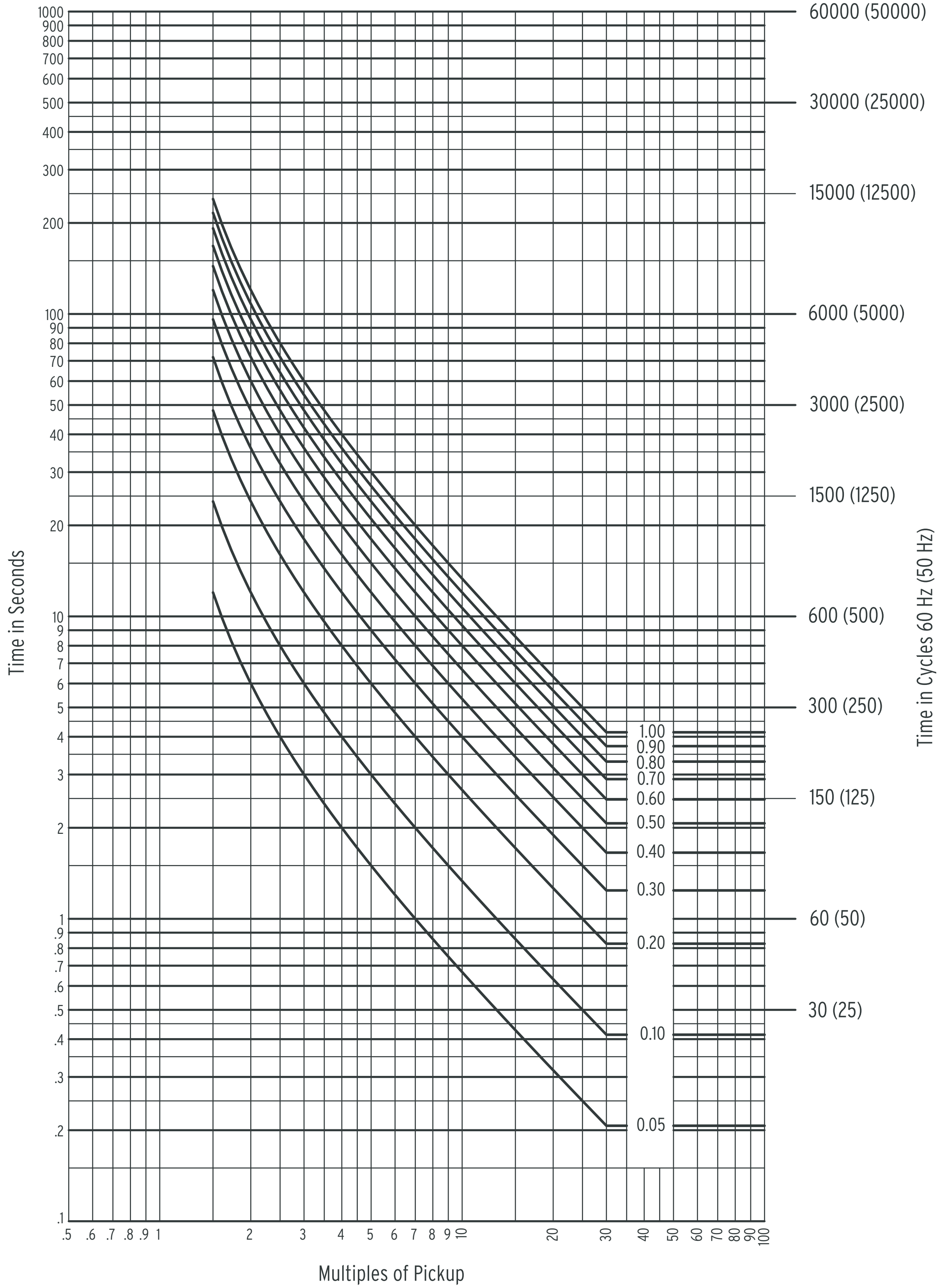

Figure 1.29 IEC Long-Time Inverse—C4

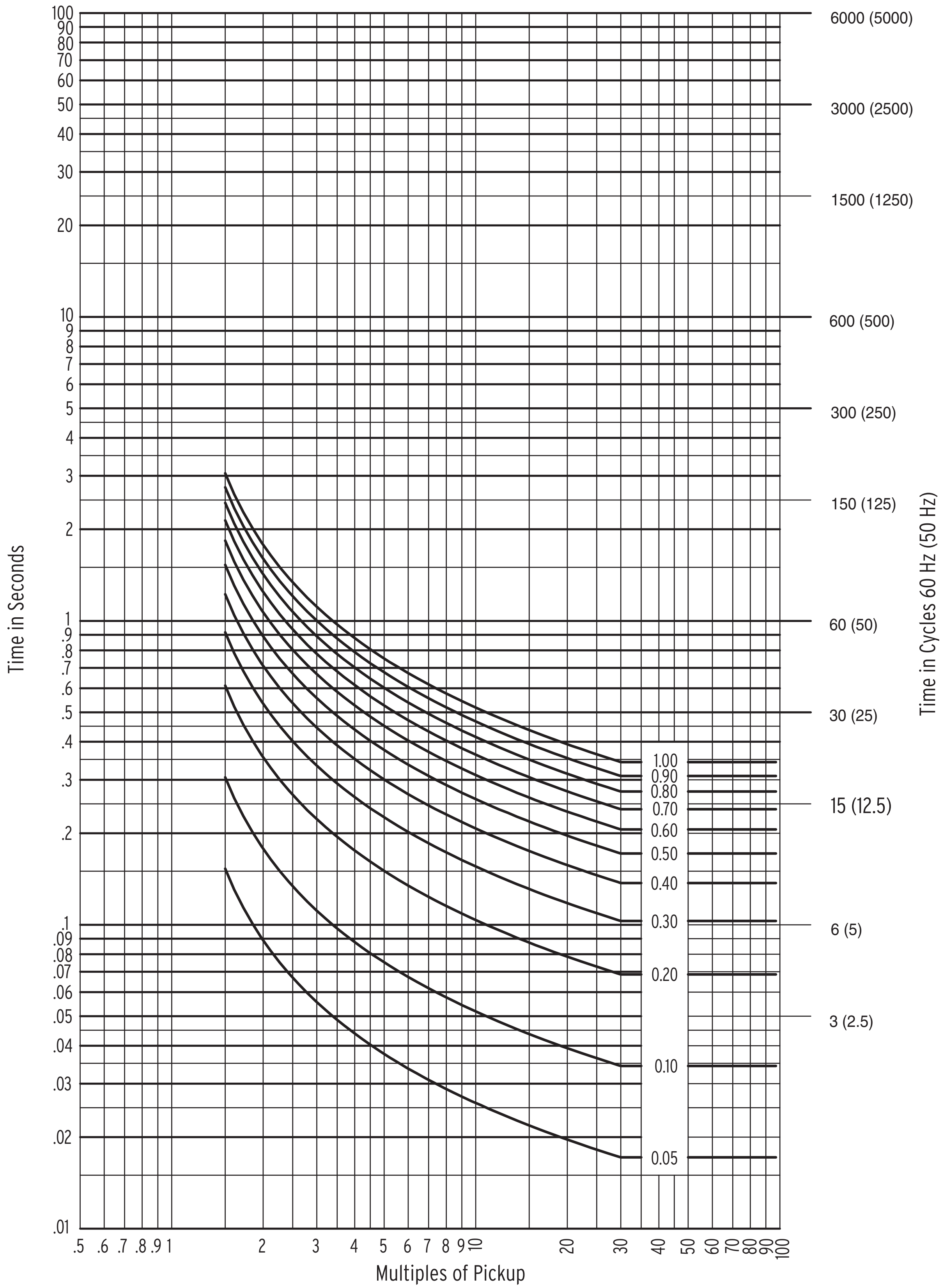

Figure 1.30 IEC Short-Time Inverse—C5

Figure 1.31 shows the time-overcurrent element logic diagram. Labels FIM (Filtered, Instantaneous, Magnitude) are included for informational purposes and indicate specific processes used in the relay (see *Appendix B: Analog Quantities* for more information on analog quantities). Consider I01FIM, the input current from Terminal I01. If the element should only measure under certain conditions, specify those conditions with 51P01TC, the torque control setting. For example, if the element should only measure when the circuit breaker is closed, enter the following:

51P01TC := **52A01**

With this setting, the element compares the current in Terminal 01 with the setting 51P01P only when 52A01 is a logical 1. If the element must measure all the time, enter the following:

51P01TC := **1**

Output Relay Word bits are 51P01, which asserts when the measured current exceeds the 51P01P setting; 51P01T, which asserts when the curve has timed out; and 51P01R, which asserts when the element is fully reset.

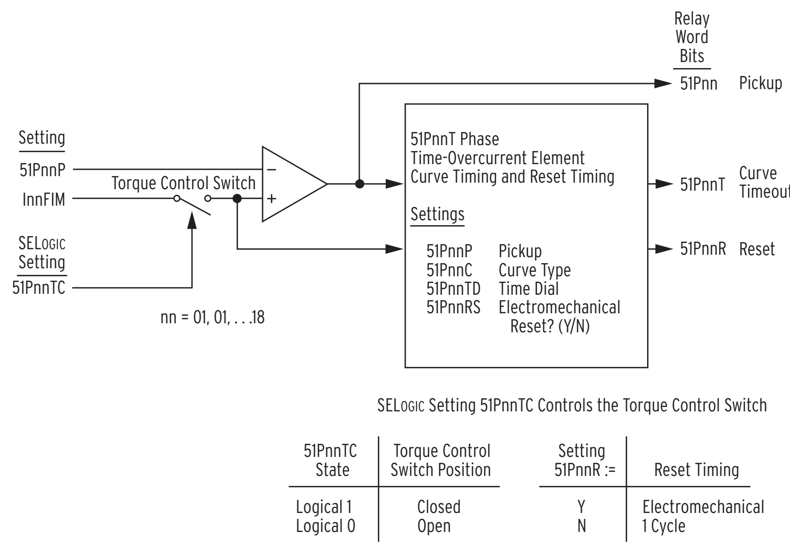

Figure 1.31 Time-Overcurrent Element Logic Diagram

Table 1.15 and *Table 1.16* show setting information for Terminal I01 time-overcurrent elements; Terminals I02 through I18 have the same settings.

Table 1.15 Settings for the Time-Overcurrent Elements (5 A Relay)

Setting	Setting Description	Range	Default Value (5 A)
51P01P	51P01 O/C Pickup (amps, sec)	0.5–16.0	0.5
51P01C	51P01 Inv-Time O/C Curve	U1–U5, C1–C5	U1
51P01TD	51P01 Inv-Time O/C Time Dial [U1–U5] or 51P01 Inv-Time O/C Time Dial [C1–C5]	0.5–15 or 0.05–1	0.5
51P01RS	51P01 Inv-Time O/C EM Reset (Y, N)	Y or N	Y
51P01TC	51P01 Inv-Time O/C Torque Cont	SV	1

Table 1.16 Settings for the Time-Overcurrent Elements (1 A Relay)

Setting	Setting Description	Range	Default Value (1 A)
51P01P	51P01 O/C Pickup (amps, sec)	0.1–3.2	0.1
51P01C	51P01 Inv-Time O/C Curve	U1–U5, C1–C5	U1
51P01TD	51P01 Inv-Time O/C Time Dial [U1–U5] or 51P01 Inv-Time O/C Time Dial [C1–C5]	0.5–15 or 0.05–1	0.5
51P01RS	51P01 Inv-Time O/C EM Reset (Y, N)	Y or N	Y
51P01TC	51P01 Inv-Time O/C Torque Cont	SV	1

⚠WARNING
Do not use Relay Word bit 51PnnT in any trip equation if inverse-time overcurrent protection is not required.

The inverse-time overcurrent elements are not enabled in the default settings. Enable the elements by setting E51 := *nn* (*nn* = 01 through 18). After enabling the elements, the inverse-time overcurrent elements up to and including the number *nn* entered at the E51 := prompt are active. For example, assume we want inverse-time overcurrent protection for Terminal 12. Enter the setting E51 := 12. Inverse-time overcurrent protection for all terminals up to and including Terminal 12 are active. To prevent the inadvertent omission of the inverse time overcurrent protection, the relay does not permit a torque control SELOGIC control equation (51P01TC) setting of 0 or NA. Because the torque control SELOGIC control equation does not disable the inverse-time overcurrent elements, do not include Relay Word bit 51P*nn*T in any trip equation for terminals that do not require inverse-time overcurrent protection. To prevent the inverse-time overcurrent protection LED (51) illumination for faults on terminals that do not require inverse-time overcurrent protection, remove Relay Word bits 51P01T through 51P11T from the SELOGIC control equation of LED 10. (The LEDs are part of the front-panel settings.)

Instantaneous Voltage Elements

Certain protection philosophies require voltage supervision for a trip. Each SEL-487B provides two levels of negative-sequence voltage and two levels of zero-sequence voltage elements to satisfy this requirement. In addition, the relay also provides two levels of phase undervoltage (27) and overvoltage (59) elements for each of the three phases.

Based on an ABC phase rotation, the relay uses the instantaneous phase voltage outputs from the cosine filter (V01F, V02F, V03F) to calculate phase voltage magnitudes and angles, as shown in *Table 1.17*.

Table 1.17 Phase Filtered Instantaneous Voltage Magnitudes and Angles

Quantity	Description	Units
V01FIM	Phase filtered instantaneous voltage magnitude	V (secondary)
V01FIA	Phase filtered instantaneous voltage angle	degrees
V02FIM	Phase filtered instantaneous voltage magnitude	V (secondary)
V02FIA	Phase filtered instantaneous voltage angle	degrees
V03FIM	Phase filtered instantaneous voltage magnitude	V (secondary)
V03FIA	Phase filtered instantaneous voltage angle	degrees

Figure 1.32 shows the logic for two levels of undervoltage and overvoltage elements for voltage channel V01. Labels FIM (Filtered, Instantaneous, Magnitude) are included for informational purposes, indicating the specific values used in the relay (see *Appendix B: Analog Quantities* for more information about analog quantities).

For the undervoltage elements, the logic compares the magnitudes of input voltage V01FIM to a pickup setting, 27P11P. If the voltage magnitude falls below the 27P11P setting level, Relay Word bit 27P11 asserts. When the voltage magnitude exceeds the 27P11P setting level, Relay Word bit 27P11 deasserts without delay. You can set the two levels (27P11P and 27P12P) independently.

For the overvoltage elements, the logic compares the magnitude of input voltage V01FIM to a pickup setting, 59P11P. If the voltage magnitude exceeds the 59P11P setting level, Relay Word bit 59P11 asserts. When the voltage magnitude falls below the 59P11P setting level, Relay Word bit 59P11 deasserts without delay. You can set the two levels (59P11P and 59P12P) independently.

Figure 1.33 and *Figure 1.34* show the same logic for voltage channels V02 and V03.

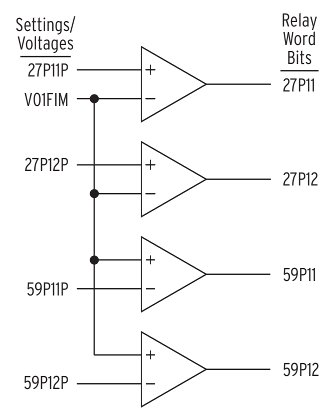

Figure 1.32 Levels 1 and 2 of Phase V01 Over- and Undervoltage Elements

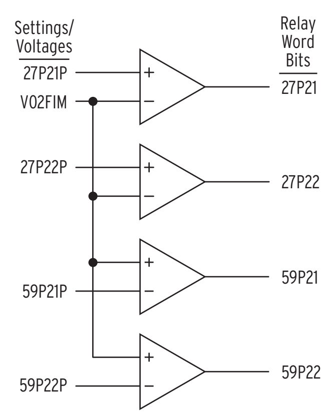

Figure 1.33 Levels 1 and 2 of Phase V02 Over- and Undervoltage Elements

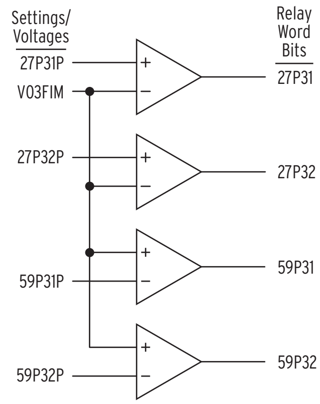

Figure 1.34 Levels 1 and 2 of Phase V03 Over- and Undervoltage Elements

Figure 1.35 shows the logic for two levels of negative-sequence voltage elements and two levels of zero-sequence voltage elements. To use these elements, be sure to wire a voltage input from each phase of the power system to the relay. In a three-relay application, wire three voltages to each of the three relays.

Using the same outputs from the cosine filter (V01F, V02F, V03F), the relay also calculates the negative- and zero-sequence voltage magnitudes, according to the expressions below:

$$3V0F = V01F + V02F + V03F \quad \textbf{Equation 1.8}$$

$$3V2F = (V01F + a^2 V02F + aV03F) \quad \textbf{Equation 1.9}$$

where:

$a = 1 \angle 120°$

Table 1.18 shows the negative- and zero-sequence filtered instantaneous voltage magnitudes.

Table 1.18 Negative- and Zero-Sequence Filtered Instantaneous Voltage Magnitudes

Quantity	Description	Units
3V2FIM	Negative-sequence filtered instantaneous voltage magnitude, 3V2	V (sec)
3V0FIM	Zero-sequence filtered instantaneous voltage magnitude, 3V0	V (sec)

For the negative-sequence element in *Figure 1.35*, the logic compares the magnitude of negative-sequence input voltage 3V2FIM to a pickup setting, 59Q1P. If the negative-sequence voltage magnitude exceeds the 59Q1P setting level, Relay Word bit 59Q1 asserts. When the negative-sequence voltage magnitude falls below the 59Q1P setting level, Relay Word bit 59Q1 deasserts without delay. You can set the two levels (59Q1P and 59Q2P) independently.

For the zero-sequence element in *Figure 1.35*, the logic compares the magnitude of zero-sequence input voltage 3V0FIM to a pickup setting, 59N1P. If the zero-sequence voltage magnitude exceeds the 59N1P setting level, Relay Word bit 59N1 asserts. When the zero-sequence voltage magnitude falls below the 59N1P setting level, Relay Word bit 59N1 deasserts without delay. You can set the two levels (59N1P and 59N2P) independently.

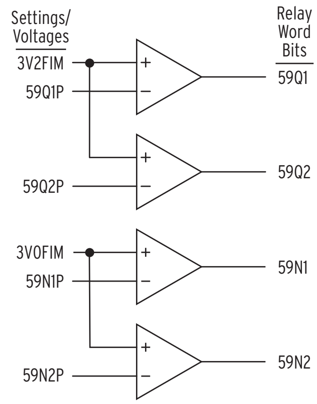

Figure 1.35 Levels 1 and 2 of the Negative- and Zero-Sequence Voltage Elements

Table 1.19 shows the setting information for Levels 1 and 2 of phase V01 under- and overvoltage elements; phases V02 and V03 have the same settings.

Table 1.19 Phase Instantaneous Under-Overvoltage Elements

Setting	Setting Description	Range	Default Value
27P11P	Voltage 1 Level 1 U/V Pickup (volts)	OFF, 1.0–200	OFF
27P12P	Voltage 1 Level 2 U/V Pickup (volts)	OFF, 1.0–200	OFF
59P11P	Voltage 1 Level 1 O/V Pickup (volts)	OFF, 1.0–200	OFF
59P12P	Voltage 1 Level 2 O/V Pickup (volts)	OFF, 1.0–200	OFF

Table 1.20 shows the setting information for Levels 1 and 2 of the negative- and zero-sequence voltage elements.

Table 1.20 Sequence Overvoltage Elements

Setting	Setting Description	Range	Default Value
59Q1P	Neg.-Seq. Level 1 O/V Pickup (volts)	OFF, 1.0–200	20
59Q2P	Neg.-Seq. Level 2 O/V Pickup (volts)	OFF, 1.0–200	40
59N1P	Zero-Seq. Level 1 O/V Pickup (volts)	OFF, 1.0–200	20
59N2P	Zero-Seq. Level 2 O/V Pickup (volts)	OFF, 1.0–200	40

Open Phase Detector Logic

Subsidence current results from energy trapped in a CT magnetizing branch after a circuit breaker opens to clear a fault or interrupt load. This current exponentially decays and delays the resetting of instantaneous overcurrent elements used for breaker failure protection. Breaker failure protection requires fast open phase detection to ensure fast resetting of instantaneous overcurrent elements. *Figure 1.36* shows open phase logic that asserts SEL-487B open phase detection elements OPH*nn* (*nn* = 01, 02 …18) in less than one cycle, even during subsidence current conditions.

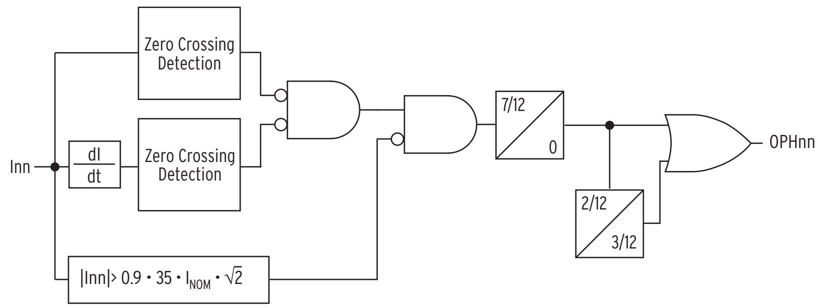

Figure 1.36 Open Phase Detection

The logic measures the zero crossings and maximum and minimum current values of each phase. The relay declares an open phase when the logic does not detect a zero crossing or current value within 7/12 of a power system cycle since the previous measurement.

Open CT Detector Logic

When a CT opens, there is an incremental increase in operating current and a corresponding incremental decrease in restraint current. The two increments should result in a summation equal to zero.

Figure 1.37 shows the open current transformer detector logic. The change in operating current (ΔIOP*n*R), the change in restraint current (ΔIRT*n*R), and operating current (IOP*n*) are the analog inputs to the logic.

The AND gate output asserts when the following conditions are true:

- ΔIOP*n*R is a positive value (greater than or equal to 0.05 pu)
- ΔIRT*n*R is a negative value (less than –0.05 pu)
- The sum of ΔIOP*n*R and ΔIRT*n*R is very small (less than 0.05 pu)
- The filtered operating current (IOP*n*) is greater than or equal to Group Setting S87P

When the AND gate output is asserted, Relay Word bit OCTZ*n* asserts and is latched. SELOGIC control equation ROCTZ*n* resets the latch and Relay Word bit OCTZ*n* clears. Reset has priority over set.

The lower portion of the logic asserts Relay Word bit RSTOCT*n*, the default value for SELOGIC control equation ROCTZ*n*. RSTOCT*n* asserts when any of the following conditions are true:

- IOP*n* is less than 90 percent of group setting S87P
- IOP*n* is less than 0.05

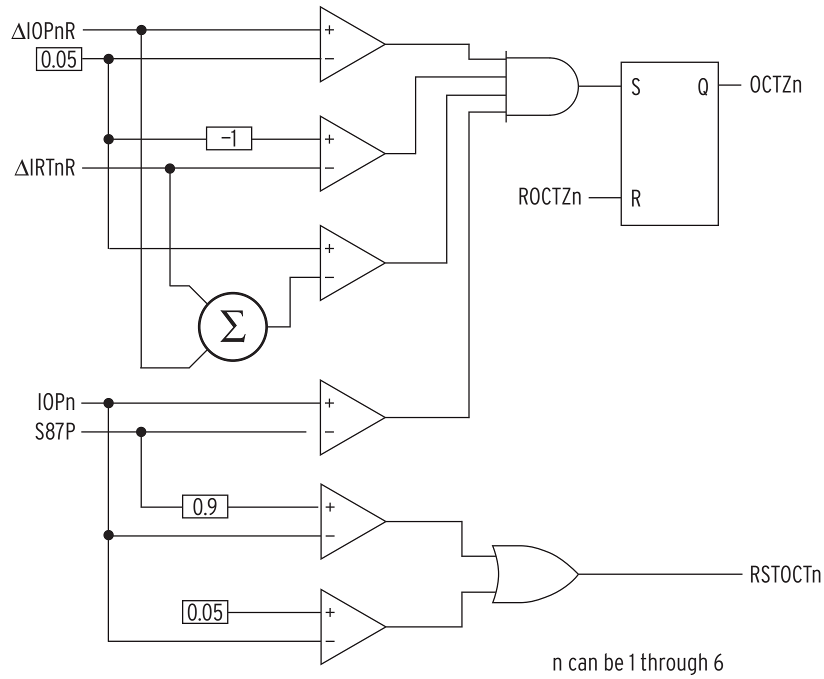

Figure 1.37 Zone n Open CT Detector

Table 1.21 shows the settings for the open CT detection logic.

Table 1.21 Open CT Detector Logic Default Settings

Setting	Zone Open CT Detector	Range	Default Value
ROCTZ*n*	Reset Zone *n* Open CT Detector (SELOGIC control equation)	SV[a]	RSTOCT*n*

[a] SELOGIC control equation variable.

Table 1.22 shows the Relay Word bits available in the check zone selection logic with their descriptions.

Table 1.22 Relay Word Bits in the Open CT Detector Logic

Quantity	Description
OCTZ*n*	Zone *n* Open CT detected
ROCTZ*n*	Reset Zone *n* Open CT detector (SELOGIC control equation)
RSTOCT*n*	Zone *n* Open CT detection reset

Circuit Breaker Failure Protection

The SEL-487B has complete breaker failure protection that includes retrip for each of the 18 terminals. This protection uses open phase detection logic, provided with subcycle current reset, to reduce breaker failure coordination times. Two options are available for application of breaker failure protection:

➤ Schemes equipped with external breaker failure relays. These schemes send a bus trip (output from the breaker failure relay on the terminal panel) command to the bus protection relay (SEL-487B) that requires only the zone selection and output contacts to operate the appropriate breakers.

➤ Schemes using the internal breaker failure protection of the SEL-487B. These schemes send a breaker failure initiate (normally a trip output) command to the bus protection relay. The SEL-487B includes breaker failure logic, as well as zone selection and output contacts, to operate the appropriate breakers.

Apply either option exclusively, or use a combination of the two options at the same station. For example, use the breaker failure relays on the feeder panels for protection philosophies requiring discrete breaker failure relays, but use the built-in breaker failure protection in the SEL-487B for all other terminals at the station. Connect breaker failure initiate signals from these terminals to any one of six independent optoisolated inputs. These inputs are available on each INT4 interface board. *Figure 1.38* shows logic for Terminal 01; similar logic is available for all 18 terminals.

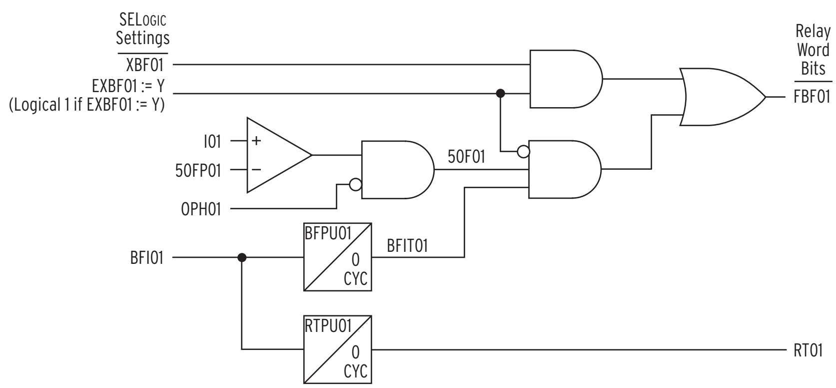

Figure 1.38 Breaker Failure Logic

Schemes Using Internal Breaker Failure Relays

The basic breaker failure logic does not include logic to seal-in the breaker failure initiate signals. For applications where BFI seal-in and extension are required, alternate BFI logic is provided. Set EXBF01 := N to enable the internal breaker failure logic for Terminal 01. Refer to *Figure 1.38*.

Breaker Failure Logic

The breaker failure logic requires the trip signal to be continuously present for the duration of the breaker failure timer because the BFI signal is not sealed in. If an external BFI signal falls away for one processing interval longer than the debounce dropout time setting of the input, the breaker failure timers reset. Wire breaker failure initiate circuitry, typically a trip output contact from a protection relay, to one of the six independent optoisolated inputs and assign the input to BFI01.

When the trip contact from the protection relay closes to assert BFI01, timers BFPU01 (Terminal I01 circuit breaker failure timer) and RTPU01 (Terminal I01 retrip timer) start timing. If BF101 remains asserted when the retrip timer expires, Relay Word bit RT01 asserts. Use this Relay Word bit as an output to attempt another trip pulse to the circuit breaker before the relay issues a bus trip command. When timer BFPU01 expires, Relay Word bit FBF01 asserts if 50F01 is asserted. Use this Relay Word bit in the circuit breaker tripping logic to cause a circuit breaker failure trip.

If the circuit breaker opens successfully before timer BFPU01 or timer RTPU01 expires, the cessation of current flow on the circuit will cause the fast breaker open detector element OPH01 to assert, dropping out element 50F01. This will block the assertion of the breaker failure Relay Word bit FBF01. If the trip contact from the protection relay opens before timer RTP01 expires, the BFPU01 timer and RTPU01 timers will drop out and neither RT01 nor FBF01 will assert.

This logic is suitable for applications where two breakers must open to interrupt fault current, such as in breaker-and-a-half and ring-bus configurations. For these applications, breaker failure logic that requires both BFI and 50F to be asserted before the timer starts is often not suitable. The problem occurs because the 50F element may not assert until the first of the two breakers opens and the current redistributes so that all of it goes through the failed breaker. This situation results in a delay of the Breaker 2 breaker failure time equal to the time for Breaker 1 to interrupt the current. The SEL-487B breaker failure logic does not have this problem.

Alternate Breaker Failure Initiating Input With Extension and/or Seal In Logic

The alternate BFI logic lets you choose to either extend the breaker failure initiate signal or seal in the breaker failure initiate signal. *Figure 1.39* shows the combined logic for both breaker failure initiating input extension (AND Gate 1) and seal-in (AND Gates 1 and 2) functions. This logic can also be used for applications where it is required to have 50F01 asserted before the breaker failure timer can start.

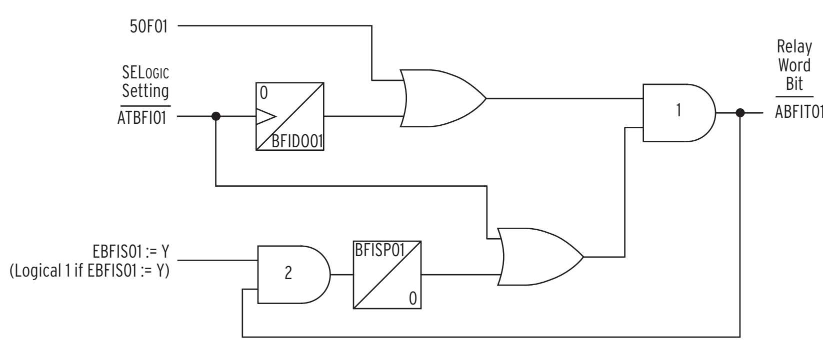

Figure 1.39 Circuit Breaker Failure Initiation Extension and Seal In

Breaker Failure Initiating Input Seal In

NOTE: Coordinate Timer BFISP01 setting with the contact debounce settings.

Use the seal-in option if the breaker failure initiation signal is not continuous and fault current is immediately available (single-breaker applications). Referring to *Figure 1.39*, set EXBF01 := N to enable the internal breaker failure logic. Set EBFIS01 := Y to set the top input of AND Gate 2 to a logical 1. Wire the breaker failure initiate signal to the SEL-487B, and assign the input to ATBFI01. Then assign Relay Word bit ABFIT01 to BFI01

(*Figure 1.38*). On receipt of the breaker failure initiate signal, AND Gate 1 turns on. The output from AND Gate 1 starts the breaker failure timers (*Figure 1.38*) and turns AND Gate 2 on. If the initiate signal is present for longer than the Timer BFISP01 setting, the output from Gate 1 seals in for as long as the current exceeds the 50FP01 threshold. Set the Timer BFISP01 setting longer than a quarter cycle to prevent seal-in for spurious signals, but set it shorter than the initiate signal to ensure seal-in.

Breaker Failure Initiating Input Extension

Use the extension option in conjunction with the seal in option if the breaker failure initiation signal is not continuous, but fault current is not immediately available to start the breaker failure timers (double-breaker applications).

The logic still requires the current to be above the 50FP01 threshold after timer BFIDO01 times out to keep Gate 1 turned on. Set EXBF01 := N to enable the internal breaker failure logic. Referring to *Figure 1.39*, wire the breaker failure initiate signal to the SEL-487B, and assign the input to ATBFI01. Then assign Relay Word bit ABFIT01 to BFI01 (*Figure 1.38*). In the absence of fault current, and on receipt of the rising edge of the breaker failure initiate signal at input ATBFI01, AND Gate 1 turns on. When AND Gate 1 turns on, Relay Word bit ABFIT01 asserts, causing timers BFPU01 and RTP01 to start timing (*Figure 1.38*).

When Breaker 1 opens, enough current flows through Breaker 2 to assert the 50F01 Relay Word bit. Refer to *Figure 1.39* and note that the current flowing through Breaker 2 replaces the output from timer BFIDO01 and keeps Gate 1 turned on, sustaining the input to the breaker failure timers. Set Timer BFIDO01 longer than the time Breaker 1 takes to interrupt the current, but shorter than the Timer BFPU01setting. This setting ensures that, after Breaker 1 opens, Timer BFPU01 will continue to run while current greater than 50FP01 is present.

Supervising Breaker Failure Initiate With the Fault Detector

NOTE: Although BFIDO01 is set to 0.0, the timer picks up for one processing interval after assertion.

Use the alternate BFI logic if the breaker failure initiation signal must be supervised by current before the BFPU01 timer can start. Set EXBF01 := N to enable the internal breaker failure logic. Referring to *Figure 1.39*, wire the breaker failure initiate signal to the SEL-487B, and assign the input to ATBFI01. Then assign Relay Word bit ABFIT01 to BFI01 (*Figure 1.38*). Set BFIDO01 to 0.0 CYC. In this configuration, the upper input to AND Gate 1 is controlled by 50F01 and the lower input to AND Gate 1 is controlled by ATBFI01. Thus, ABFIT01 will not assert and start the BFPU01 and RTP01 timers (*Figure 1.38*) unless both ATBFI01 and 50F01 are asserted.

Schemes Equipped With External Breaker Failure Relays

Set EXBF01 := Y to enable the external breaker failure logic. This setting effectively reduces the logic to that shown in *Figure 1.40*.

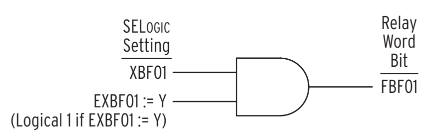

Figure 1.40 Breaker Failure Logic for External Breaker Failure

Wire breaker failure initiate circuitry to one of the SEL-487B inputs, and assign the input to XBF01. Relay Word bit FBF01 immediately asserts upon assertion of the input signal.

Retrip

Some circuit breakers have two separate trip coils. If one trip coil fails, local protection can attempt to energize the second trip coil (often connected to a separate battery) to prevent an impending circuit breaker failure operation. Configure your protection system to always attempt a local retrip using the second trip coil before the circuit breaker failure pickup timer expires. RTPU01 (Retrip Time Delay on Pickup Timer) begins timing when BFI01 asserts. Relay Word bit RT01 (Breaker 1 Retrip) asserts immediately after RTPU01 times out. Assign a control output to trip the circuit breaker when Relay Word bit RT01 asserts. *Table 1.23* shows the breaker failure default settings.

Table 1.23 Breaker Failure Default Settings

Setting	Setting Description	Range	Default
EXBF01	Enable External Breaker Fail—BK01	Y or N	N
XBF01	External Breaker Fail Initiate—BK01	SV	NA
50FP01	Fault Current Pickup—BK01 (amps, secondary)	0.5–50.0	3.0
BFPU01	Breaker Fail Initiate Pickup Delay—BK01 (cyc)	0.00–6000	6.00
RTPU01	Retrip Delay—BK01 (cyc)	0.00–6000	3.00
BFI01	Breaker Fail Initiate—BK01	SV	IN101 and PLT02
ATBFI01	Alt Breaker Fail Initiate—BK01	SV	NA
EBFIS01	Breaker Fail Initiate Seal In—BK01	Y or N	N
BFISP01	Breaker Fail Initiate Seal-In Delay—BK01 (cyc)	0.00–1000	0.5
BFIDO01	Breaker Fail Initiate Dropout Delay—BK01 (cyc)	0.00–1000	1.5

NOTE: BFI01, the breaker fail initiate input (IN101 in Table 1.23), applies to Terminal 01 only. Wire separate breaker fail initiate inputs to each of the terminals requiring breaker failure protection. The remaining settings apply to all 18 terminals.

Breaker Failure Clearing Times

Figure 1.41 is based on actual test data at room temperature using various settings. Relay element specifications given in the Introductions and Specifications include the entire temperature range of the relay. Output contact times are not included.

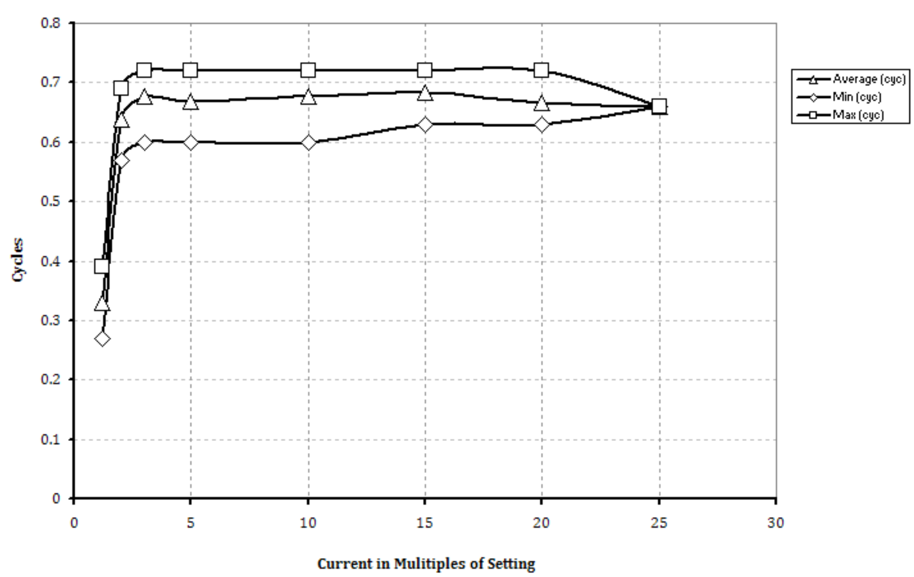

Figure 1.41 Breaker Failure Clearing Times

Circuit Breaker Failure Trip Logic

Following a breaker failure relay operation, the SEL-487B breaker failure trip logic sends trip signals to all of the breakers the logic identifies as being in the same bus-zone as the faulted breaker. The logic uses breaker failure trip information from the internal breaker failure logic and zone selection information to determine which breakers to trip. *Figure 1.42* shows the processing sequence for tripping the breakers according to the breaker failure operation FBF01.

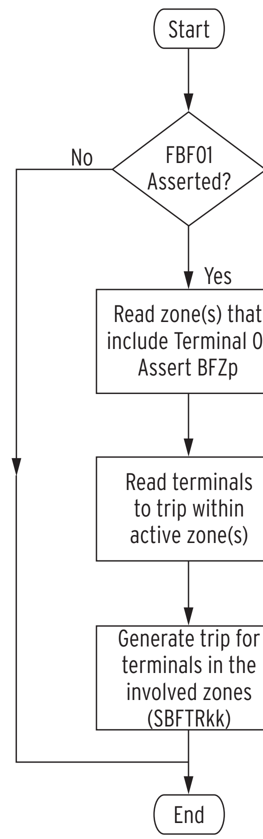

Figure 1.42 Station Breaker Failure Trip Logic

For example, assume Terminals I01, I02, I03 and I04 are in Bus-Zone 1, with Terminal 01 failing for an external fault. The logic determines that Terminal 01 is in Bus-Zone 1, just as Terminals 02, 03, and 04 are also in Bus-Zone 1. The relay asserts Relay Word bits SBFTR01, SBFTR02, SBFTR03, and SBFTR04. With the assumption that there are four breakers, assign these four Relay Word bits to the corresponding TR01, TR02, TR03, and TR04 trip equations.

The breaker failure trip logic asserts the breaker failure trips as shown in *Table 1.24*.

Table 1.24 Station Breaker Failure Trips

Terminal Within a Zone	Station Breaker Failure Trip Bit
I01	SBFTR01
I02	SBFTR02
I03	SBFTR03
I04	SBFTR04
I05	SBFTR05
I06	SBFTR06
I07	SBFTR07
I08	SBFTR08
I09	SBFTR09
I10	SBFTR10
I11	SBFTR11
I12	SBFTR12
I13	SBFTR13
I14	SBFTR14
I15	SBFTR15
I16	SBFTR16
I17	SBFTR17
I18	SBFTR18

SBFTR is the OR combination of SBFTR01 to SBFTR18.

Buscoupler/Bus Sectionalizer Configurations

With the flexibility of SELOGIC control equations, you can configure any one of the bus sectionalizer (tie breaker) configurations in *Figure 1.43* through *Figure 1.45* without additional wiring; it is simply a software configuration change.

CT Either Side of the Breaker With Overlap. *Figure 1.43* shows a bus sectionalizer with a CT on either side of the circuit breaker with the protection arranged in overlap. For an overlap application, connect the CTs so that each zone of protection (B1 and B2) includes the tie-breaker circuit breaker. For example, for Fault 1, only the differential element of Busbar B2 operates; the differential element of Busbar B1 is stable. However, because of the overlap connections, both differential elements operate for Fault F2.

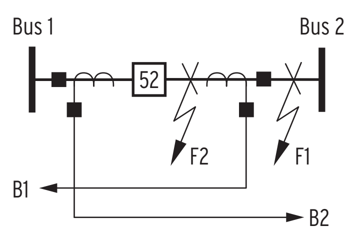

Figure 1.43 Two CTs With the Busbar Protection Configured in Overlap

CT Either Side of the Breaker With Breaker Differential. *Figure 1.44* also shows a bus sectionalizer with a CT on either side of the circuit breaker with the protection arranged in a breaker differential application. For a breaker differential application, connect the CTs so that each zone of protection (B1 and B2) excludes the tie-breaker circuit breaker. For example, for Fault F1, the differential element of Busbar B2 operates; the differential element of Busbar B1 is stable. The differential element of both Busbar B1 and Busbar B2 is stable for Fault F2. To provide protection for Fault F2, configure an additional differential zone of protection across the tie-breaker circuit breaker.

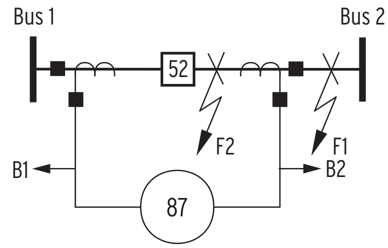

Figure 1.44 Two CTs With the Busbar Protection Configured as Breaker Differential

Single CT, Single or Two Cores With Overlap. *Figure 1.45* shows a bus sectionalizer with a single CT on one side of the circuit breaker with the protection arranged in overlap.

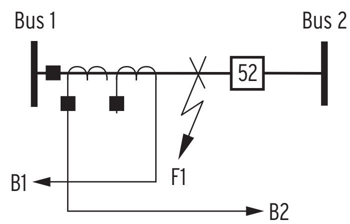

Figure 1.45 Single CT With the Busbar Protection Configured in Overlap

Refer to the application examples in *Section 1: System Configuration Guideline and Application Examples in the Applications Handbook* for more information.

Coupler Security Logic

A fault between buscoupler circuit breaker and CT usually results in the loss of multiple zones as well as in delayed fault clearance, except for where the buscoupler has overlapping zones of protection where both zones are tripped instantaneously. For buscoupler configurations such as breaker differential and single CT applications, fault clearance time usually equals the buscoupler breaker failure time for faults between the CT and the breaker. The coupler security logic includes logic to shorten this time so that it equals the operating time of the buscoupler circuit breaker. Coupler security logic also includes logic to prevent tripping of multiple bus-zones instead of just the faulted bus-zone. Although identifying the faulted bus-zone introduces a trip delay, this delay is still shorter than the buscoupler breaker failure time.

Preventing the loss of multiple bus-zones requires two steps. First, the coupler security logic allows the differential elements to trip only the buscoupler circuit breaker, thereby interrupting the fault current from the unfaulted bus-zone. Then, this logic removes the buscoupler CTs from all differential calculations. Removing the buscoupler CTs from the differential calculations of the unfaulted bus-zone has no effect on the stability of this bus-zone because it no longer contributes to the fault current. However, removing the buscoupler CTs from the differential calculations of the faulted bus-zone causes the differential elements of the faulted bus-zone to operate. This application trips only the faulted bus-zone, thereby preventing the indiscriminate loss of multiple zones, irrespective of the fault position or CT location.

In most cases, breaker auxiliary contacts provide circuit breaker status information. However, circuit breaker auxiliary contact failure or misalignment can result in relay misoperation instead of accelerated tripping. The following discussion describes network operating conditions that may result in relay misoperation and shows how the coupler security logic in the SEL-487B prevents these possible misoperations. Two examples of accelerated tripping show how to apply the coupler security logic to breaker differential and single CT applications. In all cases, assume circuit breaker operating times to be two cycles.

Network Operating Condition 1

Figure 1.46 depicts a subset of a substation showing Bus Sectionalizer Breaker Z, and two terminals labeled Feeder 1 and Feeder 2. Zone 1 and Zone 2 are the two bus sections at the station, with the bus sectionalizer busbar protection arranged in overlap. Because both sectionalizer disconnects (Z891 and Z892) are closed, the currents from the sectionalizer CTs are considered in the differential calculations. In this example, the bus sectionalizer circuit breaker is open, and both feeder circuit breakers are closed. *Table 1.25* summarizes the prevailing network operating conditions.

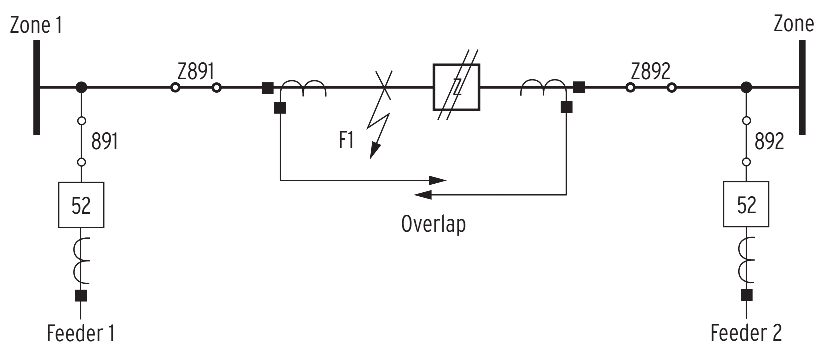

Figure 1.46 Fault F1 Between Bus Sectionalizer and CT With the Bus Sectionalizer Circuit Breaker Open

Table 1.25 Summary of the Network Conditions Shown in Figure 1.46

Station Conditions	Fault Description
Bus sectionalizer Circuit Breaker Z open Both bus sectionalizer disconnects (Z891 and Z892) closed All other breakers and disconnects closed	Fault F1 develops between the sectionalizer circuit breaker and CT

Assume now that Fault F1 occurs as indicated in *Figure 1.46*. Because the currents from the sectionalizer CTs are considered in the differential calculations, and because the bus sectionalizer busbar protection is arranged in overlap, both zones trip. *Table 1.26* summarizes the event.

Table 1.26 Summary of the Event for Fault F1 Shown in Figure 1.46

Tripping for Fault F1	Clearing Time	Zones Lost	Comment
All breakers in both zones trip without time delay	2 cycles	2	Zone 2 tripped unnecessarily

One solution for overcoming this problem is to include the bus sectionalizer circuit breaker auxiliary contact together with the disconnect auxiliary contact as a condition for CT consideration in the differential calculations. With the bus sectionalizer circuit breaker auxiliary contact included in the conditions, the current inputs from the bus sectionalizer CTs are not considered in the differential calculations when the bus sectionalizer circuit breaker is open. In this case, only Zone 1 trips for Fault F1 in *Figure 1.46*.

Including the bus sectionalizer circuit breaker auxiliary contact solves the problem in Network Operating Condition 1. However, Network Operating Condition 2 shows that the busbar protection is still not completely secure, although the conditions for CT consideration in the differential calculations now include the bus sectionalizer circuit breaker auxiliary contact.

Network Operating Condition 2

Figure 1.47 shows the same substation under different operating conditions. The bus sectionalizer circuit breaker auxiliary contact 52A forms part of the conditions for CT consideration in the differential calculations. Although the disconnects are closed, the bus sectionalizer circuit breaker is open and the differential calculations do not consider the bus sectionalizer CT inputs in the differential calculation. Fault F2 in *Figure 1.47* represents grounding straps that were inadvertently left on the busbars in Zone 1. The Feeder 1 circuit breaker is open, and the bus sectionalizing circuit breaker is about to close. *Table 1.27* summarizes the prevailing network operating conditions.

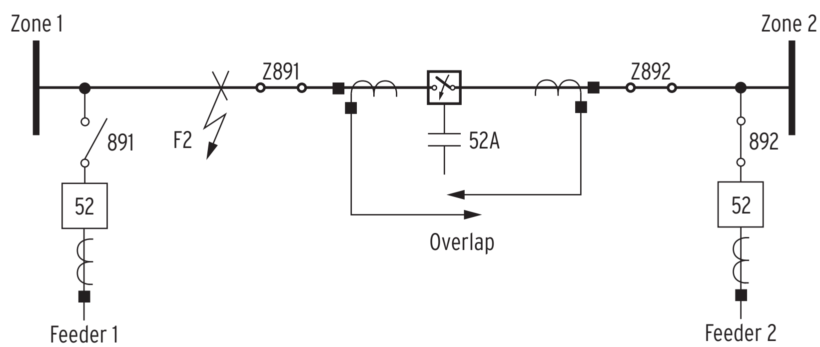

Figure 1.47 Closing the Bus Sectionalizing Circuit Breaker Onto a Faulted Busbar

Table 1.27 Summary of the Events for Fault F2 Shown in Figure 1.47

Station Conditions	Fault Description
Bus sectionalizer Breaker Z closing Both bus sectionalizer disconnects (Z891 and Z892) are closed All Zone 2 feeder breakers and disconnects (892) are closed All Zone 1 feeder disconnects (891) are open	Sectionalizer breaker closes onto Fault F2

If the bus sectionalizing circuit breaker auxiliary contacts are misaligned or fail in such a way that the CTs from the sectionalizer are not considered in the differential calculation at fault inception, the Zone 2 differential elements misoperate. *Table 1.28* summarizes the event.

Table 1.28 Summary of the Event for Fault F2 Shown in Figure 1.47

Tripping for F2	Clearing Time	Zones Lost	Comment
All breakers in Zone 2 trip without time delay (Feeder 2 and Circuit Breaker Z)	2 cycles	1	Incorrect tripping for terminals connected to Zone 2; only terminals connected to Zone 1 (Breaker Z) should have tripped.

Use the coupler security logic (see *Figure 1.48*) in the SEL-487B to prevent relay misoperation for network conditions 1 and 2.

Coupler Security Logic

Inserting the bus sectionalizer CTs into the differential calculations before fault inception prevents relay misoperation for Network Operating Condition 2. *Figure 1.48* shows one of the four coupler security logics available in the relay. Wire a bus sectionalizer auxiliary contact to input CB52A1, and wire the bus sectionalizer circuit breaker closing signal to input CBCLS1. Inputs CB52A1 and CBCLS1 coordinate the bus sectionalizer CT insertion into and removal from the differential calculation. For breaker differential applications, enter CSL1, the output from the coupler security logic, instead of the bus sectionalizer circuit breaker auxiliary contact, as a condition for CT consideration in the differential calculations.

As shown in *Figure 1.48*, the breaker auxiliary contact (CB52A1) and the close signal (CBCLS1) are in parallel. Issuing the close signal to the bus sectionalizer circuit breaker close coil also asserts Relay Word bit CSL1. Timer CBCLD01 maintains the close signal for five cycles (default setting), allowing ample time for the bus sectionalizer circuit breaker auxiliary contact to change state. When Relay Word bit CSL1 asserts, the CTs are immediately considered in the differential calculation. Because the bus sectionalizer CTs are considered in the differential calculation before fault inception, Zone 2 is stable for Network Operating Condition 2.

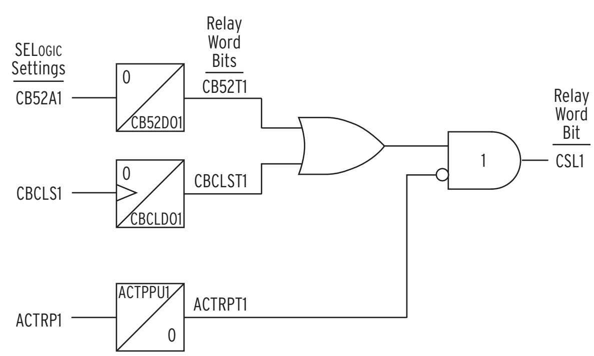

Figure 1.48 Coupler Security Logic for Accelerated Tripping and Busbar Protection Security for Circuit Breaker Auxiliary Contact Misalignment

When the bus sectionalizer circuit breaker trips, misaligned circuit breaker auxiliary contacts can remove the bus sectionalizer CTs from the differential calculation while current still flows through the bus sectionalizer circuit breaker. Timer CB52D01 maintains the status of the bus sectionalizer circuit breaker auxiliary contact as closed for four cycles (default setting) after the contact changes state. During this four-cycle time delay, the bus sectionalizer CTs are still considered in the differential calculation, allowing the bus sectionalizer circuit breaker ample time to interrupt the current.

ACTRP1, the third input into the coupler security logic provides an input to accelerate tripping of the bus sectionalizer circuit breaker for faults between bus sectionalizer circuit breaker and CT. Accelerated tripping operating time is the time period greater than the bus sectionalizer circuit breaker operating time (typically 2 cycles) but shorter than the breaker failure time (typically 6–10 cycles).

Breaker Differential

Figure 1.49 shows an application of breaker differential protection. There are CTs on either side of the bus sectionalizing circuit breaker, and we configure a differential zone of protection across the bus sectionalizing circuit breaker. This is in addition to Zone 1 and Zone 2 of the busbar protection. Any of the six zones may be used for breaker differential protection. Breaker differential protection is a good choice for stations where preservation of supply is more important than a very fast clearing time.

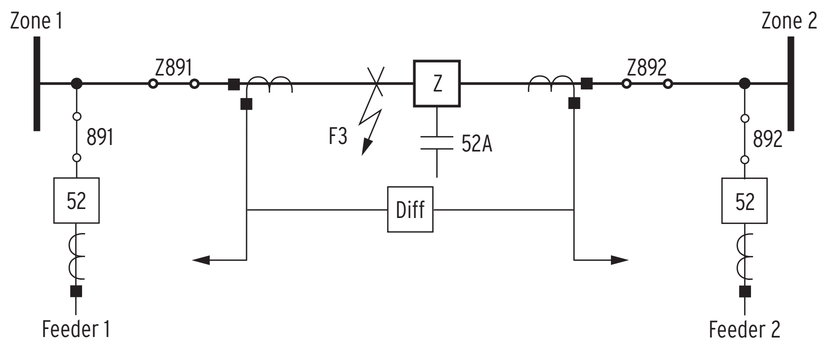

Figure 1.49 CTs on Either Side of the Sectionalizer Circuit Breaker With Breaker Differential Across Breaker Z

We use the coupler security logic (initially without an ACTRP1 input) and consider the relay operation for Fault F3 in *Figure 1.49*. Circuit Breaker Z opens after two cycles, deasserting the input to CB52A1. When Circuit Breaker Z trips, fault current no longer flows from Zone 2, but Zone 1 still contributes to the fault. Four cycles after Circuit Breaker Z trips (CB52D01 default time), Relay Word bit CSL1 deasserts, removing both bus sectionalizing CTs from all three differential elements (breaker differential, Zone 1, and Zone 2). Zone 2 is stable after removing the CTs from the Zone 2 differential calculations because Zone 2 no longer contributes to the fault. However, Zone 1 still contributes to the fault, and removing the CTs from the Zone 1 differential calculations causes the Zone 1 differential elements to operate, clearing the fault. Only one zone is lost, although this loss occurs after a time delay. *Table 1.29* summarizes the events.

Table 1.29 Summary of the Event for Fault F3 Shown in Figure 1.49

Relay and Circuit Breaker Operation for F3	Time Delay	Zones Lost	Comment
Breaker differential (87R3) asserts	1 cycle	0	Typical operating time is 0.75 cycles
Bus sectionalizer trips	2 cycles	0	Correct tripping
Timer CB52A1 expires	4 cycles	0	Relay Word bit CSL1 deasserts, unbalancing Zone 1
SEL-487B operating time	1 cycle	0	Typical operating time is 0.75 cycles
All circuit breakers in Zone 1 trip	2 cycles	1	Total clearing time is 10 cycles

Because Fault F3 is external to Zone 1 and Zone 2, both of these zones are stable for as long as the sectionalizing breaker CTs are considered in the differential calculations. If the sectionalizing breaker fails, both Zone 1 and Zone 2 trip only after breaker failure time.

Function ACTRP1 provides an input for removing the bus sectionalizing CTs sooner. One solution is to assign 87R3, the output from the sectionalizer breaker differential element to input ACTRP1. Relay Word bit 87R3 asserts when there is a fault within the sectionalizer zone. With ACTPPU1 set to 4 cycles, Relay Word bit CSL1 deasserts about 2 cycles after the sectionalizing circuit breaker interrupts the fault current. *Table 1.30* summarizes the events.

Table 1.30 Summary of the Event for Fault F3 Using the Accelerated Trip Function

Relay and Circuit Breaker Operation for F3	Time Delay	Zones Lost	Comment
Breaker differential (87R3) asserts	1 cycle	0	Typical operating time is 0.75 cycles. Timer ACTPPU1 starts timing
Bus sectionalizer trips	2 cycles	0	Correct tripping
Timer ACTPPU1 expires	2 cycles	0	Reduce this setting for faster clearance
SEL-487B operating time	1 cycle	0	Typical operating time is 0.75 cycles
All circuit breakers in Zone 1 trip	2 cycles	1	Total clearing time is 8 cycles

Single CT Application

Figure 1.50 shows the same substation, now with only one CT installed on the bus sectionalizer. The busbar protection is connected in overlap. The challenge for the busbar protection is to distinguish between faults F4 and F5. When Fault F5 occurs, Zone 1 is stable and the Zone 2 protection immediately trips Feeder 2 and the bus sectionalizer circuit breaker. Tripping Feeder 2 and the bus sectionalizer circuit breaker clears Fault F5.

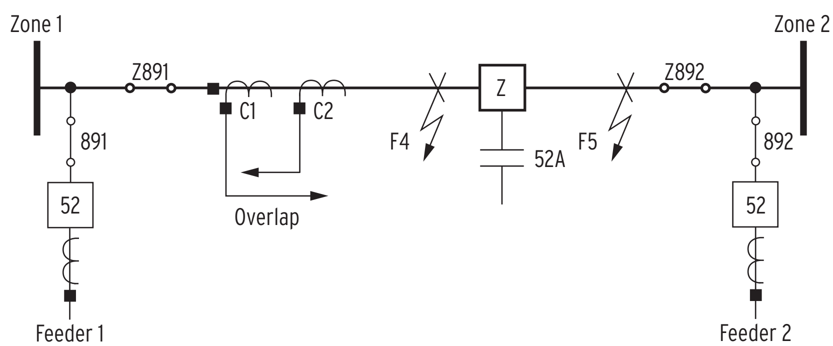

Figure 1.50 Single CT Application With Fault F4 Between the Bus Sectionalizer Circuit Breaker and CT

When Fault F4 occurs, Zone 1 is stable, and, as before, the Zone 2 protection immediately trips Feeder 2 and the bus sectionalizer circuit breaker. Tripping Feeder 2 and the bus sectionalizer circuit breaker, however, does not clear Fault F4, and fault current still flows through the bus sectionalizer CT. At the same time, the busbar protection also initiates breaker failure protection on Feeder 2 and the bus sectionalizer. This fault current causes the breaker failure protection of the bus sectionalizer to continue timing, although the bus sectionalizer circuit breaker tripped. After the bus sectionalizer breaker failure timer times out, all circuit breakers in Zone 1 trip. Both Zone 1 and Zone 2 trip to clear this fault.

If delayed tripping time for Zone 2 busbar faults is in order, use a combination of the zone supervision and coupler security logic to prevent losing both zones. Assign 87R2, the output from the Zone 2 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. Assign the negated output from the coupler security logic (NOT CSL1) to supervise the Zone 2 differential element output (Z2S := NOT CSL1). For single CT applications, enter **CB52A1**, the bus sectionalizer circuit breaker auxiliary contact, as a condition for CT consideration in the differential calculations for the zone supervised by CSL1 (Zone 2 in this case). Then, enter **CB52T1**, the coupler status timed out bit, as a condition for CT consideration in the differential calculations for the unsupervised zone (Zone 1 in this case).

For faults in Zone 2, trip only the bus sectionalizer circuit breaker. After the bus sectionalizer opens, remove the bus sectionalizer CT from the differential calculations of Zone 2. After a set delay of at least 2 cycles (to allow the 87R2 element to reset), remove the Zone 2 supervision and the bus sectionalizer CT from the differential calculations of Zone 1.

When either Fault F4 or Fault 5 occurs, the Zone 2 differential element operates to clear the fault. The Zone 2 zone supervision prevents Relay Word bit 87Z2 from asserting, and only the bus sectionalizer circuit breaker receives a trip signal. The circuit breaker trips two cycles later, removing CT cores C1 and eventually C2 from the differential calculations for Zone 1 and Zone 2.

For Fault F4, the bus sectionalizer circuit breaker is open, but fault current still flows through CT Cores C1 and C2. Removing the bus sectionalizer CTs from all differential calculations prevents Zone 2 from operating (current from CT Core C1 removed) but causes Zone 1 to operate (balancing current from CT Core C2 removed).

For Fault F5, tripping the bus sectionalizer circuit breaker interrupts the fault current contribution from Zone 1, and the Zone 1 differential element is stable. The Zone 2 zone supervision prevents tripping of terminals in Zone 2, until Accelerate Trip Timer ACTRP1 times out. When ACTRP1 times out, coupler security logic output CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, allowing the Zone 2 differential element (87Z2) to operate and issuing a trip signal to all circuit breakers in Zone 2. See *Application 7: Double and Transfer Bus (Outboard CTs) on page A.1.190* for an example.

Table 1.31 shows the coupler security logic default settings for Coupler 1; Couplers 2 through 4 have the same settings.

Table 1.31 Coupler Security Logic Settings (Sheet 1 of 2)

Setting	Setting description	Range	Default Value
CB52A1	Coupler 1 Status (SELOGIC control equation)	SV	NA
CB52DO1	Coupler 1 Status Dropout Delay (0.00–1000 cyc)	0.00–1000	4
CBCLS1	Coupler 1 Close Command (SELOGIC control equation)	SV	NA
CBCLDO1	Coupler 1 Close Command D/O Delay (0.00–1000 cyc)	0.00–1000	5

Table 1.31 Coupler Security Logic Settings (Sheet 2 of 2)

Setting	Setting description	Range	Default Value
ACTRP1	Coupler 1 Acc Trip (SELOGIC control equation)	SV	NA
ACTPPU1	Coupler 1 Acc Trip Pickup Delay (0.00–1000 cyc)	0.00–1000	4

Disconnect Monitor

Disconnect auxiliary contacts provide the zone selection logic with the information required to dynamically assign current inputs to the appropriate differential elements. *Figure 1.51* depicts the logic for Disconnect Logic Circuit 01 in the relay, one of 48 disconnect logic circuits available in the relay. This logic requires both normally open (89A) and/or normally closed (89B) disconnect auxiliary contacts.

Table 1.32 shows the four possible disconnect auxiliary contact combinations, and the way in which the relay interprets these combinations. Applying the principle of (disconnect) NOT OPEN = (disconnect) CLOSED, the relay properly coordinates the primary current flow and the CT current assignment to the appropriate differential element.

Table 1.32 Disconnect 89A and 89B Auxiliary Contact Status Interpretation

Case	89A01	89B01	Disconnect Status (89CL01)
1	0	0	Closed (1)
2	0	1	Open (0)
3	1	0	Closed (1)
4	1	1	Closed (1)

The following description of the contact combinations assumes the disconnect auxiliary contacts are the only conditions declared in the terminal-to-bus-zone variable settings.

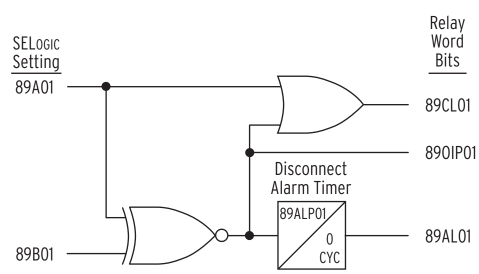

Figure 1.51 Disconnecting Switch Status Logic

Case 1 occurs when disconnect auxiliary contact 89A and auxiliary contacts 89B are open simultaneously. This case is the intermediate position in an open-to-close or close-to-open operation. Timer 89ALP01 times for this condition and asserts Relay Word bit 89AL01 when the disconnect auxiliary contacts remain in the intermediate position for a period exceeding the 89ALP01 timer setting. Relay Word bit 89OIP01 also asserts during this period, indicating a disconnect operation in progress condition. The relay considers the disconnect main contact closed during this period, and the CTs are considered in the differential calculations.

Case 2 is the only combination of disconnect auxiliary contacts for which the relay considers the disconnect main contact to be open. This is also the only combination for which the CTs are not considered in the differential calculations.

NOTE: Use Relay Word bit 89CL01 in SELOGIC control equations when entering the conditions in the terminal-to-bus-zone settings.

Case 3 is the only combination of disconnect auxiliary contacts for which the relay confirms the disconnect main contacts to be closed. Relay Word bit 89CL01 asserts to indicate the main contact close position. The CTs are considered in the differential calculations.

Case 4 is an illegitimate condition, with the disconnect auxiliary contacts showing the disconnect main contact to be open and closed simultaneously. Timer 89ALP01 times for this condition and asserts Relay Word bit 89AL01 when the disconnect auxiliary contacts remain in this condition for a period exceeding the timer setting. The relay considers the disconnect main contact closed during this period, and the CTs are considered in the differential calculations.

The relay includes 48 alarm timers that provide individual time settings for 48 disconnect logic circuits. These individual timers are useful in installations where the disconnect travel times differ substantially. In particular, sequentially operated devices (pantographs, for example) have travel times much longer than normal disconnects.

Relay Word bit 89OIP represents the OR combination of Relay Word bits 89OIP01 through 89OIP48, and Relay Word bit 89AL (not shown) is respectively the OR combination of Relay Word bits 89AL01 through 89AL48.

To ensure correct differential element operation, the contacts must comply with the requirements listed in *Table 1.33*.

Table 1.33 Disconnect Auxiliary Contact Requirements to Ensure Correct Differential Element Operation

Operation	Requirement
From disconnect open to disconnect close operation	Assign the currents to the applicable differential element before the disconnect reaches the arcing point (the point where primary current starts to flow).
From disconnect close to disconnect open operation	Remove the current from the applicable differential element only once the disconnect has passed the arcing point (the point where primary current has stopped flowing).

Figure 1.52 shows the disconnect auxiliary contact requirements with respect to the arcing point.

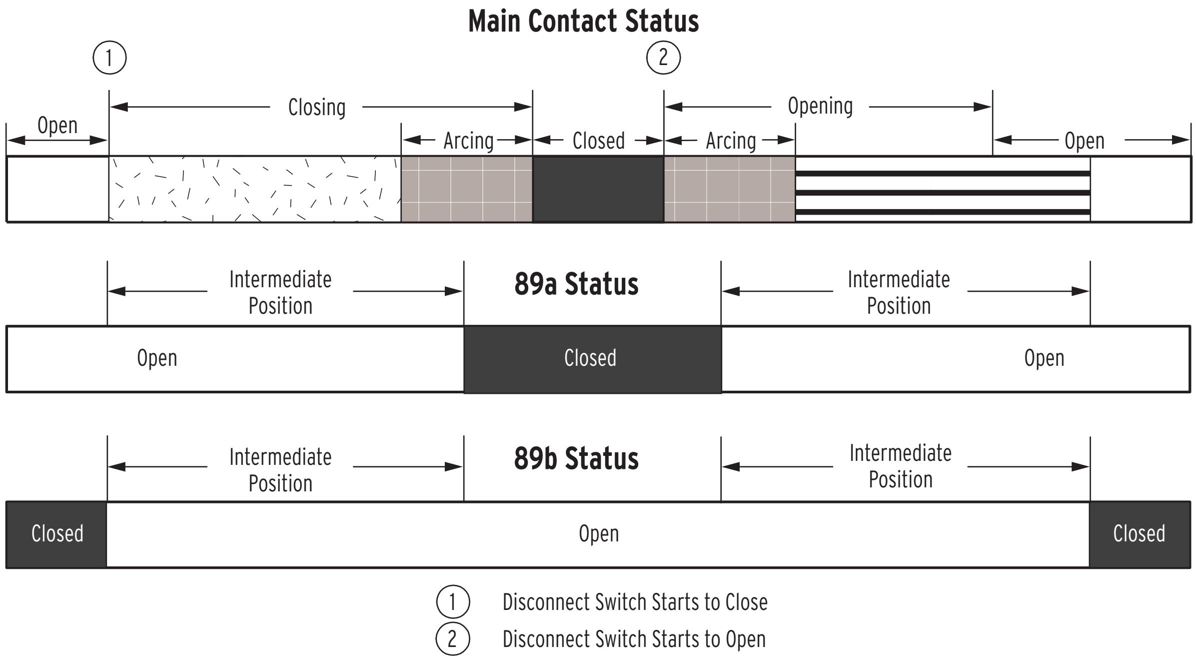

Figure 1.52 Disconnecting Switch Main Contact, 89a, and 89b Status for Open-to-Close and Close-to-Open Conditions

Zone-Switching Supervision Logic

Because the disconnect monitoring logic requires both 89A and 89B disconnect auxiliary contacts, installations with only an 89A (or 89B) contact available cannot use the disconnect monitoring logic. In these installations, there is always uncertainty whether the disconnect auxiliary contact actually changed status. This is important information, because busbar protection will misoperate if input currents are assigned to the incorrect differential elements. Zone-switching supervision logic uses the ZSWOP Relay Word bit (see *Dynamic Zone Selection Logic on page R.1.15*) that asserts for any terminal-to-bus-zone or bus-zone-to-bus-zone change. In other words, the ZSWOP Relay Word bit provides an acknowledgment that the relay has recognized a change in disconnect auxiliary contact status. *Figure 1.53* shows the logic.

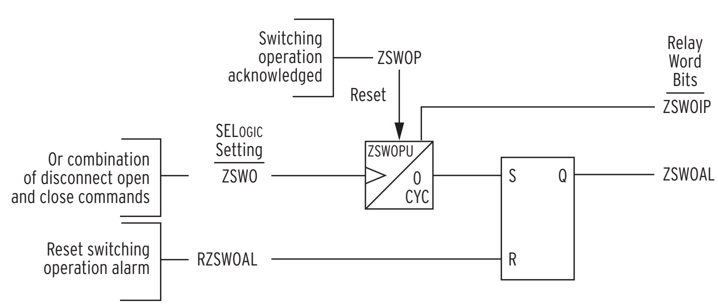

Figure 1.53 Zone-Switching Supervision Logic

Asserting Relay Word bit ZSWO activates the logic, the rising edge of ZSWO starting timer ZSWOPU, and asserts the ZSWOIP bit for the period when the timer is timing. When the zone selection logic acknowledges a change in disconnect status, the ZSWOP Relay Word bit asserts and resets the timer. If the Zone Selection does not acknowledge the switching operation within the

ZSWOPU time setting, the logic asserts the switching operation alarm ZSWOAL. SELOGIC control equation RZSWOAL provides the input to reset the alarm.

There is only one zone-switching supervision logic in the relay; disconnect open and close commands must be combined externally to the relay for electrically operated disconnects, as shown in *Figure 1.54*.

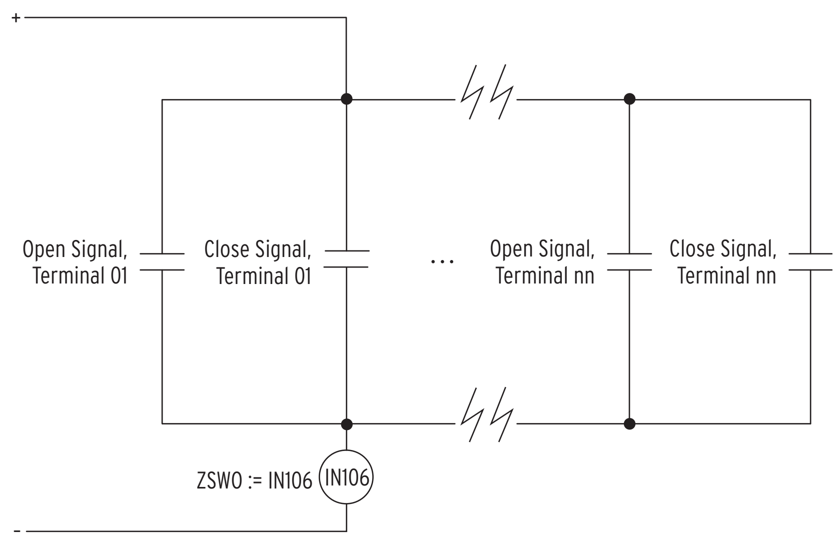

Figure 1.54 External Wiring and Initiation Input for Zone-Switching Supervision

For manually operated disconnects, configure one of the SEL-487B front-panel pushbuttons as an input to assert the ZSWO Relay Word bit. Timer ZSWOPU has a range of more than 27 minutes, allowing ample time for the operating procedures. *Table 1.34* shows zone-switching supervision logic default settings.

Table 1.34 Zone-Switching Supervision Logic Default Settings

Setting	Setting Description	Range	Default Value (Cycles)
EZSWSUP	Enable Zone Switching Supervision	Y or N	N
ZSWO	Zone Switching Operation	SV	NA
RZSWOAL	Reset Zone Switching Op. Alarm	SV	NA
ZSWOPU	Zone Switching Operation Pickup Delay	0–99999 cyc	1800

Differential Trip Logic

This is the final stage of the differential trip output. *Figure 1.55* is the Bus-Zone portion of *Figure 1.19* from the zone supervision logic. At this point, the differential element has operated (87R1), and all supervising criteria are met (Z1S). The differential trip logic now acquires all Zone 1 terminals and generates a trip output to the appropriate breakers.

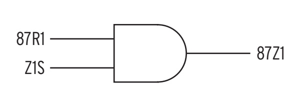

Figure 1.55 Differential Element Zone Supervision for Zone 1

Figure 1.56 shows the processing sequence for tripping the breakers as a function of the differential element operation, 87Z*n*, where *n* = 1 through 6.

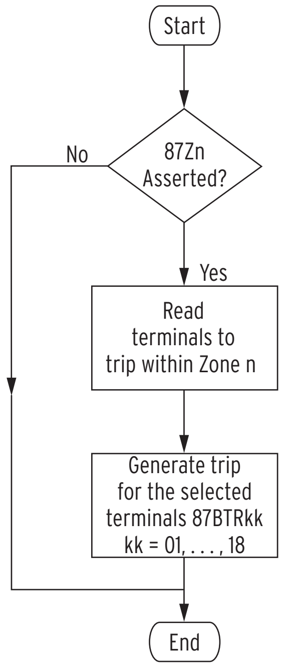

Figure 1.56 Bus Differential Trip Logic

The differential trip logic asserts differential trips as shown in *Table 1.35*.

Table 1.35 Differential Trips

Terminal Within a Zone	Differential Trip Bit
I01	87BTR01
I02	87BTR02
I03	87BTR03
104	87BTR04
105	87BTR05
106	87BTR06
107	87BTR07
108	87BTR08
109	87BTR09
110	87BTR10
I11	87BTR11
I12	87BTR12
I13	87BTR13
I14	87BTR14
I15	87BTR15
I16	87BTR16
I17	87BTR17
I18	87BTR18

Check Zone Differential Trip Output

This is the final stage of the check zone differential trip output. *Figure 1.57* is the check zone portion of *Figure 1.19 on page R.1.14* from the zone supervision logic. At this point, the Check Zone Differential Element has operated (87RCZ1), and all supervising criteria are met (CZ1S). The supervised trip output is then asserted (87CZ1). The check zone output is independent of the bus zones and is not processed by the differential trip logic shown in *Figure 1.56*.

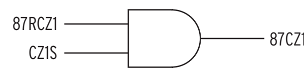

Figure 1.57 Differential Element Zone Supervision for Check Zone

Breaker Trip Logic

NOTE: In the trip logic, the set or latch function (TRkk) has priority over the reset or unlatch (ULTRkk) function (kk = 1–18).

Figure 1.58 shows the tripping logic for Terminal 01 in the SEL-487B. The remaining logic for Terminal 02 through Terminal 18 is identical and uses variables TR02 through TR18 and ULTR02 through ULTR18, and TRIP02 through TRIP18, respectively.

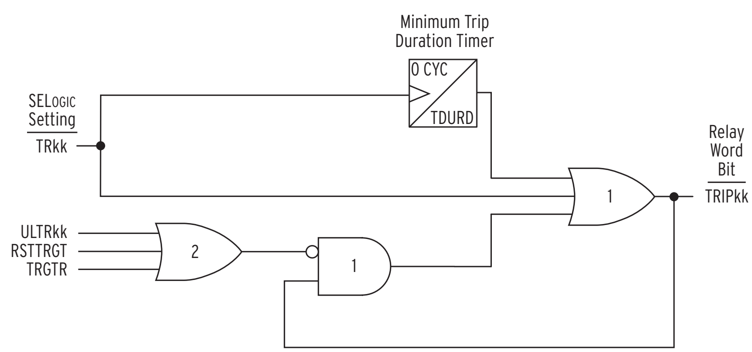

Figure 1.58 Trip Logic for Breaker 1

Enable the trip logic settings by setting the global setting NUMBK = *kk*, where *kk* is the number of breakers at the station. For example, if you have 12 terminals installed at a substation, set NUMBK = 12.

Asserting TR01 directly asserts TRIP01 via input OR Gate 1 and starts the Minimum Trip Duration Timer (TDURD). TRIP01 asserts for a minimum of TDURD cycles, even if TR01 is asserted for as little as one processing interval, or if the unlatch portion of the logic is asserted before TDURD expires. The default setting of TDURD is twelve cycles.

TRIP01 also seals itself in via AND Gate 1. This AND gate receives the negated inputs from the unlatching functions. As long as ULTR01 or TRGTR are not asserted, TRIP01 remains sealed in. TRIP01 is used to drive an output contact to initiate tripping of the breaker.

You can use one of four methods to unlatch the trip logic. One method is to assert either one of SELOGIC control equation setting ULTR01 or SELOGIC control equation setting RSTTRGT. You can also push the **{TARGET RESET}** pushbutton on the front panel or send the **TAR R** serial port command to assert Relay Word bit TRGTR. Relay Word bit TRGTR also resets the LED targets on the front panel. In the trip logic, assertion of ULTR01, RSTTRGT, or TRGTR places a zero input on AND Gate 1 and, thereby, breaks the TRIP01 seal-in loop.

Note that TRIP01 is always asserted when TR01 is asserted, regardless of the action of ULTR01 or the **TARGET RESET** commands, and that TRIP01 will be asserted for a minimum of TDURD cycles no matter how short the length of time TR01 has been asserted.

Circuit Breaker Status Logic

Figure 1.59 shows the circuit breaker status logic, which uses the combination of breaker 52A (normally open) auxiliary contact and the open phase detection function, OPH. Because 52B (normally closed) contacts are not always available and as a means to reduce the number of I/O required, the 52B contacts are not required in the logic. However, for applications where the protection philosophy requires a 52B (normally closed) contact, wire the 52B contact into the relay, but use the negated form of the 52B contact in the logic, i.e., NOT 52B (52A01: = NOT IN301).

Relay Word bits 52CL01 through 52CL18 assert when the breaker is closed. Open phase detection logic (OPH*nn*) Relay Word bits are included in the circuit breaker status logic to guard against delayed breaker status declaration resulting from possible breaker auxiliary contact misalignment. If a discrepancy between the open phase detection logic and the breaker auxiliary contact exists for as long as five cycles, the logic generates an alarm that indicates one of the following:

- ➤ Possible auxiliary contact supply voltage failure
- ➤ Possible failure in an auxiliary contact connection circuit
- ➤ Possible failure of auxiliary contact mechanism

The logic in *Figure 1.59* is generic for three-pole or single-pole breaker mechanisms.

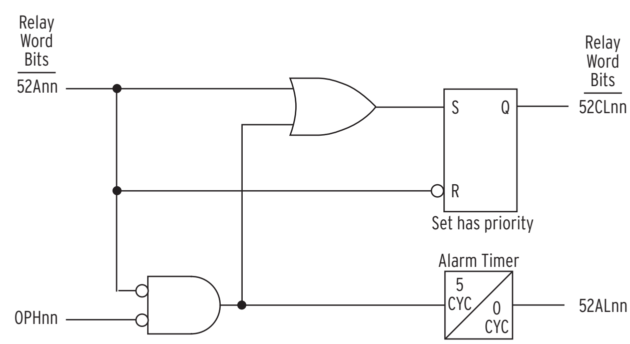

Figure 1.59 Breaker Status and Alarm Logic

Note that OPH*nn* Relay Word bits assert when no current flows through the circuit breaker, and that set has priority over reset in the circuit breaker status logic. *Table 1.36* shows the output states for all possible breaker conditions.

Table 1.36 Conditions and Results for the Circuit Breaker Status Logic

Breaker Status	52A01 or NOT 52B01	OPH01	52CL01	52AL01
Open	0	1 (no current)	0	0
Closed	1	1 (no current)	1	0
Open	0	0 (current flow)	1	1 (after 5 cyc)
Closed	1	0 (current flow)	1	0

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Section 2

SELOGIC Control Equation Programming

Overview

This section describes the use of SELOGIC® control equation programming to customize relay operation and automate substations. This section covers the following topics:

- SELOGIC control equation elements
- SELOGIC control equation operators
- Guidelines for effective SELOGIC control equation programming
- SELOGIC control equations for users of SEL-300 series relays

SELOGIC Control Equation History

SEL introduced SELOGIC control equations in the SEL-300 series relays to provide relay operation customization. SELOGIC control equations in the SEL-487B Relay provide both protection application flexibility and a platform for substation automation.

SELOGIC control equation programming in the SEL-487B includes several features and capabilities not included in SEL-300 series relays. The new features with a brief description are listed in *Table 2.1*.

Table 2.1 Advanced SEL-487B SELOGIC Control Equation Features

Feature	Description
Protection/automation separation	Segregation of protection and automation work and settings
Free-form logic	Custom logic operation and execution order
Comments	Documentation of SELOGIC control equations within the equation
Math operations	Calculations for automation or extended protection functions
Sequencing timers	Additional timers designed for sequencing automated operations
Counters	Increased sophistication in custom protection and automation programming
Aliases	Custom programming is more readable when you rename up to 200 analog or digital quantities

Use SELOGIC control equations in the SEL-487B to customize protection operation, create custom protection elements, and automate substation operation. The SEL-487B introduces several advanced programming features, operators, and methods. *Table 2.2* is a summary that compares SELOGIC control equation programming in SEL-351 and SEL-311 series relays with the SEL-487B.

Table 2.2 SEL-487B SELOGIC Control Equation Programming Summary

Element	SEL-351/ SEL-311 Series	SEL-487B	
		Protection Free Form	Automation Free Form
SELOGIC control equation variables	16	64	256
SELOGIC math variables	0	64	256
Conditioning timers[a]	16	16	0
Sequencing timers	0	32	32
Counters	0	32	32
Latch bits	16	32	32

[a] Similar to SEL-300 series relay SELOGIC control equation programming.

Separation of Protection and Automation Areas

The SEL-487B acts as a protective relay and as a node in distributed substation automation. The relay collects data, coordinates inputs from many interfaces, and automatically controls substation equipment. The relay performs protection and automation functions but keeps programming of these functions separate. For example, someone modifying or testing a station restoration system created in automation programming should not be able to corrupt programming for protection tasks. Similarly, extended protection algorithms must operate at protection speeds unaffected by the volume of automation programming.

The SEL-487B contains several separate programming areas discussed in *SELOGIC Control Equation Setting Structure on page R.2.6*. Separate access levels and passwords control access to each programming area and help eliminate accidental programming changes. For example, use Access Level P to modify protection configuration and protection free-form SELOGIC control equation programming and Access Level A to access automation programming.

NOTE: If you want unlimited access to both automation and protection configuration and programming, log in to Access Level 2.

NOTE: Be careful how you combine automation variables and protection variables. The relay updates protection variables every twelfth of a cycle but updates the automation variables much less often (within a one-second period).

Protection and automation areas must interact and exchange information. Protection and automation interact and exchange information through separate storage areas (variables) for results of automation and protection programming. The relay combines the results in the output settings that drive automation storage areas as illustrated in *Figure 2.1*.

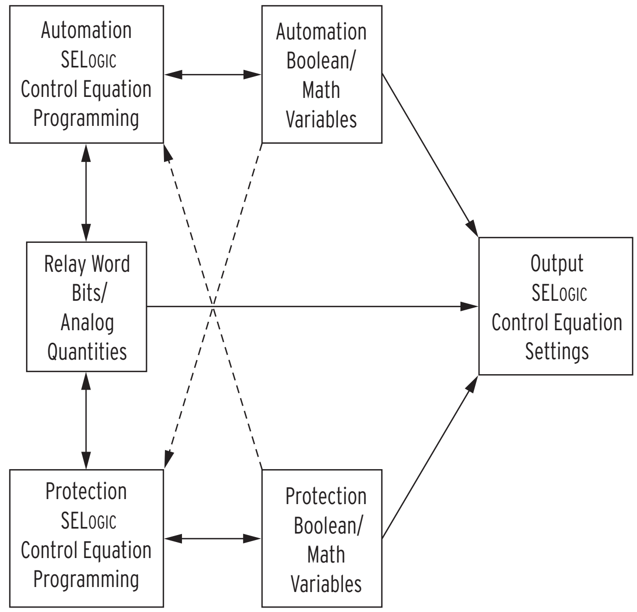

Figure 2.1 Protection and Automation Separation

Figure 2.1 illustrates how the SEL-487B keeps protection and automation programming separate while still exchanging information. The arrows indicate data flow between components. The Relay Word Bits and Analog Quantities are visible to protection, automation, and output programming. Protection programming uses the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables as inputs, but only writes and stores information to the Protection Variables. Similarly, automation programming uses data from all parts of the relay, but only stores data in the Automation Variables.

The Output SELOGIC control equation settings use the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables to control outputs and other information leaving the relay. Use the output settings to create a custom combination of the results of protection and automation operations. For example, an OR operation will activate an output when protection or automation programming results necessitate activating the output. You can use more complicated logic to supervise control of the output with other external and internal information. For example, use a command from the SCADA master to supervise automated control of a motor-operated disconnect in the substation.

SELOGIC Control Equation Programming

There are two major areas where the SEL-487B uses SELOGIC control equations. First, fixed SELOGIC control equations define the operation of fixed protection elements or outputs. As with SEL-300 series relay programming, protection programming and outputs use fixed SELOGIC control equations. Second, you can use free-form SELOGIC control equations for free-form programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

Fixed SELOGIC Control Equations

Fixed result SELOGIC control equations are equations where the left side (result storage location), or LVALUE, is fixed. Programming in SEL-300 series relays consists of all fixed SELOGIC control equations. Fixed equations include protection and output settings that you set with SELOGIC control equations.

SEL-487B fixed SELOGIC control equations are Boolean equations. Fixed result control equations can be as simple as a single element reference (for example PSV01) or can include a complex equation. An example of fixed programming is shown in *Example 2.1*.

EXAMPLE 2.1 Fixed SELOGIC Control Equations

The following equations are examples of fixed SELOGIC control equations for relay Output OUT101. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

OUT101 := **1** # Turn on OUT101

OUT101 := **NA** # Do not evaluate an equation for OUT101

OUT101 := **OUT102 AND RB02** # Turn on OUT101 if OUT102 and RB02 are on

Fixed SELOGIC control equations include expressions that evaluate to a Boolean value, True or False, represented by a logical 1 or logical 0.

OUT101 := **PSV04** # Turn on OUT101 if protection PSV04 is on

More complex programming in the free-form area controls OUT101. The result of free-form programming is available as an element in a fixed equation.

OUT101 := **AMV003 > 5** # Turn on OUT101 if AMV003 is greater than 5

While you cannot perform mathematical operations in fixed programming, you can perform comparisons on the results of mathematical operations performed elsewhere.

Free-Form SELOGIC Control Equations

Free-form SELOGIC control equations provide advanced relay customization and automation programming. There are free-form SELOGIC control equation programming areas used for protection and automation. You can use free-form SELOGIC control equation programming to enter sequential program steps that the relay will execute in the order you specify. You can refer to storage locations multiple times and build up intermediate results in successive equations. You can also enter comment lines to help document programming. Mathematical operations are available only in free-form SELOGIC control equation programming areas. An example of free-form SELOGIC control equation programming is shown in *Example 2.2*.

EXAMPLE 2.2 Free-Form SELOGIC Control Equations

The following equations are examples of free-form SELOGIC control equations. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

Free-form equation example programming

#

Is 80% of A-phase fundamental voltage greater than 12 kV

PMV01 := **V01FM * 0.8** # 80% of V01 input voltage

PSV04 := **PMV01 >= 12** # True if A-phase fundamental voltage is greater than or equal to 12000

Use comments to group settings in the free-form SELOGIC control equations by task and to document individual equations. In this example, an intermediate calculation generates the value we want to test to determine if PSV04 will be turned on.

Assignment Statements

Both fixed and free-form SELOGIC control equations are a basic type of computer programming statement called an assignment statement. Assignment statements have a basic structure similar to that shown below:

LVALUE := Expression

Starting at the left, the LVALUE is the location where the result of an evaluation of the expression on the right will be stored. The := symbol marks the statement as an assignment statement and provides a delimiter or separator between the LVALUE and the expression. Type the **:=** symbol as a colon and equal sign. The assignment symbol is different than a single equal sign, =, to avoid confusion with a logical comparison between two values. The type of LVALUE must match the result of evaluating the expression on the right. The following discussion provides more detail.

There are two basic types of assignment statements that form SELOGIC control equations. In the first type, Boolean SELOGIC control equations, the SEL-487B evaluates the expression on the right to a result that is a logical 1 or a logical 0. The LVALUE must be some type of Boolean storage location or setting that requires a Boolean value. For example, the setting for the Protection Conditioning Timer 7 Input, PCT07IN, requires a value of 0 or 1, which you set with a Boolean SELOGIC control equation.

The second type is a math SELOGIC control equation. Use the math SELOGIC control equation to perform numerical calculations on data in the relay. For example, in protection free-form programming, enter **AMV034 := 5 * I01FIM** to store the product of 5 and the Terminal 01 current in automation math variable AMV034. *Example 2.3* lists several examples of Boolean and math SELOGIC control equations.

EXAMPLE 2.3 Boolean and Math SELOGIC Control Equations

The equations below are examples of Boolean SELOGIC control equations.

Example Boolean SELOGIC control equations

PSV01 := **IN101** # Store the value of IN101 in PSV01

PSV02 := **IN101 AND RB03** # Store result of logical AND in PSV02

PST01IN := **IN104** # Use IN104 as the input value for PST01

PSV03 := **PMV33 >= 7** # Set PSV03 when PMV33 is greater than or equal to 7

The lines below are examples of math SELOGIC control equations.

Example math SELOGIC control equations

PMV01 := **5** # Store the constant 5 in PMV01

PMV02 := **0.5 * V01FM** # Store the product of V01 voltage and 0.5 in PMV02

Comments

Include comment statements in SELOGIC control equations to help document SELOGIC control equation programming. You can start a comment anywhere in a SELOGIC control equation with the # character. The comment then continues to the end of the line. If you begin a SELOGIC control equation with a comment character, then the entire line is a comment.

NOTE: During troubleshooting or testing, reenter a line and insert the comment character to disable it. Enter the line without the comment character to enable the line later when you want it to be executed.

Comments are a powerful documentation tool for helping both you and others understand the intent of programming and configuration in the SEL-487B. Use comments liberally; comments do not reduce SELOGIC control equation execution capacity.

SELOGIC Control Equation Setting Structure

The SEL-487B uses SELOGIC control equations in three areas: protection programming, automation programming, and output programming. First, you can customize protection operations with SELOGIC control equation settings and free-form programming. Second, automation contains a free-form programming area for more sophisticated SELOGIC control equation programming. Third, output programming contains a fixed area for relay output programming. The SELOGIC control equation programming areas are shown in *Figure 2.2*.

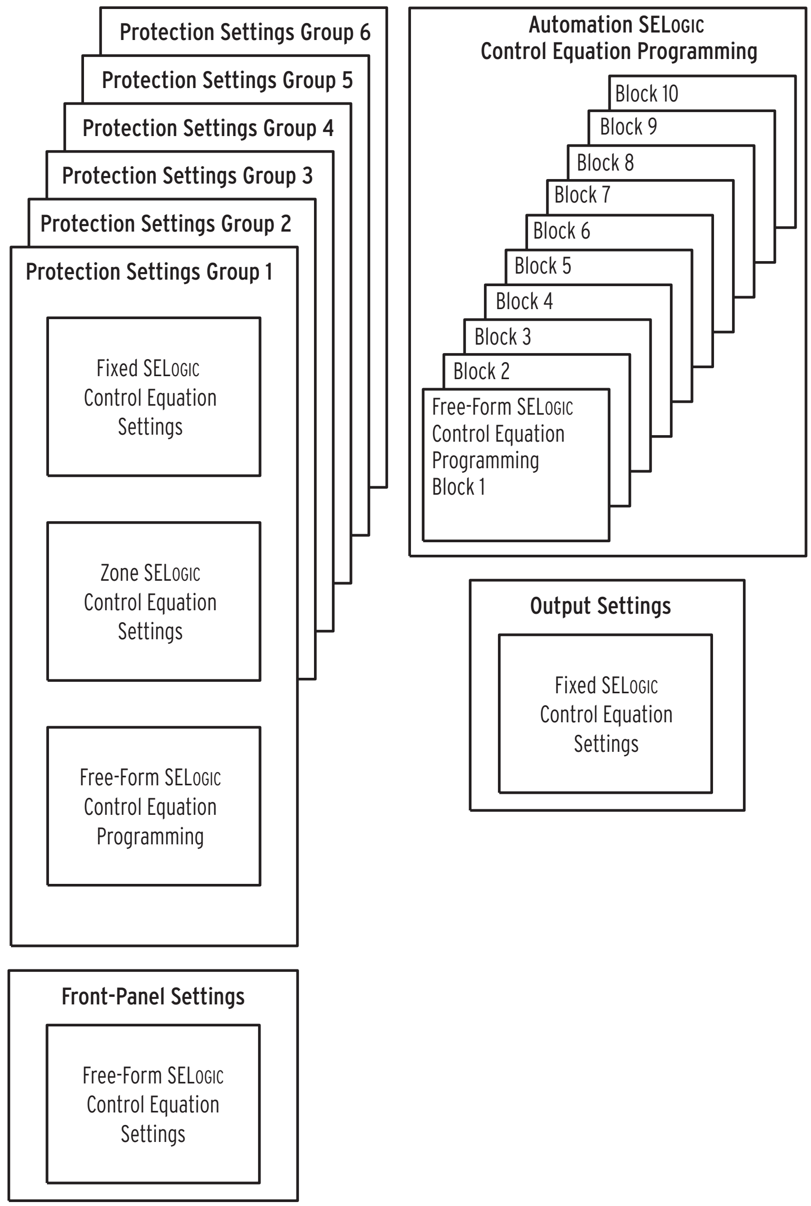

Figure 2.2 SELOGIC Control Equation Programming Areas

Protection

Protection SELOGIC control equation programming includes a fixed area and a free-form area. You can configure many protection settings within the relay with fixed SELOGIC control equation programming. Use these settings to control protection operation and customize relay operation. Programming of fixed SELOGIC control equations in this area is very similar to programming in SEL-300 series relays.

There is a free-form SELOGIC control equation programming area associated with protection. Because this area operates at the protection processing interval along with protection algorithms and outputs, use this area to extend and customize protection operation. Protection free-form SELOGIC control equation programming includes a complete set of timers, counters, and variables.

For all protection settings, including protection SELOGIC control equation programming, there are six groups of settings that you activate with the protection settings group selection. Only one group is active at a time. When you switch groups, for example, you can activate completely different programming that corresponds to the conditions indicated by the active group. If you want the programming to operate identically in all groups, develop the settings in one group and copy these to all groups. You can copy settings using the **COPY** command documented in *Section 7: ASCII Command Reference*. You can also perform cut-and-paste operations in the ACSELERATOR QuickSet® SEL-5030 software.

NOTE: Perform operations that are not time critical in automation SELOGIC control equation programming. You can use this automation to reduce the demand and complexity of protection SELOGIC control equation programming.

Perform time-critical tasks with protection free-form SELOGIC control equations. For example, if you require a SELOGIC control equation for TR01 (Terminal 01 trip) that contains more than 30 elements, you must perform that calculation in several steps. Because detection of a TR01 condition is a time-critical activity, perform the calculation with protection free-form SELOGIC control equations and set TR01 to the protection SELOGIC control equation variable that contains the result.

Automation

Automation SELOGIC control equation programming is a large free-form programming area that consists of 10 blocks. The relay executes each block sequentially from the first block to the last. You do not need to fill a block completely or enter any equations in a block before starting to write SELOGIC control equations in the following blocks.

NOTE: Organize automation SELOGIC control equation programming into blocks based on function. It is easier to edit and troubleshoot small partially filled blocks that contain related programming.

Use automation SELOGIC control equation programming to automate tasks that do not require time-critical, deterministic execution. For example, if you are coordinating control inputs from a substation HMI and SCADA master, use automation free-form SELOGIC control equations and set the output contact setting to the automation SELOGIC control equation variable that contains the result.

Outputs

To provide protection and automation area separation, the output settings are in a fixed SELOGIC control equation area separate from protection and automation programming. You can take advantage of this separation to combine protection and automation in a manner that best fits your application. Outputs include the relay control outputs, outgoing MIRRORED BITS® points, and communications card control points. The relay executes output logic and processes outputs at the protection processing interval.

Multiple Setting Groups

The SEL-487B has six (6) independent setting groups, as shown in the left-hand side of *Figure 2.2 on page R.2.6*. Each setting group has complete relay settings and protection SELOGIC settings. The active setting group can be:

- ➤ Shown or selected with the SEL ASCII serial port **GROUP** command—see *GROUP on page R.7.16*.
- ➤ Shown or selected with the MAIN menu Set/Show menu item and the Active Group submenu item as described in *Figure 5.10 on page U.5.10*.
- ➤ Selected with SELOGIC control equation settings SS1 through SS6. Settings SS1 through SS6 have priority over all other selection methods. Use remote bits in these equations to select setting groups with Fast Operate commands as described in *SEL Fast Meter, Fast Operate, and Fast SER Messages on page R.4.8*.
- ➤ Shown with DNP3 Objects 20 and 22 as described in *Table 5.10 on page R.5.18* and selected with Objects 40 and 41.

Settings Groups: Application Ideas

Setting groups can be used for such applications as:

- ➤ Environmental conditions such as winter storms, periods of high summer heat, etc.
- ➤ Hot-line tag that disables closing and sensitizes protection
- ➤ Commissioning and operation

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1 through SG6 indicate the active setting group, as shown in *Table 2.3*.

Table 2.3 Definitions for Active Setting Group Indication Relay Word Bits SG1 Through SG6

Relay Word Bit	Definition
CHSG	Indication that a group switch time is operating, or a group switch change is underway
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group
SG5	Indication that setting Group 5 is the active setting group
SG6	Indication that setting Group 6 is the active setting group

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Active Setting Group Selection

The Global settings class contains the SELOGIC control equation settings SS1 through SS6, as shown in *Table 2.4*.

NOTE: The settings group switching settings are checked once per cycle. When setting TGR := 0, in order for a transient assertion to be recognized, it should be conditioned to remain asserted for at least one cycle.

Table 2.4 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1 Through SS6

Setting	Definition
SS1	go to (or remain in) setting Group 1
SS2	go to (or remain in) setting Group 2
SS3	go to (or remain in) setting Group 3
SS4	go to (or remain in) setting Group 4
SS5	go to (or remain in) setting Group 5
SS6	go to (or remain in) setting Group 6

The operation of these settings is explained in the following example:

Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group.

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6. With settings SS1 through SS6 all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR (global settings):

TGR	Group Change Delay Setting	(settable from 0 to 54000 cycles)

NOTE: The CHSG Relay Word bit does not operate for settings changes initiated by the serial port or front-panel methods.

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group. Relay Word bit CHSG asserts when the TGR time is picked-up and time, and also when a setting group change has been initiated.

Active Setting Group Changes

The SEL-487B is disabled for less than 1 second while in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in the specific logic description. For example, local bit (LB01 through LB32), remote bit (RB01 through RB32), and latch bit (PLT01 through PLT32) states are retained during an active setting group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group.

After a group change, an automatic message will be sent to any serial port that has setting AUTO := Y.

Active Setting: Nonvolatile State

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, the same setting group is active when power is restored.

Settings Change

If individual settings are changed for the active setting group or one of the other setting groups, the active setting group is retained, much like in the preceding explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group, so the relay is not momentarily disabled.

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1 through SS6, the active setting group can be changed, subject to the newly enabled SS1 through SS6 settings.

SELOGIC Control Equation Capacity

SELOGIC control equation capacity is a measure of how much remaining space you have available for programming. In both protection and automation, SELOGIC control equation capacity includes execution capacity and settings storage capacity. A single free-form protection or automation SELOGIC setting can have up to 30 elements (terms) with a 512-character maximum.

The relay will reject any setting that exceeds the available settings storage capacity and execution capacity. You can then accept the previous settings you have entered and examine your settings.

Protection

The SEL-487B provides storage space for as many as 100 lines of protection free-form programming. Because the relay executes protection fixed and free-form logic at a deterministic interval, there is a limit to the amount of SELOGIC control equation programming that the relay can execute. The relay calculates total capacity in terms of settings capacity and execution capacity.

Rather than limit parameters to guarantee that your application does not exceed the maximum processing requirements, the relay measures and calculates the available capacity when you enter SELOGIC control equations. The relay will not allow you to enter programming that will cause the relay to be unable to complete all protection SELOGIC control equations each protection processing interval.

There are six protection settings groups that can be active. When a protection settings group is active, the relay executes SELOGIC control equations in the Global Settings, Zone Configuration Settings, Protection Group Settings, Protection Free-Form Settings, Output Settings, and several other settings areas. The relay calculates protection capacities based on the total amount of SELOGIC control equation programming executed when the protection settings group is active. Use the **STATUS S** command to display the remaining settings capacity and execution capacity for protection fixed and free-form logic.

Automation

The SEL-487B provides storage space for 10 blocks of as many as 100 lines of automation free-form programming in each block. The relay executes automation programming differently than protection logic programming. The result is that automation free-form logic execution time varies with the amount of free-form logic expressions that you enter. As you enter more expressions, the time required for the relay to execute all expressions increases. You can display the peak and average execution time using the **STATUS S** command.

There is a maximum execution capacity and settings storage capacity. If you enter a setting that exceeds maximum capacity, the relay will reject the setting. You will have the opportunity to reenter the setting or save any other settings you entered during that session.

SELOGIC Control Equation Elements

SELOGIC control equation elements are a collection of storage locations, timers, and counters that you can use to customize the operation of your SEL-487B and use the relay to automate substation operation. The elements that you can use in SELOGIC control equations are summarized in *Table 2.5*.

Table 2.5 Summary of SELOGIC Control Equation Elements

Element	Description
Relay Word bits	Boolean value data
Analog quantities	Received, measured, and calculated values
Special condition bits	Bits that indicate special SELOGIC control equation execution conditions
SELOGIC control equation variables	Storage locations for the results of Boolean SELOGIC control equations
SELOGIC control equation math variables	Storage locations for the results of math SELOGIC control equations
Latch bits	Nonvolatile storage for the results of Boolean SELOGIC control equations
Conditioning timers	Pickup and dropout style timers similar to those used in SEL-300 series relays
Sequencing timers	On-delay timers similar to those used in programmable logic controllers
Counters	Counters that count rising edges of Boolean value inputs

Relay Word Bits and Analog Quantities

Data within the relay are available for use in SELOGIC control equations. Relay Word bits are binary data that include protection elements, input status, and output status. *Appendix A: Relay Word Bits* contains a list of Relay Word bits available within the SEL-487B. Analog quantities are analog values within the relay including measured and calculated values. *Appendix B: Analog Quantities* contains a list of analog quantities available within the SEL-487B.

Special Condition Bits

Several Relay Word bits are available for special conditions related to SELOGIC control equation programming in the SEL-487B. You can use these bits in SELOGIC control equation programming to react to these conditions. You can also send these bits to other devices through relay interfaces including MIRRORED BITS communications and DNP3. The special condition bits are shown in *Table 2.6*.

The relay sets the first execution bits AFRTEXA, AFRTEXP, and PFRTEX momentarily to allow you to detect changes in the relay operation. The relay sets these bits and clears them as described in *Table 2.6*, *Table 2.7*, and *Table 2.8*. You can use these bits to force logic and calculations to reset or take a known state on power up or settings change operations.

Table 2.6 First Execution Bit Operation on Power Up

Name	Description
AFRTEXA	Relay sets on power up and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on power up. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on power up. Relay clears after protection runs for one cycle.

Table 2.7 First Execution Bit Operation on Automation Settings Change

Name	Description
AFRTEXA	Relay sets on settings change and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on settings change. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on settings change. Relay clears after protection runs for one cycle.

Table 2.8 First Execution Bit Operation on Protection Settings Change and Group Switch

Name	Description
AFRTEXA	Relay does not set.
AFRTEXP	Relay sets when listed event occurs. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets when listed event occurs. Relay clears after protection runs for one cycle.

SELOGIC Control Equation Variables

SELOGIC control equation variables are Boolean storage locations. Each variable equals either logical 1 or logical 0. This manual refers to these variables and the relay displays these as 1 and 0, respectively. Think also of the states 1 and 0 as True and False when you evaluate Boolean logic statements. The quantities of SELOGIC control equation variables available in the different programming areas are listed in *Table 2.9*.

Table 2.9 SELOGIC Control Equation Variable Quantities

Type	Quantity	Name Range
Protection SELOGIC control equation variables	64	PSV01–PSV64
Automation SELOGIC control equation variables	256	ASV001–ASV256

Use the SELOGIC control equation variables in free-form logic statements in any order you want. Use a SELOGIC control equation variable more than once in free-form logic programming, and use SELOGIC control equation variables as arguments in SELOGIC control equations. *Example 2.4* illustrates SELOGIC control equation variable usage.

EXAMPLE 2.4 SELOGIC Control Equation Variables

The equations below show free-form SELOGIC control equation programming examples that use SELOGIC control equation variables. Each line has a comment after the # that provides additional detail.

PSV01 := **1** # Set PSV01 to 1 always

PSV09 := **PSV54 AND ASV005** # Set to result of Boolean AND

PSV02 := **PMV05 > 5** # Set if PMV05 is greater than 5

You can use SELOGIC control equation variables more than once in free-form programming. The SELOGIC control equations below use ASV100 and ASV101 to calculate intermediate results.

Remote control 1

ASV100 := **RB14 AND ALT01** # Supervise remote control with ALT01

ASV101 := **RB15 AND PLT07** # Supervise remote control with PLT07

ASV201 := **ASV100 OR ASV101** # Store desired control in ASV201

Remote control 2

ASV100 := **RB18 AND ALT09** # Supervise remote control with ALT09

ASV101 := **RB19 AND PLT13** # Supervise remote control with PLT13

ASV202 := **ASV100 OR ASV101** # Store desired control in ASV202

SELOGIC Control Equation Math Variables

SELOGIC control equation math variables are math calculation storage results. As with protection and automation SELOGIC control equation variables, there are separate storage areas for protection and automation math calculations. The quantities of SELOGIC control equation math variables available in the SEL-487B are shown in *Table 2.10*.

Table 2.10 SELOGIC Control Equation Math Variable Quantities

Type	Quantity	Name Range
Protection SELOGIC control equation math variables	64	PMV01–PMV64
Automation SELOGIC control equation math variables	256	AMV001–AMV256

Use math variables in free-form programming to store the results of math calculations as arguments in math calculations and comparisons. *Example 2.5* illustrates SELOGIC control equation math variable usage.

EXAMPLE 2.5 SELOGIC Control Equation Math Variables

The equations below show free-form SELOGIC control equation programming examples that use SELOGIC control equation math variables. Each line has a comment after the # that provides additional description.

PMV01 := **378.62** # Store 387.62 in PMV01

PMV09 := **5 + V01FM** # Store sum of 5 and input V01 voltage in kV in PMV09

You can use SELOGIC control equation math variables more than once in free-form programming. Use AMV010 in the following SELOGIC control equations to calculate intermediate results.

Determine if any phase voltage is greater than 13 kV

Input V01 voltage

AMV010 := **V01FM** # V01 in kV

ASV010 := **AMV010 > 13** # Set if greater than 13 kV

Input V02 voltage

AMV010 := **V02FM** # V02 in kV

ASV011 := **AMV010 > 13** # Set if greater than 13 kV

Input V03 voltage

AMV010 := **V03FM** # V03 in kV

ASV012 := **AMV010 > 13** # Set if greater than 13 kV

Combine phase results

ASV013 := **ASV010 OR ASV011 OR ASV012**

Latch Bits

Latch bits are nonvolatile storage locations for Boolean information. Latch bits are in several settings areas of the relay, as shown in *Table 2.11*. Latch bits have two input parameters, Reset and Set, and one Latched Value, as shown in *Table 2.12*.

Table 2.11 Latch Bit Quantities

Type	Quantity	Name Range
Protection free-form latch bits	32	PLT01–PLT32
Automation latch bits	32	ALT01–ALT32

Table 2.12 Latch Bit Parameters

Type	Item	Description	Setting	Name Examples
Input	Reset	Reset latch when on	Boolean SELOGIC control equation	PLT01R ALT01R
Input	Set	Set latch when on	Boolean SELOGIC control equation	PLT01S ALT01S
Output	Latched Value	Latched Value of 0 or 1	Value for use in Boolean SELOGIC control equations	PLT01 ALT24

Latch bits provide nonvolatile storage of binary information. A latch can have the value of logical 0 or logical 1. Latch bits also retain their state through changes in the active protection settings group. Because storage of latch bits is in nonvolatile memory, the state of latch bits remains unchanged indefinitely even when power is lost to the relay.

As with logic latches used in digital electronics, each latch bit has a Set input and a Reset input. The relay evaluates the latch bit value at the end of each logic processing interval using the values for Set and Reset calculated during the processing interval. Latch bits are reset dominant. If the Set and Reset inputs are both asserted, the relay will reset the latch.

Latch bits are available in two different programming areas of the SEL-487B. First, there are 32 latch bits, PLT01–PLT32, that are associated with protection settings. Second, there are 32 latch bits, ALT01–ALT32, available in automation free-form programming.

Protection Latch Bits

Program the 32 latch bits, PLT01–PLT32, in the protection free-form SELOGIC control equation programming area. There is a separate protection free-form SELOGIC control equation programming area associated with each protection settings group. The latches in protection can have separate programming for Set and Reset in each protection setting groups. While each protection latch value remains unchanged for a change in the active protection settings group, you can enter different Set and Reset programming for each protection settings group.

There are Set and Reset settings for each latch bit available in each group. For example, PLT01R and PLT01S are available in all six free-form settings groups and all control the same Latch Bit, PLT01. This structure allows you to either program each latch to operate in the same way for each group or behave differently based on the active protection settings group. For example, you could program the protection latch to set (latch on) IN106 when Protection Settings Group 1 is active and program the latch to set on IN107 when Protection Settings Group 2 is active. If you do not enter a setting for the Reset and Set in a protection settings group, the latch bit will remain unchanged when that protection settings group is active. *Example 2.6* illustrates protection latch bit usage.

EXAMPLE 2.6 Protection Latch Bits

In this example, we use Pushbutton **{PB5}** to emulate a disconnect auxiliary contact. Pressing Pushbutton **{PB5}** asserts Relay Word bit PLT01S. Pressing **{PB5}** one more time deasserts Relay Word bit PLT01S.

1: PLT01S := **PB5_PUL AND NOT PLT01** # ASSIGN I01 TO BZ1

2: PLT01R := **PB5_PUL AND PLT01** # REMOVE I01 FROM BZ1

Asserting Relay Word bit PLT01S also asserts Relay Word bit I01BZ1V. When Relay Word bit I01BZ1V asserts, the relay assigns the current from Terminal I01 to the differential element of Bus-Zone BZ1. Deasserting Relay Word bit PLT01S also deasserts Relay Word bit I01BZ1, removing the Terminal I01 current from the differential element of Bus-Zone BZ1. The terminal-to-bus-zone settings are as follows:

I01BZ1V := **PLT01** # FDR_1 to BUS_1 Connection (SELOGIC control equation)

Evaluation of the latch bit value occurs at the end of the protection SELOGIC control equation execution cycle. The values evaluated for Reset (PLT*nn*R) and Set (PLT*nn*S) during SELOGIC control equation execution remain unchanged until after the evaluation of all SELOGIC control equations, when the relay evaluates the latch bit value (PLT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the protection free-form area dominates, and the relay uses this equation to evaluate the latch.

Automation Latch Bits

The automation latch bits, ALT01–ALT32, are available in automation free-form settings. Write free-form SELOGIC control equations to set and reset these bits. As with protection latch bits, the relay stores automation latch bits in nonvolatile memory and preserves these through a relay power cycle and group change operations. With protection latch bits, you can implement Set and Reset programming for each protection settings group. Automation SELOGIC control equation programming, however, has only one programming area active for all protection settings groups.

The relay evaluates the latch bit value at the end of the automation free-form SELOGIC control equation execution cycle. The values for Reset (ALT*nn*R) and Set (ALT*nn*S) remain unchanged until evaluation of all SELOGIC control equations, when the relay evaluates the latch (ALT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the protection free-form area dominates, and the relay uses this equation to evaluate the latch.

Conditioning Timers

NOTE: Counters and timers have an upper limit of 8,388,608. Counters and timers stop incrementing when crossing this threshold. Do not enter preset values exceeding this value.

Use conditioning timers to condition Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state. Conditioning timers are available in the protection free-form area, as shown in *Table 2.13*. Conditioning timers have the three input parameters and one output shown in *Table 2.14*.

Table 2.13 Conditioning Timer Quantities

Type	Quantity	Name Range
Protection free-form conditioning timers	16	PCT01–PCT16

Table 2.14 Conditioning Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PCT01IN
Input	Pickup Time	Time that the input must be on before the output turns on	Time value in cycles	PCT01PU
Input	Dropout Time	Time that the output stays on after the input turns off	Time value in cycles	PCT01DO
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PCT01Q

A conditioning timer output turns on and becomes logical 1 after the input turns on and the Pickup Time expires. An example timing diagram for a conditioning timer, PCT01, with a Pickup Time setting greater than zero and a Dropout Time setting of zero is shown in *Figure 2.3*. In the example timing diagram, the Input, PCT01IN, turns on and the timer Output, PCT01Q, turns on after the Pickup Time, PCT01PU, expires. Because the Dropout Time setting is zero, the Output turns off when the Input turns off.

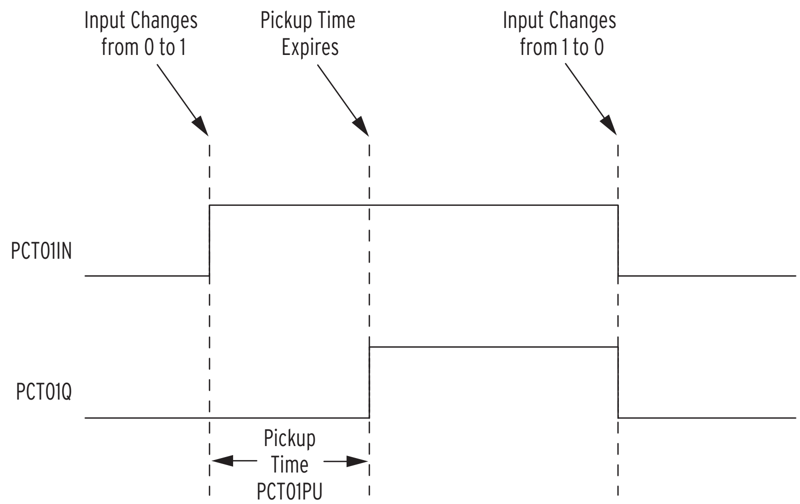

Figure 2.3 Conditioning Timer With Pickup and No Dropout Timing Diagram

If the Pickup Time is not satisfied, the timer Output never turns on, as illustrated in *Figure 2.4*.

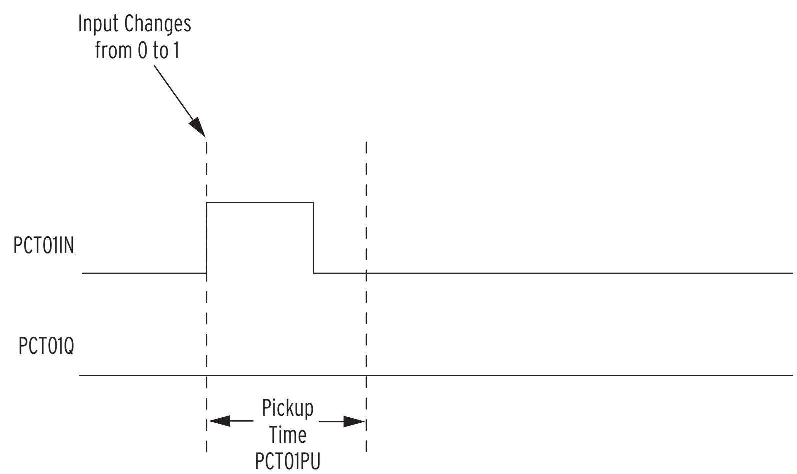

Figure 2.4 Conditioning Timer With Pickup Not Satisfied Timing Diagram

A conditioning timer output turns off when the input turns off and the Dropout Time expires. An example timing diagram for a conditioning timer, PCT02, with a Pickup Time setting of zero and a Dropout Time setting greater than zero is shown in *Figure 2.5*. Because the Pickup Time, PCT02PU, setting is zero, the Output, PCT02Q, turns on when the Input, PCT02IN, turns on. The Output turns off after the Input turns off and the Dropout Time, PCT02DO, expires.

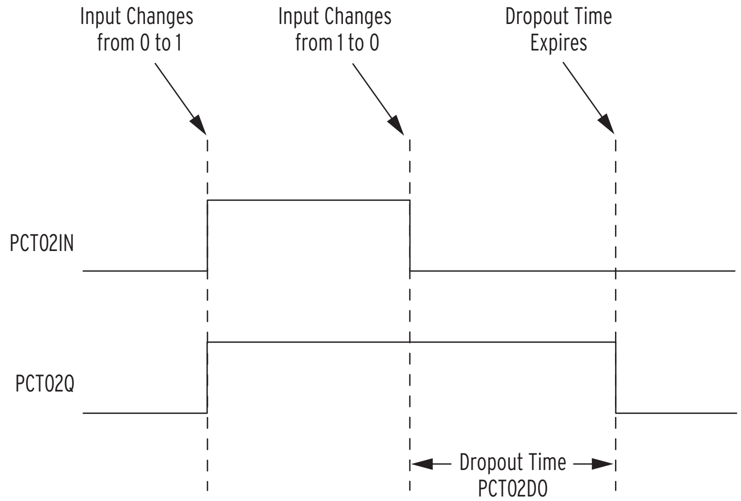

Figure 2.5 Conditioning Timer With Dropout and No Pickup Timing Diagram

Combining the features shown in *Figure 2.5*, *Figure 2.6* illustrates conditioning timer operation for use of both the pickup and dropout characteristics. The Output, PCT03Q, turns on after the Input, PCT03IN, turns on and the Pickup Time, PCT03PU, expires. The Output turns off after the Input turns off and the Dropout Time, PCT03DO, expires.

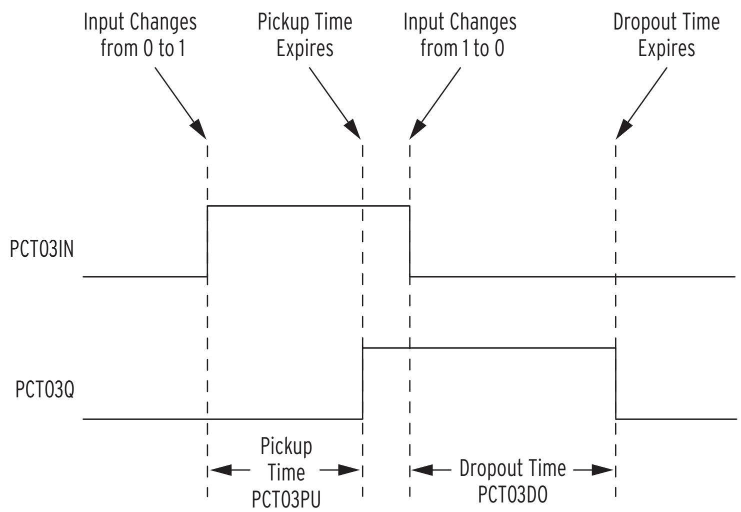

Figure 2.6 Conditioning Timer With Pickup and Dropout Timing Diagram

Set the conditioning timer settings for Pickup and Dropout in cycles and fractions of a cycle (represented in decimal form). The relay processes conditioning timers once for each protection processing interval. The relay asserts the timer output on the first processing interval when the elapsed time exceeds the setting. In the SEL-487B, the protection processing interval is 1/12th cycle. Actual settings, programming, and operation are illustrated in *Example 2.7*.

EXAMPLE 2.7 Conditioning Timer Programming and Operation

This example uses Protection Free-Form Conditioning Timer Seven, PCT07. The free-form settings are as shown here:

PCT07PU := **5.3** # Pickup set to 5.3 cycles

PCT07DO := **6.0** # Dropout set to 6.0 cycles

PCT07IN := **IN101** # Operate on the first input on the main board

PSV29 := **PCT07Q** # Protection SELogic control equation variable follows the timer output

The operation of the timer when IN101 turns on for 7 cycles is shown in the timing diagram in Figure 2.7. Because the pickup setting is an uneven number of protection processing intervals (1/12th cycle), the pickup occurs on the first 1/12th cycle after the Pickup Time of 5.3 cycles expires.

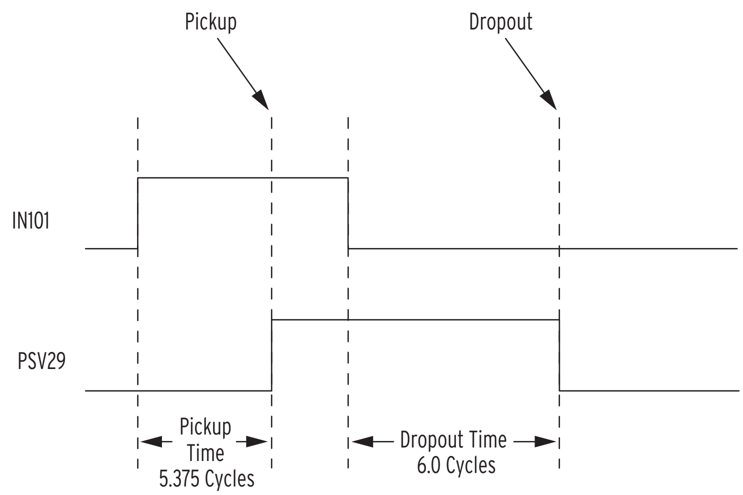

Figure 2.7 Conditioning Timer Timing Diagram for Example 2.7

In protection free-form programming, the relay evaluates the timer at execution of the timer Input SELogic control equation (PCT*nn*IN). The relay loads the Pickup Time (PCT*nn*PU) and Dropout Time (PCT*nn*DO) into the timer when the relay observes the appropriate edge in the input. If you enter a math expression for Pickup Time or Dropout Time, the relay uses the value calculated before the Input SELogic control equation. If your Pickup Time or Dropout Time equation is below the Input equation (has a higher expression line number), the relay will use the value calculated on the previous SELogic control equation execution interval. Because the relay calculates the last value for pickup or dropout in this manner, we recommend for most applications that you enter the Pickup Time, Dropout Time, and Input statements together in the order shown in *Example 2.7*.

Sequencing Timers

Sequencing timers are useful for sequencing operation. There are two main differences between sequencing timers and conditioning timers. First, sequencing timers integrate pulses of the input to count up a total time. Second, the elapsed time a sequencing timer counts is visible; you can use this time in other SELogic control equation programming or make this time visible through one of the relay communications protocol interfaces. Sequencing timers are available in the protection free-form area and automation free-form area as shown in *Table 2.15*. Sequencing timers have three input parameters and two outputs listed in *Table 2.16*.

NOTE: Counters and timers have an upper limit of 8,388,608. Counters and timers stop incrementing when crossing this threshold. Do not enter preset values exceeding this value.

Table 2.15 Sequencing Timer Quantities

Type	Quantity	Name Range
Protection free-form sequencing timers	32	PST01–PST32
Automation free-form sequencing timers	32	AST01–AST32

Table 2.16 Sequencing Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PST01IN AST07IN
Input	Preset Time	Time the input must be on before the output turns on	Time value. Protection uses cycles, while automation uses seconds.	PST01PT AST07PT
Input	Reset	Timer reset	Boolean SELOGIC control equation setting	PST01R AST07R
Output	Elapsed Time	Time accumulated since the last reset	Value for math SELOGIC control equations. Protection uses cycles, while automation uses seconds.	PST01ET AST07ET
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PST01Q AST07Q

A sequencing timer counts time by incrementing the Elapsed Time when SELOGIC control equation execution reaches the Input equation if the Reset is off and the Input is on. The Output turns on when the Elapsed Time reaches or exceeds the Preset Time. Whenever the Reset is on, the relay sets the Output to zero, then clears the Elapsed Time, and stops accumulating time (even if Input is on).

Figure 2.8 is a timing diagram for typical sequencing timer operation.

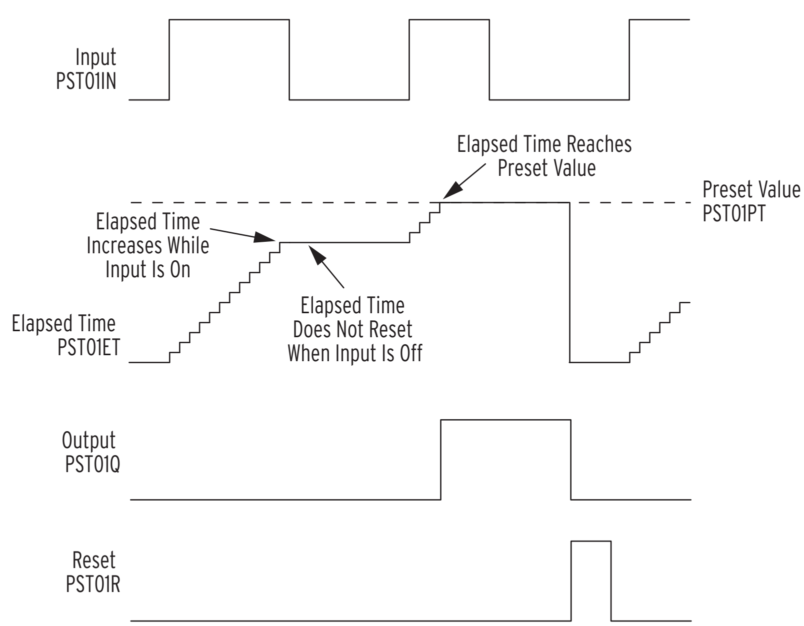

Figure 2.8 Sequencing Timer Timing Diagram

Timers in protection programming operate in cycles, while timers in automation programming operate in seconds. As with sequencing timers, operation depends on the logic processing interval. For protection programming, the logic processing interval is 1/12 of a cycle, so the relay effectively rounds up all operation to the nearest 1/12 of a cycle. With automation programming, the execution interval depends on the amount of automation programming. Determine the average automation execution interval with the **STATUS S** command.

The automation timers operate using a real time clock. Each time the relay evaluates the Input (AST*nn*IN) the relay adds the elapsed time since the last execution to the Elapsed Time (AST*nn*ET). The timer is evaluated each time the relay executes automation SELOGIC control equations. Use the **STATUS S** command to check the automation average execution cycle time to verify that you will obtain satisfactory accuracy for your application. *Example 2.8* describes typical timer programming and describes the resulting operation.

EXAMPLE 2.8 Automation Sequencing Timer Programming

The equations below are an example of programming for an automation sequencing timer, AST01. Each timer input is programmed as a separate statement in automation SELOGIC control equation programming.

Example programming of sequencing timer to time Input IN101 and IN102

AST01PT := **7.5** # Timer Preset Time of 7.5 seconds

AST01R := **RB03** # Reset timer when RB03 turns on

AST01IN := **IN101 AND IN102** # Timing time when IN101 and IN102 are on

ASV001 := **AST01Q** # ASV001 tracks output of timer

AMV256 := **AST01ET** # AMV256 tracks timing progress

In this example, timer AST01 times the quantity IN101 AND IN102 and turns on when the total time reaches 7.5 seconds. If the Input, AST01IN, is on for approximately 1 second every minute, the Output, AST01Q, will turn on during the eighth minute, when the accumulated elapsed time exceeds 7.5 seconds.

In free-form programming, the relay evaluates the timer at the timer Input SELOGIC control equation (PST*nn*IN or AST*nn*IN). If you enter an expression for the timer Reset (PST*nn*R or AST*nn*R) or Preset Time (PST*nn*PT or AST*nn*PT), the values for Reset and Preset Time that the relay uses are the last values that the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset Time value in this manner, we recommend for most applications that you enter the Preset Time, Reset, and Input statements together in the order shown in *Example 2.8*.

Counters

NOTE: Counters and timers have an upper limit of 8,388,608. Counters and timers stop incrementing when crossing this threshold. Do not enter preset values exceeding this value.

Use counters to count changes or edges in Boolean values. Each time the value changes from logical 0 to logical 1 (a rising edge), the counter Current Value increments. Counters are available in the protection free-form area and automation free-form area, as shown in *Table 2.17*. Counters have three input parameters, Input, Preset Value, and Reset; and two outputs, Current Value and Output as listed in *Table 2.18*.

Table 2.17 Counter Quantities

Type	Quantity	Name Range
Protection counters	32	PCN01–PCN32
Automation counters	32	ACN01–ACN32

Table 2.18 Counter Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay counts	Boolean SELOGIC control equation setting	PCN01IN ACN09IN
Input	Preset Value	Number of counts before the output turns on	Constant or expression for the number of counts	PCN01PV ACN09PV
Input	Reset	Counter reset	Boolean SELOGIC control equation setting	PCN01R ACN09R
Output	Current Value	Current accumulated count	Value for math SELOGIC control equations	PCN01CV ACN09CV
Output	Output	Counter output	Value for Boolean SELOGIC control equations	PCN01Q ACN09Q

In free-form programming, the relay evaluates the counter at execution of the counter Input SELOGIC control equation (PCN*nn*IN or ACN*nn*IN). If you enter an expression for the counter Reset (PCN*nn*R) or the counter Preset (PCN*nn*PV), the values for Reset and Preset that the relay uses are the last values the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset in this manner, we recommend for most applications that you enter the Preset, Reset, and Input statements together in the order shown in *Example 2.9*.

EXAMPLE 2.9 Counter Programming

The free-form programming equations that follow demonstrate how to enter settings to control a protection counter in protection free-form SELOGIC control equation programming. Programming for an automation counter is similar.

Protection Counter 1 counts close operations of the circuit breaker associated with the 52CL01 element. Initially, the current value, PCN01CV, is zero. The relay increments the current value each time the circuit breaker closes. The relay increases the count value, PCN01CV, each time the circuit breaker closes and the element 52CL01 value changes from 0 to 1 (a rising edge). When the count reaches 1000, the timer automatically resets and begins counting again.

```
# Example protection counter programming
#
# This example counts how many times the circuit breaker of Terminal 01 closes
# The counter automatically resets every 1,000 operations
PCN01PV := 1000
PCN01R := PCT01Q
PCN01IN := 52CL01
```

The SELOGIC control equations below provide multiple-change detection counting the close operations of the circuit breaker. The intermediate value PSV01 turns on for one processing interval each time the circuit breaker closes.

```
# Example protection counter programming
#
# This example counts how many times a circuit breaker closes
#
```

Detect CLOSE

PSV01 := **52CL01** # Pulse for each close

#

The counter automatically resets every 1,000 operations

PCN01PV := **1000**

PCN01R := **PCT01Q**

PCN01IN := **PSV01** # Count close operations

PSV02 := **PCN01CV > 900** # PSV02 signals more than 900 operations

Aliases

Although the SEL-487B provides extensive programming facilities and opportunity for comments, troubleshooting customized programs is sometimes difficult. Aliases provide an opportunity to assign more meaningful names to the generic variable names in order to improve the readability of the program. *Example 2.10* provides examples of assigning aliases.

EXAMPLE 2.10 Assigning and Removing Aliases

The following free-form math SELOGIC control equations show you how to create aliases.

Assign the alias names with the **SET T** command

SET T

PMV01,THETA # Assign the alias "THETA" to PMV01

PMV02,TAN # Assign the alias "TAN" to PMV02

Use the alias names "THETA" and "TAN " in a free-form SELOGIC control equation:

Calculate the tangent of THETA

TAN := **SIN(THETA)/COS(THETA)**

To remove the alias from the alias setting, issue the **SET T** command and press **<Enter>** until the alias appears; then type **DELETE <Enter>**:

SET T

nn: PMV01,THETA # (where nn = line number)

DELETE

Assign up to 200 alias names to any Relay Word bit, analog quantity, terminal name, or bus-zone name, using the **SET T** command. The maximum length of an alias is seven characters. Valid characters are 0–9, A–Z (only uppercase) and _ (underscore). Make sure no Relay Word bit, analog quantity, terminal name, or bus-zone name appears more than once in the alias settings. Each alias name must be unique, i.e., you cannot use the name of an existing Relay Word bit, analog quantity, or terminal name. If you remove the alias name, all settings that referenced that alias revert to the original name.

SELOGIC Control Equation Operators

There are two types of SELOGIC control equations. Boolean SELOGIC control equations comprise the first type. These equations are expressions that evaluate to a Boolean value of 0 or 1. Math SELOGIC control equations constitute the second type. The relay evaluates these equations to yield a result having a numerical value (for example, 6.25 or 1055).

Left value, LVALUE, determines the type of SELOGIC control equation you need for a setting or for writing free-form programming. If the LVALUE is a Boolean type (ASV001, etc.) then the type of expression you need is a Boolean SELOGIC control equation. If the LVALUE is a numerical (non-Boolean) value (PMV12, PCT01PV, etc.), the type of expression you need is a math SELOGIC control equation.

Writing SELOGIC control equations requires that you use the appropriate operators and correct SELOGIC control equation syntax to combine relay elements including analog values, Relay Word bits, incoming control points, and SELOGIC control equation elements within the relay. The operators are grouped into two types, according to the type of SELOGIC control equation in which you can apply these operators.

Operator Precedence

When you combine several operators and operations within a single expression, the SEL-487B evaluates the operations from left to right starting with the highest precedence operators working down to the lowest precedence. This means that if you write an equation with three AND operators, for example PSV01 AND PSV02 AND PSV03, each AND will be evaluated from the left to the right. If you substitute NOT PSV04 for PSV03 to make PSV01 AND PSV02 AND NOT PSV04, the relay evaluates the NOT operation of PSV04 first and uses the result in subsequent evaluation of the expression. While you cannot use all operators in any single equation, the overall operator precedence follows that shown in *Table 2.19*.

Boolean Operators

Use Boolean operators to combine values with a resulting Boolean value. The arguments of the operator may be either numbers or Boolean values, but the result of the operation must be a Boolean value. Combine the operators to form statements that evaluate complex Boolean logic. *Table 2.20* contains a summary of Boolean operators available in the SEL-487B.

Table 2.19 Operator Precedence from Highest to Lowest (Sheet 1 of 2)

Operator	Description
(Expression)	Parenthesis
Identifier (argument list)	Function evaluation
–	Negation
NOT	Complement
R_TRIG F_TRIG	Edge Trigger
SQRT, LN, EXP, LOG, COS, SIN, ACOS, ASIN, ABS, CEIL, FLOOR	Math Functions
*	Multiply
/	Divide
+	Add
–	Subtract

Table 2.19 Operator Precedence from Highest to Lowest (Sheet 2 of 2)

Operator	Description
<, >, <=, >=	Comparison
=	Equality
<>	Inequality
AND	Boolean AND
OR	Boolean OR

Table 2.20 Boolean Operator Summary

Operator	Description
OR	Logical OR
AND	Logical AND
NOT	Logical inverse
( )	Parentheses
R_TRIG	Rising-edge trigger
F_TRIG	Falling-edge trigger
>, <, =, <=, >=, <>	Comparison of values

OR

Use OR to combine two Boolean values according to the truth table shown in *Table 2.21*.

Table 2.21 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

AND

Use AND to combine two Boolean values according to the truth table shown in *Table 2.22*.

Table 2.22 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

NOT

Use NOT to calculate the inverse of a Boolean value according to the truth table shown in *Table 2.23*.

Table 2.23 NOT Operator Truth Table

Value A	NOT A
0	1
1	0

Parentheses

Use paired parentheses to control the execution order of operations in a SELOGIC control equation. Use as many as 14 nested sets of parentheses in each SELOGIC control equation. The relay calculates the result of the operation on the innermost pair of parentheses first and then uses this result with the remaining operations. *Table 2.24* is a truth table for an example operation that illustrates how parentheses can affect equation evaluation.

Table 2.24 Parentheses Operation in Boolean Equation

A	B	C	A AND B OR C	A AND (B OR C)
0	0	0	0	0
0	0	1	1	0
0	1	0	0	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

R_TRIG

R_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Figure 2.9*. Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only when the value changes.

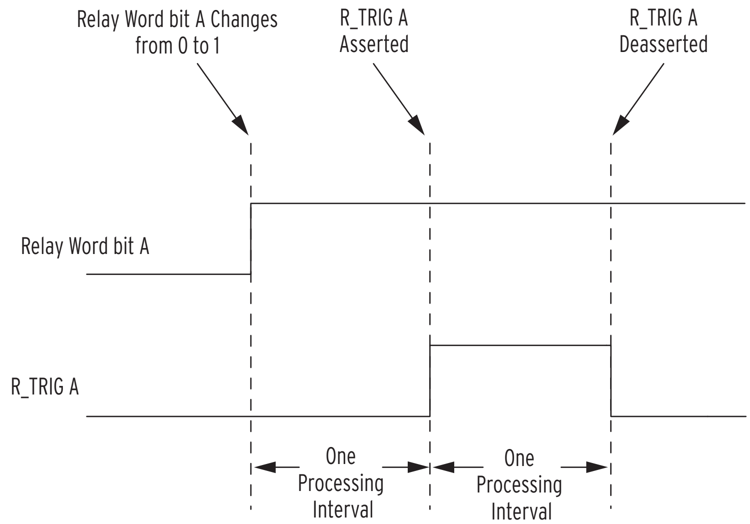

Figure 2.9 R_TRIG Timing Diagram

The argument of an R_TRIG statement must be a single bit within the SEL-487B. An example of the relay detecting a rising edge of a calculated quantity is shown in *Example 2.11*.

EXAMPLE 2.11 R_TRIG Operation

The SELOGIC control equation below is invalid.

PSV15 := **R_TRIG (PSV01 AND PSV23)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the R_TRIG operation on the result, as shown below.

PSV14 := **PSV01 AND PSV23** # Calculate quantity in an intermediate result variable

PSV15 := **R_TRIG PSV14** # Perform an R_TRIG on the quantity

F_TRIG

F_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Figure 2.10*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state.

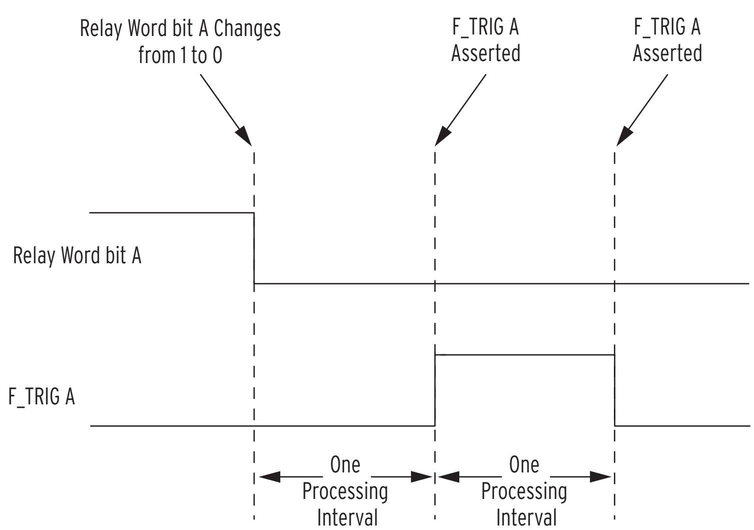

Figure 2.10 F_TRIG Timing Diagram

The argument of an F_TRIG statement must be a single bit within the SEL-487B. An example of the relay detecting a falling edge of a calculated quantity is shown in *Example 2.12*.

EXAMPLE 2.12 F_TRIG Operation

The SELOGIC control equation below shows an invalid use of the F_TRIG operation.

ASV015 := **F_TRIG (ASV001 AND ALT11)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the F_TRIG operation on the result, as shown below.

ASV014 := **ASV001 AND ALT11** # Calculate quantity in an intermediate result variable

ASV015 := **F_TRIG ASV14** # Perform an F_TRIG on the quantity

Comparison

NOTE: Be careful how you use the equal (=) and the inequality (<>) operators. Because the relay uses a floating-point format to calculate analog values, only integer numbers will match exactly. Allow a small hysteresis of the following form: PSV01 := IO1FM < 10.002 AND IO1FM > 9.988.

Comparison is a mathematical operation that compares two numerical values with a result of logical 0 or logical 1. AND and OR operators compare Boolean values; comparison functions compare floating-point values such as currents and other quantities. Comparisons and truth tables for operation of comparison functions are shown in *Table 2.25*.

Table 2.25 Comparison Operations

A	B	A>B	A>=B	A=B	A<>B	A<=B	A<B
6.35	7.00	0	0	0	1	1	1
5.10	5.10	0	1	1	0	1	0
4.25	4.00	1	1	0	1	0	0

Math Operators

Use math operators when writing math SELOGIC control equations. Math SELOGIC control equations manipulate numerical values. *Table 2.26* summarizes the operators available for math SELOGIC control equations.

Table 2.26 Math Operator Summary

Operator	Description
( )	Parentheses
+, –, *, /	Arithmetic
SQRT	Square root
LN, EXP, LOG	Natural logarithm, exponentiation of e, base 10 logarithm
COS, SIN, ACOS, ASIN	Cosine, sine, arc cosine, arc sine
ABS	Absolute value
CEIL	Rounds to the nearest integer towards infinity
FLOOR	Rounds to the nearest integer towards minus infinity
–	Negation

Parentheses

Use parentheses to control the order in which the relay evaluates math operations within a math SELOGIC control equation. Also use parentheses to group expressions that you use as arguments to function operators such as SIN and COS. You can include as many as 14 levels of nested parentheses in your math SELOGIC control equation. *Example 2.13* shows how parentheses affect the operation and evaluation of math operations.

EXAMPLE 2.13 Using Parentheses in Math Equations

The free-form math SELOGIC control equations below show examples of parentheses usage.

Examples of parenthesis usage

AMV001 := **AMV005 * (AMV004 + AMV003)** # Calculate sum first, then product

AMV002 := **AMV010 * (AMV009 + (AMV016 / AMV015))** # Nest parentheses

AMV003 := **SIN (AMV037 + PMV42)** # Group terms for a function

Math Error Detection

If a math operation results in an error, the SEL-487B turns on the math error bit, MATHERR, in the Relay Word. A settings change or the **STATUS SC** command provides reset for this bit. For example, if you attempt to take the square root of a negative number (SQRT –5), the math error bit will be asserted until you clear the bit with a **STATUS SC** command or change settings.

Table 2.27 Math Error Examples

Example	Value in PMV01	Type	MATHERR
PMV01 := PMV02 / 0	Infinity	Divide by zero	Yes
PMV01 := LN (0)	0[a]	LN of 0	Yes
PMV01 := LN (-1)	0[a]	LN of negative number	Yes
PMV01 := SQRT (-1)	0[a]	Square root of a negative number	Yes

[a] Evaluation of the expression results in an error and prevents storage of a new result. In the example, PMV01 remains 0. If the argument were a variable, PMV01 would contain the result of the last evaluation when the argument is valid.

Arithmetic

Use arithmetic operators to perform basic mathematical operations on numerical values. Arguments of an arithmetic operation can be either Boolean or numerical values. In a numerical operation, the relay converts logical 0 or logical 1 to the numerical value of 0 or 1. For example, multiply numerical values by Boolean values to perform a selection operation. Use parentheses to group terms in math SELOGIC control equations and control the evaluation order and sequence of arithmetic operations.

The relay uses IEEE® 32-bit floating-point numbers to perform SELOGIC control equation mathematical operations. If an operation results in a quantity that is not a numerical value, the SELOGIC control equation status bit that signals a math error, MATHERR, asserts. The value that the relay stored previously in the specified result location is not replaced. The SEL-487B clears the corresponding math error bits if you change SELOGIC control equation settings (protection or automation), or if you issue a **STATUS SC** command. *Example 2.14* contains examples of arithmetic operations in use.

EXAMPLE 2.14 Using Arithmetic Operations

The free-form math SELOGIC control equations below show examples of arithmetic operator usage.

Arithmetic examples

AMV001 := **AMV005 + AMV034** # Calculate sum

AMV002 := **AMV005 – AMV034** # Calculate difference

AMV003 := **AMV005 * AMV034** # Calculate product

AMV004 := **AMV005 / AMV034** # Calculate quotient

The lines below demonstrate the use of Boolean values with the multiplication operation.

Use of multiplication to select numerical values based on active settings group

Use 7 if protection settings group 1 active

Use 5 if protection settings group 2 active

AMV005 := **7 * SG1 + 5 * SG2**

The lines below demonstrate math calculation error detection.

The line below results in a math error if AMV029 becomes 0

AMV006 := **732 / AMV029**

In the second line, if AMV029 is 6 on the first pass through the automation programming, the relay stores the result, 122, in AMV006. If on the next pass AMV029 is 0, the MATHERR bit asserts and the value in AMV006 does not update.

SQRT

Use the SQRT operation to calculate the square root of the argument. Use parentheses to delimit the argument of a SQRT operation. A negative argument for the SQRT operation results in a math error and assertion of the corresponding math error bit described in *Arithmetic on page R.2.29*. *Example 2.15* shows examples of the SQRT operator in use.

EXAMPLE 2.15 Using the SQRT Operator

The free-form math SELOGIC control equations below show examples of SQRT operator usage.

SQRT examples

AMV001 := **SQRT (AMV005)** # Single argument version of SQRT

AMV002 := **SQRT (AMV005 + AMV034)** # Calculates the square root of the sum

AMV003 := **SQRT (AMV007)** # Produces a math error if AMV007 is negative

LN, EXP, and LOG

LN and EXP are complementary functions for operating with natural logarithms or logarithms calculated to the natural base e. LN calculates the natural logarithm of the argument. LOG calculates the base 10 logarithm of the argument. A negative or zero argument for the LN and LOG operation results in a math error and assertion of the corresponding math error bit described in *Arithmetic*. EXP calculates the value of e raised to the power of the argument. *Example 2.16* shows examples of expressions that use the LN, EXP, and LOG operators.

EXAMPLE 2.16 Using the LN, EXP, and LOG Operators

The free-form math SELOGIC control equations below are examples of LN, EXP, and LOG operator usage.

LN examples

AMV001 := **LN (AMV009)** # Natural logarithm of AMV009

AMV002 := **LN (AMV009 + AMV034)** # Natural logarithm of the sum

AMV003 := **LN (AMV010)** # Produces error if AMV010 is 0 or negative

EXP examples

AMV004 := **EXP (2)** # Calculates e squared

AMV005 := **EXP (AMV003)** # Calculates e to the power AMV003

AMV006 := **EXP (AMV046 + AMV047)** # e raised to the power of the sum

LOG examples

AMV007 := **LOG (AMV012)** # Base 10 logarithm of AMV012

AMV008 := **LOG (AMV012 + AMV022)** # Base 10 logarithm of the sum

AMV009 := **LOG (AMV100)** # Produces an error if AMV100 is 0 or negative

SIN and COS

Use the SIN or COS operators to calculate the sine or cosine of the argument. SIN and COS operate in degrees, the unit of angular measure the SEL-487B uses to express metering quantities. *Example 2.17* shows examples of SIN and COS.

EXAMPLE 2.17 Using the SIN and COS Operators

The free-form math SELOGIC control equations below are examples of SIN and COS.

SIN examples

AMV001 := **SIN (AMV005)** # Sine of AMV005

AMV002 := **SIN (AMV005 + AMV034)** # Sine of the sum

COS examples

AMV003 := **COS (AMV005)** # Cosine of AMV005

AMV004 := **COS (AMV005 + AMV006)** # Cosine of the sum

ASIN and ACOS

Use the ASIN or ACOS operators to calculate the angle in degrees resulting from the trigonometric function equivalent to a given number (the argument), where the function is sine or cosine. ASIN and ACOS operate in degrees. An argument less than –1 or larger than 1 results in a math error and assertion of the corresponding math bit described in *Arithmetic*. *Example 2.18* shows examples of ASIN and ACOS.

EXAMPLE 2.18 Using the ASIN and ACOS Operators

The free-form math SELOGIC control equations below are examples of ASIN and ACOS.

ASIN examples

AMV001 := **ASIN (AMV010)** # Arc sine of AMV010

AMV002 := **ASIN (AMV010 + AMV011)** # Arc sine of the sum

AMV003 := **ASIN (AMV012)** # Produces an error if |AMV012| > 1

ACOS examples

AMV004 := **ACOS (AMV010)** # Arc cosine of AMV010

AMV005 := **ACOS (AMV010 + AMV011)** # Arc cosine of the sum

AMV006 := **ACOS (AMV012)** # Produces an error if |AMV012| > 1

ABS

Use the ABS operation to calculate absolute value of the argument. Use parentheses to group a math expression as the argument of an ABS operation. If the argument of the ABS operation is negative, the result is the value multiplied by –1. If the argument of the ABS operation is positive, the result is the same quantity as the argument. *Example 2.19* contains examples of the ABS operator in use.

EXAMPLE 2.19 Using the ABS Operator

The free-form math SELOGIC control equations below show examples of the ABS operator usage.

ABS examples

AMV001 := **ABS (–6)** # Stores 6 in AMV001

AMV002 := **ABS (6)** # Stores 6 in AMV002

AMV003 := **ABS (AMV009)** # Absolute value of AM009

AMV004 := **ABS (AMV005 + AMV034)** # Absolute value of the sum

CEIL

Use the CEIL operator to round the argument to the nearest integer towards infinity. Use parentheses to group a math expression as the argument of a CEIL operation. *Example 2.20* contains examples of the CEIL operator.

EXAMPLE 2.20 Using the CEIL Operator

The free-form math SELOGIC control equations below show examples of the CEIL operator usage.

CEIL examples

AMV001 := **CEIL (5.99)** # Stores 6 in AMV001

AMV002 := **CEIL (–4.01)** # Stores –4 in AMV002

FLOOR

Use the FLOOR operator to round the argument to the nearest integer towards minus infinity. Use parentheses to group a math expression as the argument of a FLOOR operation. *Example 2.21* contains examples of the FLOOR operator.

EXAMPLE 2.21 Using the FLOOR Operator

The free-form math SELOGIC control equations below show examples of the FLOOR operator usage.

```
# FLOOR examples
AMV001 := FLOOR (5.99) # Stores 5 in AMV001
AMV002 := FLOOR (–4.01) # Stores –5 in AMV002
```

Negation

Use the negation (–) operation to change the sign of the argument. The argument of the negation operation is multiplied by –1. Negation of a positive value results in a negative value, while negation of a negative value results in a positive value. *Example 2.22* contains examples of expressions that utilize the negation operator.

EXAMPLE 2.22 Using the Negation Operator

The free-form math SELOGIC control equations below show examples of negation operator usage.

```
# Negation examples
AMV001 := -AMV009 # If AMV009 is 5, stores –5 in AMV001
AMV002 := -AMV009 # If AMV009 is –5, stores 5 in AMV002
```

Effective Programming

This section contains several ideas useful for creating, maintaining, and troubleshooting programming in the SEL-487B protection and automation SELOGIC control equation programming environments.

Planning and Documentation

When you begin to configure the relay to perform a new automation task or customize a protection operation, take time to design, document, and implement your project. Scale the planning effort to match the overall size of the project, but spend sufficient time planning to do the following:

- ➤ Document the inputs and outputs of your programming. This may include protection elements, physical inputs and outputs, metering quantities, user inputs, and other information within the relay.
- ➤ Document the processing or outcome of the programming. List the major tasks you want the relay to perform and provide detail about the algorithm you will use for each task. For example, if you need a timer or a counter, make a note of the requirements and how you will use these elements.
- ➤ Work in a top-down method, specifying and moving to more detailed levels, until you have sufficient information to create the settings. For simple tasks, one level may be sufficient. For complex tasks, such as automated station restoration, you may need several levels to move from idea to implementation.

Comments

SELOGIC control equation comments are very powerful tools for dividing, documenting, and clarifying your programming. Even if you completely understand your programming during installation and commissioning, comments will be very helpful if you need to modify operation a year later.

Create these comments in the fixed and free-form SELOGIC control equations, and store these comments in the SEL-487B. Obtain comments to assist you in using the ASCII interface or SEL configuration software, regardless of whether you have the original files downloaded to the relay.

Comments add structure to free-form programming environments such as Visual Basic, C, and free-form SELOGIC control equations. *Example 2.23* shows how to use comments to divide and structure free-form SELOGIC control equation programming.

EXAMPLE 2.23 Comments in Free-Form SELOGIC Control Equation Programming

Use comments to divide and direct your eye through free-form programming.

```
#
# This is a header comment that divides sections of free-form programming
#
AMV003 := 15 * AMV003 # Explain this line here
#
# This comment is a header for the next section.
# Inputs: provide more detail for more complex tasks
# Outputs: describe how the programming affects the relay operation
# Processing: discuss how the programming itself operates
#
ASV004 := ACN01Q AND RB03 # First line of next section
```

Many texts on programming in various computer programming languages suggest that you cannot include too many comments. The main reason to include comments is that something you find obvious may not be obvious to your coworker who will have to work with your programming in the future. Adding comments also gives you the opportunity to think about whether the program performs the function you intended.

Testing

After documentation and comments, the next essential element of an effective approach to programming is testing. Two types of testing are critical for determining if programming for complex tasks operates properly. First, test and observe whether the program performs the function you want under the conditions you anticipated. Second, look for opportunities to create conditions that are abnormal and determine how your program reacts to unusual conditions.

For example, test your system in unanticipated, but possible conditions such as loss of power, loss of critical field inputs, unexpected operator inputs, and conditions that result from likely failure scenarios of the equipment in your system. It is unlikely that you will find every possible weakness, but careful consideration and testing for abnormal conditions will help you avoid a failure and may reveal deficiencies in the normal operation of your system.

Modify your SELOGIC control equations to simulate the process. While you may be unable to change the state of a discrete input easily, such as IN101, you can substitute a logical 1 or logical 0 in your logic to simulate the operation of IN101 and observe the results.

Use the SER capabilities of the relay to monitor and record inputs, internal calculations, and outputs. For operations that occur very quickly, use the SER during testing to reconstruct the operation of your logic.

Use the **MET PMV** or **MET AMV** commands to display the contents of the last 16 protection or automation math variables, or use the **MET PMV A** and **MET AMV A** commands to see all of the protection and automation math variables.

SEL-311 and SEL-351 Series Users

You can convert logic that you have used in SEL-311 series relays and SEL-351 series relays to logic for the SEL-487B. In the SEL-311 series relays, SELOGIC control equation programming is restricted to equations where the left side value, LVALUE, is fixed. The SEL-487B uses primarily free-form programming. *Table 2.28* shows comparable features between the SEL-311 series relays and the SEL-487B. Convert programming into either the free-form style or the fixed style of SELOGIC control equations, or whatever combination you deem appropriate for your application.

Table 2.28 SEL-311 Series Relays and SEL-487B SELOGIC Control Equation Programming Features

Feature	SEL-311 Series	SEL-487B Protection Free-Form Style
SELOGIC control equation variables	SV1–SV16	PSV01–PSV64
Timer Input	SV1–SV16	PCT01–PCT16
Timer Pickup settings	SV1PU–SV16PU	PCT01PU–PCT16PU
Timer Dropout settings	SV1DO–SV16DO	PCT01DO–PCT16DO
Timer Outputs	SV1T–SV16T	PCT01Q–PCT16Q
Latch Bit Set Control	SET1–SET16	PLT01S–PLT16S
Latch Bit Reset Control	RST1–RST16	PLT01R–PLT16R
Latch Bit	LT1–LT16	PLT01–PLT16

Table 2.29 shows the SEL-487B Boolean operators compared to the operators used in the SEL-311 series relays.

Table 2.29 SEL-311 Series Relays and SEL-487B SELOGIC Control Equation Boolean Operators

Feature	SEL-311 Series	SEL-487B
Logical AND operator	*	AND
Logical OR operator	+	OR
Logical NOT operator	!	NOT
Parentheses	( )	( )
Rising, falling edge operators	/, \	R_TRIG, F_TRIG

In the SEL-311 series relays, SELOGIC control equation variables and timers are connected. Each SELOGIC control equation variable is the input to a timer. In the SEL-487B, timers and SELOGIC control equation variables are independent.

The SELOGIC control equation Boolean operators in the SEL-487B are different from those used in SEL-300 series relays. For example, if you wish to convert programming from an SEL-311 or SEL-351 series relay for the SEL-487B, you must convert the operators. *Example 2.24* and *Example 2.25* demonstrate conversion of several settings to the SEL-487B setting.

EXAMPLE 2.24 Converting SEL-311 Series Relay SELOGIC Control Equation Variables

If you have the following SELOGIC control equation in an SEL-311 series relay, convert it as shown below.

```
SV1 = IN101 + RB3 * LT4
```

In the SEL-487B, use the line shown below.

PSV01 := **IN101 OR RB03 AND PLT04**

In the example above, first convert the + and * operators in the expression to the OR and AND operators. In the free-form example, use a protection SELOGIC control equation variable for the result.

EXAMPLE 2.25 Converting SEL-311 Series Relay SELOGIC Control Equation Timers

If you have the following SELOGIC control equation timer in an SEL-311 series relay, convert it as shown below.

```
SV1 = IN101

SV1PU = 5.25

SV1DO = 3.5
OUT101 = SV1T
```

In the SEL-487B, use the format shown below.

#

Free-form programming conversion of timer

#

PCT01PU := **5.25** # Pickup of 5.25 cycles

PCT01DO := **3.5** # Dropout of 3.5 cycles

PCT01IN := **IN101** # Use the timer to monitor IN101

In the output settings, set OUT101 as shown below:

OUT101 := **PCT01Q**

EXAMPLE 2.26 Converting SEL-311 Series Relay Latch Bits

If you have the following SELOGIC control equation latch programming in an SEL-311 series relay, convert it as shown below.

```
SET1 = RB4

RST1 = RB5

OUT101 = LT1
```

In the SEL-487B, use the format shown below.

Protection free-form style settings:

```
#
# Free-form programming conversion of latch bit
#
PLT01S := RB04 # Set if RB04
PLT01R := RB05 # Reset if RB05
```

In the output settings, set OUT101 as shown below:

```
OUT101 := PLT01
```

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Section 3
Communications Interfaces

Overview

This section provides information on communications interface options for the SEL-487B Relay. The following topics are discussed:

- ➤ EIA-232 Serial Communications
- ➤ EIA-485 Serial Communications
- ➤ Fiber-Optic Serial Communications
- ➤ Communications Card

Communications Interfaces

The SEL-487B collects, stores, and calculates a variety of data. These include electrical power system measurements, calculated quantities, diagnostic data, equipment monitoring data, fault oscillography, and Sequential Events Recorder (SER). Enter settings to configure the SEL-487B to protect and monitor your power system properly. A communications interface is the physical connection on the relay that you can use to collect data from the relay, set the relay, and perform relay test and diagnostic functions.

The SEL-487B has three rear-panel serial ports and one front-panel serial port. These serial ports conform to the EIA-232 standard. Several optional SEL plug-in devices are available to provide alternative physical interfaces including EIA-485 and fiber-optic cable. The relay also has a communications card slot for an optional communications board including Ethernet.

Once you have established a physical connection, you must use a communications protocol to interact with the relay. A communications protocol is a language that you can use to perform relay operations and collect data. For information on protocols that you can use with the SEL-487B, see the instruction manual sections listed in *Table 3.1*.

Table 3.1 SEL-487B Communications Protocols

Communications Protocol	Communications Interface	For More Information See
DNP3 (serial)	EIA-232[a]	*Section 5: DNP3 Communications*
DNP LAN/WAN	Ethernet Card	*Section 5: DNP3 Communications*
IEC 61850	Ethernet Card	*Section 6: IEC 61850 Communications in the Reference Manual*
Distributed Port Switch (LMD)	SEL-2885 EIA-232 to EIA-485 Transceiver on an EIA-232 port	*Section 4: SEL Communications Protocols*
SEL Binary Protocols (Fast Meter, Fast Operate, Fast SER)	EIA-232[a]	*Section 4: SEL Communications Protocols*
MIRRORED BITS® communications	EIA-232[a]	*Section 4: SEL Communications Protocols*
ASCII Commands	EIA-232[a] or Telnet using Ethernet Card	*Section 7: ASCII Command Reference*
FTP	Ethernet Card or EIA-232 port[a]	*Section 5: Direct Network Communications in the Applications Handbook*

[a] You can add converters to transform EIA-232 to other physical interfaces.

Section 4: SEL Communications Processor Applications in the Applications Handbook and *Section 5: Direct Network Communications in the Applications Handbook* include more information on communication topologies and protocols.

Serial Communication

EIA-232

The SEL-487B has four EIA-232 communications ports. The serial port locations are shown in *Figure 3.1* and *Figure 3.2*. The front-panel port is Port F, and the three rear-panel ports are Port 1, Port 2, and Port 3.

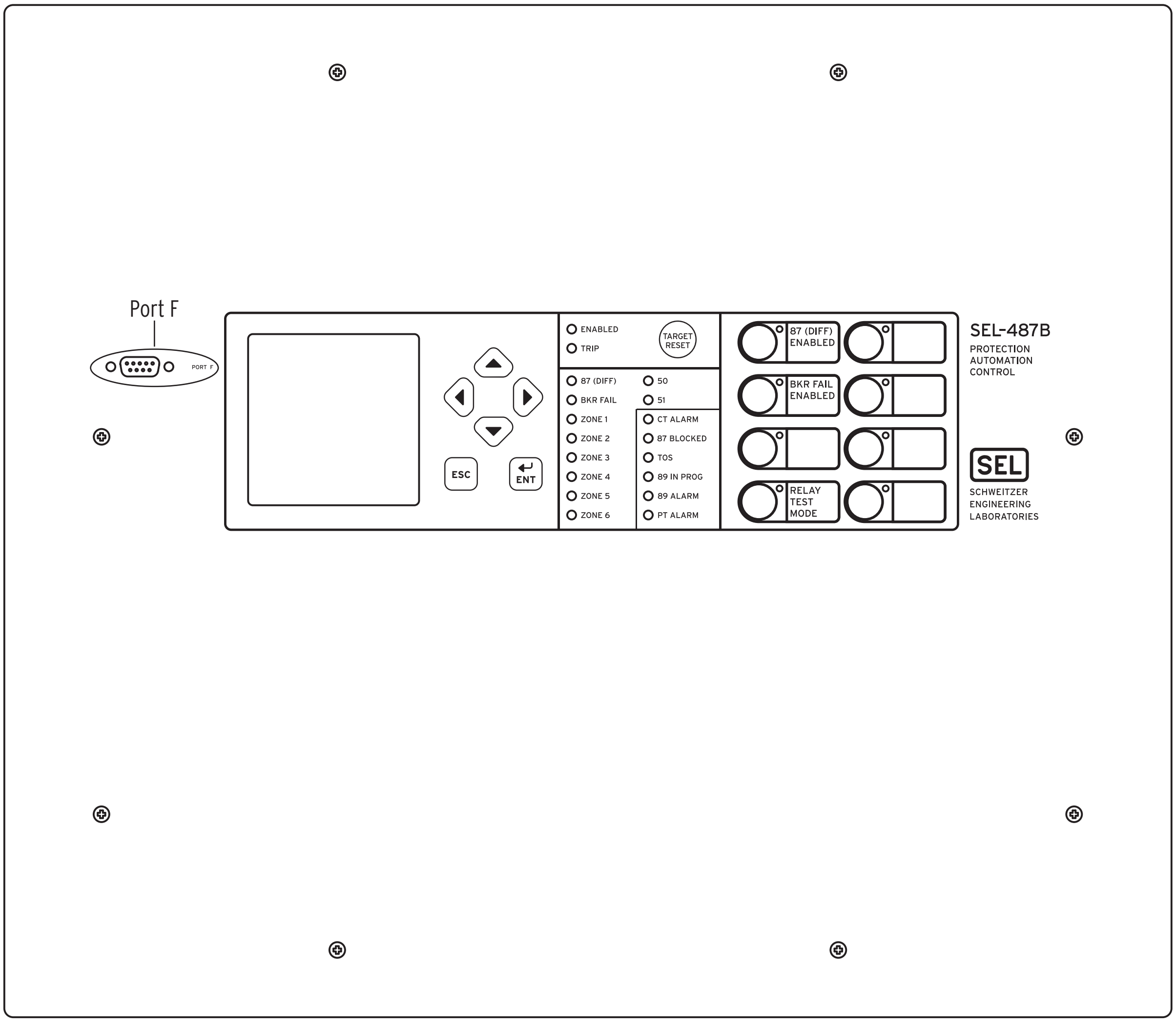

Figure 3.1 SEL-487B Front-Panel Layout (9U Version)

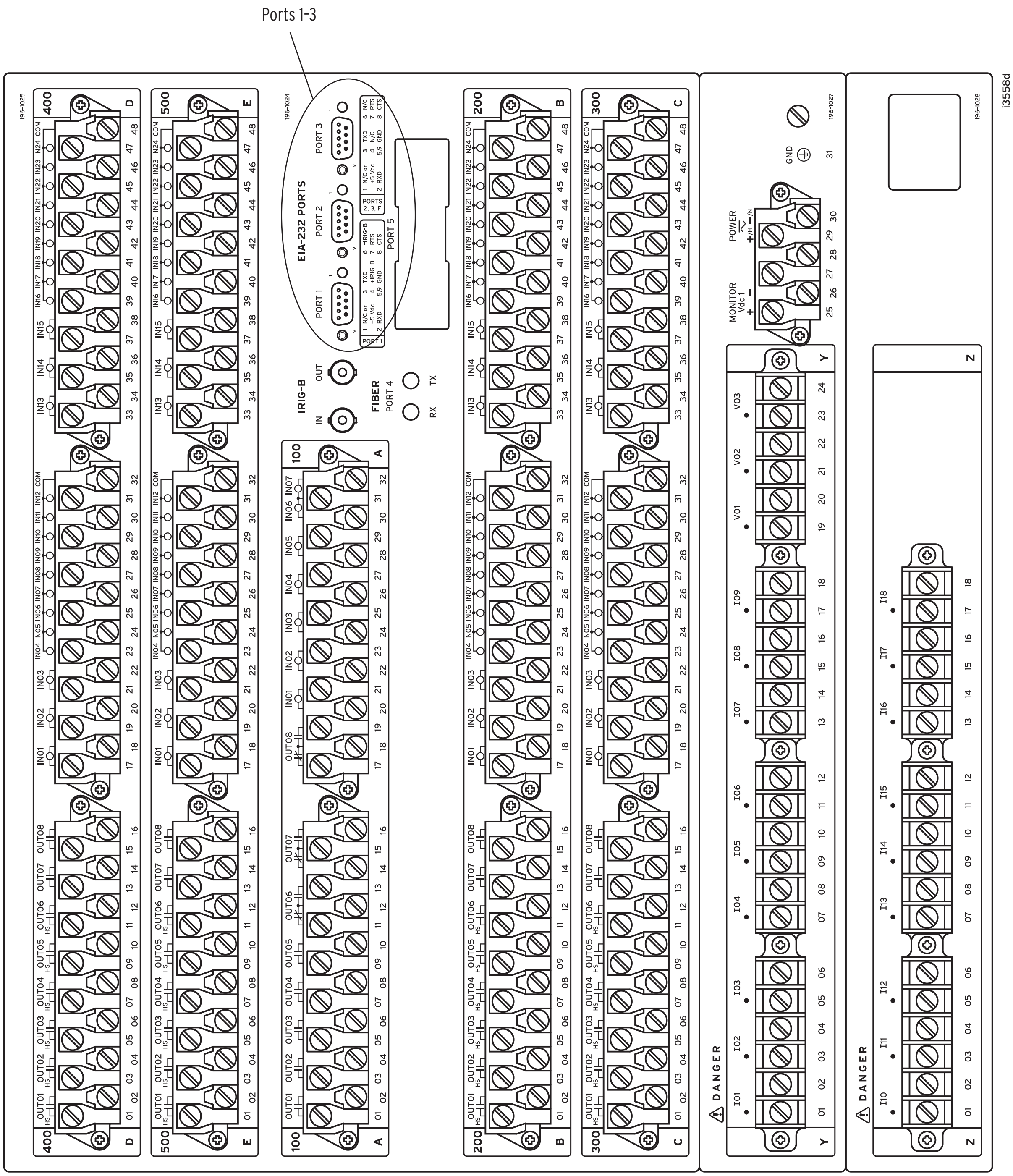

Figure 3.2 SEL-487B Rear-Panel Layout (9U Version)

The EIA-232 ports are standard female 9-pin connectors with the pin numbering shown in *Figure 3.3*. The pin functions are listed in *Table 3.2*. See the manual section listed in *Table 3.1* for a description of how the relay uses these pins with your specific protocol. Pin 1 can provide power to an external device. See *Serial Port Jumpers on page U.2.18* for more information on installing the jumper to provide voltage on Pin 1.

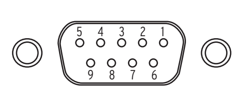

Figure 3.3 EIA-232 Connector Pin Numbers

Table 3.2 EIA-232 Pin Assignments

Pin	Signal Name	Description	Comments
1	5 Vdc	Modem power	Jumper selectable on Ports 1–3. No connection on Port F.
2	RXD	Receive data	
3	TXD	Transmit data	
4	+IRIG-B	Time code signal positive	Port 1 only. No connection on Ports F, 2, and 3.
5	GND	Signal ground	Also connected to chassis ground. See Note.
6	–IRIG-B	Time code signal negative	Port 1 only. No connection on Ports F, 2, and 3.
7	RTS	Request to send	
8	CTS	Clear to send	
9	GND	Chassis ground	See Note.

NOTE: Pins 5 and 9 are not intended to provide a chassis ground connection. See Section 2: Installation in the User's Guide.

EIA-232 Communications Cables

For most installations, you can obtain information on the proper EIA-232 cable configuration from the SEL-5801 Cable Selector Program from the SEL website at www.selinc.com. Using the SEL-5801 software, you can choose a cable by application. The software provides the SEL cable number with wiring and construction information so you can order the appropriate cable from SEL or construct one. If you do not see information for your application, contact SEL and we will assist you. You can obtain a copy of the SEL-5801 software by contacting SEL or from the SEL website www.selinc.com.

⚠CAUTION
Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use Standard null-modem cables with this equipment.

You can connect to a standard 9-pin computer port with SEL Cable C234A for relay configuration and programming with a terminal program or with the ACSELERATOR QuickSet® SEL-5030 software program.

Fiber-Optic Interface

You can add transceivers to the EIA-232 ports to use fiber-optic cables to connect devices. We strongly recommend that you use fiber-optic cables to connect devices within a substation. Power equipment and control circuit switching can cause substantial interference with communications circuits. You can also experience significant ground potential differences during fault conditions that can interfere with communications and damage equipment. Fiber-optic cables provide electrical isolation that increases safety and equipment protection.

Multimode

You can install one of the SEL-2800 family of transceivers on an SEL-487B EIA-232 port to provide a connection to multimode fiber-optic cable. All of these transceivers are port powered, require no settings, and operate automatically over a broad range of data rates. SEL-2800 series transceivers operate over the same wide temperature ranges as SEL relays, providing reliable operations in extreme conditions.

The SEL-2800 Fiber-Optic Transceiver/Modem provides conversion to multimode fiber-optic cable using V-pin connectors for applications as long as 500 m (1500 feet). The SEL-2810 Fiber-Optic Transceiver/Modem provides the same benefits as those from the SEL-2800, but the SEL-2810 also includes multiplexing of IRIG-B time synchronization signals with the data over the fiber-optic cable. Use the SEL-2810 to connect between any of the SEL communications processors and the SEL-487B to provide a path for both data and IRIG-B with a single pair fiber-optic cable.

For greater distances, or when cable installations require more power, the SEL-2815 Fiber-Optic Transceiver/Modem provides signal strength for distances as long as 15 km (9.4 miles) using standard ST connectors.

SEL also provides fiber-optic cables with terminations and bulk cable with splicing kits for use with these products. See the product flyers or the SEL website for the SEL-2800 series devices and SEL fiber-optic cable product flyers for more information on applications and specifications.

Single Mode

The SEL-2830 Single-Mode Fiber-Optic Transceiver/Modem provides media conversion from EIA-232 to single-mode fiber-optic cable. As with other SEL-2800 series devices, the SEL-2830 is port powered and needs no settings. You can apply the SEL-2830 with ST connector-terminated fiber-optic cables as long as 80 km (50 miles). See the product flyer for the SEL-2830 or the SEL website for more information on applications and specifications.

EIA-485

There is no EIA-485 port integral to the SEL-487B. You can install an SEL-2885 EIA-232 to EIA-485 Transceiver or SEL-2886 EIA-232 to EIA-485 Interface Converter to convert one of the rear-panel EIA-232 ports (Port 1–3) on the relay to an EIA-485 port. The SEL-2885 and SEL-2886 are powered by the +5 Vdc output on Pin 1. These transceivers offer transformer isolation not found on most EIA-232-to-EIA-485 transceivers. See the transceiver product flyers or the SEL website for more information.

The SEL-2885 offers the SEL distributed port switch (LMD) protocol. With this protocol you can selectively communicate with multiple devices on an EIA-485 network. You can communicate with other network nodes including EIA-232 devices with an SEL-2885 and SEL devices having integral EIA-485 ports. You can find more information about using SEL LMD protocol in *Section 4: SEL Communications Protocols*.

Table 3.3 summarizes the family of available transceivers.

Table 3.3 Summary of Available Transceivers

Transceiver	Mode	Distance
SEL-2800	Multimode	500 m
SEL-2810	Multimode	500 m
SEL-2815	Multimode	15 km
SEL-2830	Single mode	80 km

Communications Card

Port 5 of the SEL-487B is a communications card slot. You can either field install the optional communications card or order the relay with the card installed at the factory. The communications card slot provides an interface to SEL-2700 series communications cards. As with other SEL products, SEL has designed and tested SEL communications cards for operation in harsh environments.

Ethernet Card

The optional Ethernet card provides Ethernet communications for the SEL-487B. The Ethernet card is available with standard twisted pair and fiber-optic physical interfaces. The Ethernet card includes redundant physical interfaces with the capability to automatically transfer communications to the backup interface in the event that the primary network fails. For information on substation integration architectures, see *Section 4: SEL Communications Processor Applications*, *Direct Network Communication on page A.5.1*, *Section 5: DNP3 Communications*, and *Section 6: IEC 61850 Communications*.

Once installed in an SEL-487B, the Ethernet card settings become part of the relay settings. The card cannot be set directly—it must be set as relay PORT 5. The settings needed for network operation and data exchange protocols, including DNP3 and IEC 61850, are available in the PORT 5 settings.

Ethernet Network Operation Settings

Several settings control how the SEL-487B with the optional Ethernet card operates on an Ethernet network. These settings include IP addressing information, network port fail-over options, and network speed.

Network Configuration

Use the network configuration settings shown in *Table 3.4* to configure the SEL-487B for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation.

Table 3.4 Ethernet Card Network Configuration Settings (Sheet 1 of 2)

Label	Description	Range	Default
IPADDR	IP network address	IP address	192.92.92.92
SUBNETM	IP network subnet mask	IP address	255.255.255.0
DEFRTR	Default router	IP address	NA
ETCPKA[a]	TCP keep-alive functionality enable[a]	Y, N	Y
KAIDLE	Length of time to wait with no detected activity before sending a keep-alive packet	1–20 s (must be greater than or equal to KAINTV)	10
KAINTV	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet	1–20 s (must be less than or equal to KAIDLE)	1
KACNT	Maximum number of keep-alive packets to send	1–20	6
NETPORT	Primary network port (D disables all network ports)	A, B, D	A

Table 3.4 Ethernet Card Network Configuration Settings (Sheet 2 of 2)

Label	Description	Range	Default
FAILOVR	Automatic fail-over enable	Y, N	Y
FTIME	Fail-over time out	5–65535 ms	5
NETASPD[b]	Network speed or auto-detect on Port A	A, 10 Mbps, 100 Mbps	A
NETBSPD[b]	Network speed or auto-detect on Port B	A, 10 Mbps, 100 Mbps	A

[a] This setting applies only to IEC 61850 communications.
[b] This setting applies only to twisted-pair ports (10/100BASE-T).

The SEL-487B uses the IPADDR and SUBNETM settings to determine its local network and node address. The SUBNETM setting defines the subnet mask. The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

The SEL-487B uses the DEFRTR address setting to determine how to communicate with nodes on other local networks. The SEL-487B communicates with the default router to send data to nodes on other local networks. If you change the DEFRTR setting from the default value of Null (meaning that there is no default router), then the default router must be on the same local network as the SEL-487B or the SEL-487B will reject the DEFRTR setting. You must also coordinate the default router with your general network implementation and administration plan. See *Table 3.5* for examples of how IPADDR and SUBNETM define the network and node and how these settings affect the DEFRTR setting.

Table 3.5 DEFRTR Address Setting Examples

IPADDR	SUBNETM	Network Number	Node Address	DEFRTR
192.92.92.92	255.255.255.0	192.92.92	92	192.92.92.a[a]
192.92.92.92	255.255.0.0	192.92	92.92	192.92.a[a], b[a]
192.92.92.92	255.0.0.0	192	92.92.92	192.a[a], b[a], c[a]
192.92.92.92	0.0.0.0	n/a	192.92.92.92	a[a], b[a], c[a], d[a]

[a] Value in the range 0–255.

If the SEL-487B is purchased with IEC 61850 support, the ETCPKA setting, along with the KAIDLE, KAINTV, and KACNT settings, can be used to verify that the computer at the remote end of a TCP connection is still available. If ETCPKA is enabled and the SEL-487B does not transmit any TCP data within the interval specified by the KAIDLE setting, the SEL-487B sends a keep-alive packet to the remote computer. If the SEL-487B does not receive a response from the remote computer within the time specified by KAINTV, the keep-alive packet is re-transmitted as many as KACNT times. After this count is reached, the SEL-487B remote device is no longer available, so the SEL-487B can terminate the connection without waiting for the idle timer (TIDLE or FTPIDLE) to expire.

The SEL-487B Ethernet card operates over either twisted-pair or fiber-optic media. Each Ethernet card is equipped with two network ports. With an initial ordering option, you can select the medium for each port (10/100 Mbps twisted pair or 100 Mbps fiber optic). Speeds for the physical media are fixed for fiber-optic connections. For twisted-pair connections, the Ethernet card can auto-detect the network speed or you can set a fixed speed.

Network Port Fail-Over Operation

The SEL-487B Ethernet card has two network ports. Network port fail-over mode enables the Ethernet card to operate as a single network adapter with a primary and standby physical interface. You can connect the two network ports to the same network or different networks depending on your specific Ethernet network architecture. If you have a single network and want to use only one network port, set NETPORT to the port you want to use and set FAILOVR to N. Only one network port operates at a time. The fail-over mode operation determines the active port. To use fail-over mode, proceed with the following steps.

Step 1. Set NETPORT to the preferred network interface.

Step 2. Set FAILOVR to Y.

Step 3. Set FTIME to the desired network port fail-over time.

NOTE: If you change settings for the host port where the Ethernet card is installed and the standby network port is active, the Ethernet card resets and returns to operation on the primary port.

If the Ethernet card detects a link failure on the primary port, it activates the standby port after the fail-over time, FTIME, elapses. If the link status on the primary link returns to normal before the fail-over time expires, the fail-over timer resets; uninterrupted operation continues on the primary network port.

Network Address Resolution

The SEL-487B Ethernet card can resolve 20 network host names to corresponding IP addresses. Settings for Network Address Resolution (NAR) are shown in *Table 3.6*. The Ethernet card uses address resolution any place settings or commands require an IP network name. NAR is similar to DNS (Domain Name Services) used on the Internet, except that NAR uses a local name list rather than a remote name server. You can use names rather than numeric IP addresses for settings like DEFRTR (default router) or when using the Ethernet card **PING** command. If a remote network host name (HOST 1–Host 20) is set NA, then the Ethernet card ignores the corresponding IP address setting (IPADR 1–IPADR 20).

Table 3.6 IP Network Address Resolution Settings

Label	Description	Range	Default
HOST1	Remote network host name	16 characters	NA
IPADR1	Remote network host IP address	IP address	NA
HOST 2	Remote network host name	16 characters	NA
IPADR2	Remote network host IP address	IP address	NA
•			
•			
•			
HOST20	Remote network host name	16 characters	NA
IPADR20	Remote network host IP address	IP address	NA

Network Operation

Access data via the standard TCP/IP Telnet and FTP interfaces or through the DNP3 LAN/WAN or IEC 61850 interfaces. You cannot access all data through all interfaces. See *Figure 3.4* for details on data access.

The root directory contains the following files if the IEC 61850 protocol is installed and enabled:

➤ CID (Configured IED Description) file—contains the IEC 61850 SCL configuration for the SEL-487B

➤ ERR.TXT file—contains any errors found during downloading of the CID file, and is present when the download is complete

➤ CFG.XML file—contains the Ethernet card and SEL-487B configuration information

Data Access Settings

Access data using either the standard TCP/IP Telnet and FTP interfaces or, optionally, through the DNP LAN/WAN or IEC 61850 interface. You cannot access all data through all interfaces. See the appropriate interface section below for details on data access.

FTP

FTP is a standard application-level protocol for exchanging files between computers over a TCP/IP network. The SEL-487B Ethernet card operates as an FTP server. It presents Ethernet card and host files to FTP clients. The SEL-487B Ethernet card can support as many as three simultaneous FTP sessions, allowing simultaneous FTP access to as many as three separate users.

The host maintains the access control list that determines FTP log-in IDs and passwords. The host also determines which files are available. Some files are available at specific log-in levels, while other files are read-only access. Subsequent host-specific sections describe access control for each host.

File Structure

The basic file structure common to all hosts is organized as a directory and subdirectory tree similar to that used by Unix, DOS, Windows, and other operating systems. The root directory is "/" and has at least one subdirectory. The basic file structure is shown in *Table 3.7*.

Table 3.7 Basic File Structure

Host Directory	Subdirectories	Files
/	Host	See the host-specific sections for available files and directories.
	SEL-2702	DIAGNOSTICS.TXT ERR.TXT
	DD01_DeviceID	REGION1.TXT
	DD*nn_DeviceID*	REGION1.CAS • • • REGION*n*.TXT REGION*n*.CAS

The root directory contains the CID (Configured IED Description) file if the IEC 61850 is installed and enabled. An ERR.TXT file is present if there was an error in downloading the CID file.

The first subdirectory is for the host. Some hosts do not have a subdirectory. The HOST_ID string, if set, determines this subdirectory name. The Ethernet card strips any leading or following white-space characters. The Ethernet card then substitutes the "_" character for any white-space or delimiter characters. For example, if the HOST_ID is IED#983 Sub#45, then the host subdirectory name is IED_983_Sub_45. If the converted HOST_ID is longer than 31 characters, the host subdirectory name becomes the first 31 characters of the converted HOST_ID. The host subdirectory contains settings, reports, and diagnostic files for the host.

The next subdirectory is SEL-2702. This subdirectory contains the file DIAGNOSTICS.TXT that contains records for Ethernet card system failures. The time and date for the diagnostics file are the same as the time and date of the last system failure event. This directory will also contain the DNPMAP.TXT and DNPMAPx.TXT files if DNP LAN/WAN is enabled. The ERR.TXT file contains any error messages generated by the Ethernet card and host pertaining to these files.

The Ethernet card creates a subdirectory for each virtual device in the host. The subdirectory name is DD*nn_DeviceID*, where *nn* is the virtual device number and DeviceID is the device name derived from an identification string stored in the host that is associated with the virtual device. The Ethernet card uses the first identification string that it finds in the PORTID, DEVICEID, and FIDID strings. The same substitution rules that govern substitutions for the host subdirectory name govern creation of the substring. For example, if you have an SEL-351 connected to an SEL-2030 on Port 3 with a PORTID setting of "Feeder 1," the subdirectory name will be "DD03_Feeder_1."

Each virtual device subdirectory contains files that represent valid host data regions associated with the virtual device. Data region files provide snapshots of the corresponding host database regions. When an FTP client requests the file, the Ethernet card sends a file containing values from the host database region. If the voltage VA is 12.47 kV when you make an FTP request for the METER.TXT file, then the file METER.TXT will contain VA = 12.47. If you request the file at another time, when VA is 12.40, the file will contain VA = 12.40. Two file formats are available, ASCII text and compressed ASCII (CASCII). Names of the files correspond to the data region name (i.e. METER.TXT, METER.CAS).

Access Control

FTP settings control some basic file access features. The host is responsible for maintaining names and passwords for access control. The special FTP user name "anonymous" does not require a password. It has the same access rights as the user name in the FTPAUSR setting. For example, if FTPAUSR is set to ACC, the FTP anonymous user has Access Level 1 rights. See the host-specific sections for additional information about access rights. *Table 3.8* lists the settings that affect FTP server operation.

NOTE: SEL advises against enabling anonymous FTP logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP user name "anonymous." If you enable anonymous FTP logins, you are allowing unrestricted access to the Ethernet card and host files.

Table 3.8 SEL-2701 FTP Settings

Label	Description	Range	Default
FTPSERV[a]	FTP session enable	Y, N	N
FTPCBAN	FTP connect banner	254 characters	FTP SERVER:
FTPIDLE[a]	FTP connection timeout	5–255 minutes	5
FTPANMS[a]	Anonymous login enable	Y, N	N
FTPAUSR	Host user from which anonymous FTP client inherits access rights	See host-specific section	Empty String

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

Telnet

Telnet is also part of the TCP/IP protocol suite. You can use Telnet to establish terminal access to a remote device. A Telnet connection provides access to the user interface of either the host or the Ethernet card. Host user interface access is similar to an ASCII terminal connection to the front port of an SEL device.

You can use Telnet in the Ethernet card in one of three ways:

1. Connect from your PC to the Ethernet card user interface.
2. Connect from your PC to the host user interface.
3. Connect from a host to another Telnet server.

To determine which modes are available in your installation, see the host-specific section. The Ethernet card acts as a Telnet server for connections to the Ethernet card user interface. The user interface provides access to commands for diagnostics and other special features of the Ethernet card. Telnet settings are listed in *Table 3.9*.

Table 3.9 Ethernet Card Telnet Settings

Label	Description	Range	Default
T1CBAN	Host Telnet connect banner	254 characters	HOST TERMINAL SERVER:
T1INIT	Telnet session from host enable	Y, N	Y
T1RECV	Telnet session to host enable	Y, N	N
T1PNUM[a]	Host Telnet TCP/IP port	1–65534 except 20, 21, 102	23
T2CBAN	Ethernet card Telnet connect banner	254 characters	CARD TERMINAL SERVER:
T2RECV	Telnet session to Ethernet card enable	Y, N	N
T2PNUM[a]	Ethernet card Telnet TCP/IP port	1–65534 except 20, 21, 102	1024
TIDLE	Telnet connection timeout (0 prevents timeout)	0–255 minutes	5

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

Ethernet Card Commands

The SEL-487B Ethernet card user interface accepts Ethernet card commands. There are two ways you can connect to the Ethernet card. First, if your host allows, you can make a transparent connection to the Ethernet card. Second, you can establish a Telnet connection to the Ethernet card user interface. See the host-specific sections for more information on connecting to the Ethernet card user interface. Other connections to the Ethernet card, including FTP, require standard protocol commands and do not respond to the Ethernet card user-interface commands.

Using Commands

When you type commands, you can type in either the entire command or just use the first three letters. For example, if you type **STATUS <Enter>** or **STA <Enter>**, the Ethernet card displays status information. Commands are not case sensitive; you may use upper- or lowercase characters. Access level password entry is case sensitive. *Table 3.11* summarizes the user commands.

As with serial ports on SEL devices, you can control character transmission in a Telnet session using control characters. Send the control characters listed in *Table 3.10* to control long transmissions like event reports and SER reports.

Table 3.10 Control Characters

Control Characters	Key Commands	Results
XON	CTRL + Q	Restart paused transmission and enable subsequent transmissions.
XOFF	CTRL + S	Pause current transmission and block any subsequent transmissions.
CAN	CTRL + X	Cancel current transmission or command and return to cursor.

Command Summary

Table 3.11 summarizes the Ethernet card commands. Subsequent subsections provide full descriptions of each command in alphabetical order.

Table 3.11 SEL-2701 Command Summary

Command	Description	Access Level
2ACCESS	Go to Access Level 2.	1
ACCESS	Go to Access Level 1.	0 or 2
DATE	View or change date.	1[a] or 2
DNPMAP	Display data map(s) accessible to a DNP LAN/WAN master	1 or 2
GOOSE	Display GOOSE message multicast information and status for transmit and receive GOOSE messages.	1 or 2
HELP	Display available commands or command help.	Any
ID	View internal identification parameters for the Ethernet card.	1 or 2
MEMORY	Display RAM statistics for the Ethernet card.	1 or 2
PING	Ping another node on the network.	2
QUIT	Go to Access Level 0.	Any
STATUS	Display self-test status.	1 or 2
TIME	View or change internal clock.	1[a] or 2

[a] Limited functions at this access level. See command description below for details.

Access Levels

Access levels control whether you can perform different operations within SEL products. For example, at Access Level 1, you can view settings. You cannot change settings unless you are at Access Level 2. A complete list of access levels for the SEL-487B is shown in *Table 3.12*.

Table 3.12 SEL-2701 Access Levels

Access Level	Prompt	Allowed Ethernet Card User-Interface Operations
0	#	Log in to Access Level 1.
1	#>	View data and status information.
2	#>>	Perform all Access Level 1 functions plus advanced diagnostics and set date/time.

Each access level has a password. The Ethernet card uses passwords set in the host for the same access level. For example, if you have an SEL-2032 and Ethernet card, and have set the SEL-2032 Access Level 2 password to SUB35L2, then SUB35L2 is the password for Access Level 2 on your Ethernet card.

The Ethernet card uses access levels and passwords in two ways. First, if you are connected to the Ethernet card user interface, the Ethernet card limits command access based on your access level. You are connected to the Ethernet card user interface if you are using a terminal or Telnet program and see one of the prompts shown in *Table 3.12*. For example, if your Ethernet card is installed in an SEL-2032, you can Telnet to the Ethernet card or make a transparent connection from one of the SEL-2032 serial ports to the Ethernet card.

Second, the Ethernet card uses access level names and passwords as user names and passwords for protocols that require you to log in to establish a connection. For example, if you are making an FTP connection to the Ethernet card, you will be prompted for an FTP user name and password. In this case, use host access levels and passwords to connect. Use the host access level for the FTP user name and the corresponding password for the FTP password. Access levels are listed with corresponding passwords in *Table 3.13*.

Table 3.13 Access Level User Names and Passwords

Access Level	User Name	Password
0	QUI	None
1	ACC	User-definable
2	2AC	User-definable

Connections that are closed manually by ending the network connection or by using the Ethernet card **QUIT** command are terminated. This means that to reestablish the connection and return to the original access level, you must log in using the access level commands and passwords.

When a connection with the Ethernet card or the host “times out,” the connection is closed and the access level is reduced to 0. There is a timeout setting associated with connections to the Ethernet card and connections to the host through the Ethernet card. The timeout settings and their specific operation are described in the host-specific sections.

Access failures cause the Ethernet card to close connections, assert the alarm bit, and prevent connections for a variable delay period.

2ACCESS

Use the **2ACCESS** command to change to Access Level 2. If the current level is not Access Level 1, the Ethernet card responds with “Invalid access level.” When you enter the **2AC** command, the Ethernet card prompts you to enter the Access Level 2 password. If the password is Null or you enter the password set in the host, the access level changes to Access Level 2. Passwords are case sensitive; you must enter them exactly as set. The host maintains the password and user list. For more details, see the host-specific sections.

If you are unable to enter the correct password after the third failed attempt, the Ethernet card asserts the ALARM bit in the Status register and terminates the connection for some connection types. See the host-specific sections for more information on how your host uses the ALARM bit from the Ethernet card.

If your connection to the Ethernet card has an inactivity timeout, the Ethernet card automatically closes the connection and changes to Access Level 0 when the timeout expires.

ACCESS

Use the **ACCESS** command to change to Access Level 1. For example, if you are at Access Level 0, the Ethernet card prompts you for the password and moves you to Access Level 1 if you enter the password correctly. For additional details on access level commands, see *2ACCESS*.

DATE

Table 3.14 illustrates how to use the **DATE** command to view or set the date.

Table 3.14 DATE Command

Command	Description
DATE	Display internal Ethernet card date.
DATE mm/dd/yyyy	Set the date if the date format setting for the host is mm/dd/yyyy, where mm is the month, dd is the day of month, and yyyy is the year.
DATE dd/mm/yyyy	Set the date if the date setting for the host is dd/mm/yyyy.
DATE yyyy/mm/dd	Set the date if the date setting for the host is yyyy/mm/dd.

The **DATE** command displays the internal clock date. A setting in the host determines the date format. In order to avoid confusion, the Ethernet card displays the date format along with the date. For example, if you set the host for a European style date, the Ethernet card displays the current date and the date format text “dd/mm/yyyy.” The date format options are mm/dd/yyyy, dd/mm/yyyy, and yyyy/mm/dd.

Use the **DATE** command with a date to set the internal clock date. Enter the year in four-digit form. Enter the date in a form that matches the date form of the host. Because there is no way to differentiate between mm/dd/yyyy and dd/mm/yyyy for certain dates (02/03/2001 could be February 3 or March 2), check the date format before entering the date. To see the date format, use the **DATE** command.

DNPMAP

Use the **DNPMAP** command to display the data (object types, indices, default variation and source) and controls (object type, indices and destination) that are accessible via DNP3. The output of the **DNPMAP** command documents the DNP3 data map in the SEL-487B to help with the configuration of the DNP3 master.

If the DNPMAP setting is set to CUSTOM, then an additional integer parameter corresponding to an assigned DNPMAP number (1–5) must be specified to view each custom DNP3 data map. For example, the command **DNPMAP 2** would be used to view the custom data map for DNP session 2. If a DNPMAP number is not specified, a summary of DNP3 map settings for all configured sessions will be displayed.

Summary and detailed map configurations are also available in the DNPMAP.TXT and DNPMAP*nn*.TXT files from the Ethernet card FTP interface. The individual file names associated with the detailed custom map settings follow the DNPMAP*nn*.TXT naming convention.

GOOSE

This command outputs the GOOSE multicast information and status for every GOOSE transmit and receive message connected to the SEL-487B.

The multicast information displayed includes:

Field	Description
GOOSE Control Reference	A concatenation of the IED name, LN0 lnClass (Logical Node Class) and GSEControl name (GSE Control Block Name)
Multicast Address (MultiCastAddr)	Hexadecimal representation of the multicast addresses
Priority Tag (Ptag)	VLAN priority tag (3-bit decimal). If the priority tag is unknown, then empty spaces will be displayed in lieu of the value.
VLAN	Virtual LAN Setting (12-bit decimal value). If the Virtual LAN setting is unknown, then empty spaces will be displayed in lieu of a decimal value.

The status information includes:

Field	Description
State Number (StNum)	Increments each time a state changes
Sequence Number (SqNum)	Increments each time a GOOSE message is sent
Time to Live (TTL)	Remaining time in ms before the next message is expected
Code	Indicate a warning or error condition. See below for descriptions.

The Status codes are abbreviated as:

Code Abbreviation	Description
OUT OF SEQUENC	Out of sequence error
CONF REV MISMA	Configuration Revision mismatch
NEED COMMISSIO	Needs Commissioning
TEST MODE	Test Mode
MSG CORRUPTED	Message Corrupted
TTL EXPIRED	Time to live expired
HOST DISABLED	Host disabled/not responding

Examples of GOOSE command outputs follow:

```
#>>GOO <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------
SEL_2701_GOOSE/LLN0$GO$GooseDSet1
   01-03-A7-00-00-01  2:5     1256       347        6
   Data Set: SEL_2701_GOOSE/LLN2$Master

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------
SEL-2701/LLN0$GO$GooseDSet13
   01-03-A7-00-00-01  3:1     1253758689 4786543985 123456 MSG CORRUPTED
   Data Set: SEL-2701-2/LLN0$Positions

GE-F60/LLN0$GO$GEGooseDSet
   01-03-A7-00-00-01  3:23    12568945   34         0      TTL EXPIRED
   Data Set: GE-F60/LLN1$Station1

GE-C30/LLN0$GO$GEGooseDSet
   01-03-A7-00-00-01  3:343   1945       34456      456
   Data Set: GE-C30/LLN2$Terminal

COOPER-EDISONPRO/LLN0$GO$CooperGooseDSet
   01-03-A7-00-00-01  3:4987  45         347        123456
   Data Set: COOPER-EDISONPRO/LLN2$Transmission

SEL-351-RECLOSING_DIRECTIONAL_OVERCURRENT/LLN0$GO$GooseDSet
   01-03-A7-00-00-01  3:5     12568945   34783456   123456
   Data Set: SEL-351-RECLOSING_DIRECTIONAL_OVERCURRENT/LLN3$Recloser

GEC_ALSTOM_123/LLN0$GO$GECGooseDSet
   01-03-A7-00-00-01  3:643   12568      56         126    MSG CORRUPTED
   Data Set: GEC_ALSTOM_123/LLN2$Relay

#>>
```

No GOOSE receive and/or GOOSE transmit subscriptions:

```
##>>GOO <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum   SqNum   TTL      Code
----------------------------------------------------------------------------
No GOOSE Tx subscriptions available

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum   SqNum   TTL      Code
----------------------------------------------------------------------------
No GOOSE Rx subscriptions available

##>>
```

GOOSE is disabled by settings (EGSE := N):

```
#>GOO <Enter>

GOOSE is disabled by settings. No GOOSE statistics available.

#>
```

Error during the processing of the IEC 61850 CID file:

```
#>GOO <Enter>

Error detected in the CID file parsing. All GOOSE processing disabled.

#>
```

GOOSE command is executed during CID file processing:

```
#>GOO <Enter>

CID file is currently being parsed. No GOOSE statistics available.

#>
```

SEL-487B is disabled (after CID file parsed successfully):

```
#>GOO <Enter>

Host Disabled. All GOOSE processing disabled.

#>
```

The **GOOSE** command supports only one optional parameter, *cnt*. The *cnt* parameter causes the **GOOSE** command to be repeated *cnt* times. The valid range of *cnt* is from 1–65535; and the default value of *cnt* is 1.

HELP

Because only a limited set of commands may be available at your current access level, you may want to display a list of available commands. Use the **HELP** command to display a list of available commands for your current access level. The **HELP** command format and options are shown in *Table 3.15*.

Table 3.15 HELP Command Options

Command	Description
HELP	Display command information for the current access level.
HELP command	Display information for a specific command.

ID

It may be necessary to identify the firmware version of your Ethernet card for diagnostic purposes or to verify that it is compatible with the firmware version of your host. Use the **ID** command to identify the firmware version and several other internal parameters for your Ethernet card. The information displayed by the **ID** command is described in *Table 3.16*.

Table 3.16 ID Command Internal Parameters Displayed

Parameter	Description
FID	Firmware ID
BFID	SELBOOT Firmware ID
CID	Firmware Checksum
DEVID	Device ID
PARTNO	Part Number
CONFIG	Configuration ID

If the Ethernet card includes the IEC 61850 protocol option and the protocol is enabled (E61850 := Y), the ID command will display the following additional information:

- iedName: the IED name (e.g., SEL_487B_OtterTail)
- type: the IED type (e.g., SEL_487B)
- configVersion: the CID file configuration version (e.g., ICD-487B-R100-V0-Z001001-D20060512)

If the Ethernet card encounters an error while parsing the CID file, the value of the iedName, type, and configVersion fields shall be set to `PARSE FAILURE`; otherwise, the fields shall contain the CID file values as shown in the examples above.

MEMORY

The **MEMORY** command is a diagnostic command for determining if the Ethernet card is using onboard RAM properly. Use the **MEMORY** command to display RAM statistics for the following areas: memory in use, free memory, free memory blocks, and bytes in largest available block.

PING

When you are setting up or testing substation networks, it is helpful to determine if the network is connected properly and if the other devices are powered up and configured properly. Use the **PING** command to determine if another node on the network is available and connected to the network. The Ethernet card sends ping messages to the remote node until you interrupt the Ethernet card by pressing **<Enter>**. Command options for the **PING** command are shown in *Table 3.17*.

Table 3.17 PING Command Options

Command	Description
PING addr	Ping the address represented by addr every second.
PING addr n	Ping the address addr once every n seconds, where n is a value from 1–255.

The **PING** command requires the *addr* parameter, which can either be a name in the NAR table for the host, or an actual IP address. In response to the **PING** command, the Ethernet card displays the status of each ping attempt. When you stop the ping process, the Ethernet card displays several statistics to summarize the ping attempts.

QUIT

To close your connection to the Ethernet card and start a connection to another device without closing your terminal application, use the **QUIT** command. For example, use **QUIT** to log out and automatically terminate a Telnet session. You may then open a new Telnet session from your Telnet application. You can also use the **QUIT** command to log out of the Ethernet card for security purposes when the connection will not be closed. For example, if you are connected to an Ethernet card in a host from one of the host serial ports, you can log out without closing the transparent connection to the Ethernet card.

STATUS

Use the **STATUS** command to display the self-test status and configuration of the Ethernet card. The Ethernet card displays self-test results as either OK or FAIL. The Ethernet card displays network configuration information and network statistics.

If the Ethernet card includes the IEC 61850 protocol option and the protocol is enabled (E61850 := Y), the card shall append an error message to the output of the **STATUS** command if it fails to successfully parse the current CID file.

```
#> STA <Enter>
ETHERNET PROCESSOR WITH IEC 61850 AND DNP                TIME: 14:11:25

FID=SEL-2702-R107-V2-Z000000-D20071225
BFID=SLBT-2701-R103-V0-Z000000-D19981001
  MAC: 00-30-A7-00-01-01

  SELF-TEST
   RAM       SRAM      EXE       SLBT      SETTINGS  STORAGE   CONFIG    HOST
   OK        OK        OK        OK        OK        OK        OK        OK

              PORT      MEDIA           SPEED
  PRIMARY     B         10/100 BASE-T   100
  STANDBY     A         10/100 BASE-T   100
  ACTIVE PORT:  PRIMARY   LINK OK

  IP ADDRESS: 192.168.0.97
  SUBNET MASK: 255.255.0.0
  DEFAULT ROUTER: 192.168.0.1

  PACKETS:      IP                    BYTES:       IP
   SENT:        33                     SENT:       2051
   RECEIVED:    48                     RECEIVED:   3780

  CONNECTIONS:                        ERRORS DETECTED:
   LISTENING:   6                      SENT:       0
   ACTIVE:      1                      RECEIVED:   0

Error detected in the CID file parsing. All IEC61850 processing disabled.

#>
```

TIME

The **TIME** command is described in *Table 3.18*.

Table 3.18 TIME Command

Command	Description	Access Level
TIME	Display internal clock date.	1 or 2
TIME hh:mm	Set internal clock time to hh hours (24 hour time), mm minutes and 0 seconds.	2
TIME hh:mm:ss	Set internal clock time to hh hours (24 hour time), mm minutes, and ss seconds.	2

Some hosts support time synchronization of the Ethernet card from the host or time synchronization of the host from the Ethernet card. See the host-specific section for more information on time synchronization.

Communications Card Database

The SEL-487B presents a database to an installed communications card. This database includes a variety of data within the relay that are available for the communications card. The database includes the regions and data described in *Table 3.19*. Use the **MAP** and **VIEW** commands to display maps and contents of the database regions. See *Section 7: ASCII Command Reference on page 7.1* for more information.

Table 3.19 Communications Card Database Regions

Region Name	Contents	Update Rate
LOCAL	Relay identification data including FID, Relay ID, and active protection settings group	Updated on settings change and whenever monitored values change
METER	Real-time metering and measurement data	0.5 s
TARGET	Selected rows of Relay Word bit data	0.5 s
HISTORY	Relay event history records for the 20 most recent events	Within 15 s of any new event
STATUS	Self-test diagnostic status data	5 s
ANALOGS	Protection and automation math variables	0.50 s
STATE	Elements defined as SER points	0.5 s of any new event
D1	Analog Output points from SEL 27*xx* card	N/A

Data within the communications card regions is available for mapping to any protocol over the Ethernet interface.

The LOCAL region contains the device FID, SID, and RID. It will also provide appropriate status points. This region is updated on settings changes and whenever monitored status points change. See *Table 3.19*.

Table 3.20 SEL-487B Communications Card Database Structure—LOCAL Region

Address (Hex)	Name	Type	Description
0000	FID	char[48]	FID string
0030	BFID	char[48]	SELboot FID string
0060	SER_NUM	char[16]	Device Serial number, from factory settings
0070	PART_NUM	char[18]	Device part number, from factory settings
0082	CONFIG	char[8]	Device configuration string (as reported in **ID** command)
008A	SPECIAL	char[8]	Special device configuration string (as reported in **ID** command)
0092	DEVICE_ID	char[40]	Relay ID setting, from global settings
00BA	NODE_ID	char[40]	Station ID from global settings
00E2	GROUP	int	Active group
00E3	STATUS	int	Bit map of status flags: 0 for okay, 1 for failure

The METER region contains all the basic meter and energy information. This region is updated every 0.5 seconds. See *Table 3.21* for the Map.

Table 3.21 SEL-487B Communications Card Database Structure—METER Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
1000	_YEAR	int	4-digit year when data was sampled
1001	DAY_OF_YEAR	int	1–366 day when data was sampled
1002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
1004	FREQ	float	System frequency
1006	VDC	float	Battery voltage
1008, 100A	I01	float[2]	I01 current magnitude (Amps primary) and phase (degrees)
100C, 100E	I02	float[2]	I02 current magnitude (Amps primary) and phase (degrees)
1010, 1012	I03	float[2]	I03 current magnitude (Amps primary) and phase (degrees)
1014, 1016	I04	float[2]	I04 current magnitude (Amps primary) and phase (degrees)
1018, 101A	I05	float[2]	I05 current magnitude (Amps primary) and phase (degrees)
101C, 101E	I06	float[2]	I06 current magnitude (Amps primary) and phase (degrees)
1020, 1022	I07	float[2]	I07 current magnitude (Amps primary) and phase (degrees)
1024, 1026	I08	float[2]	I08 current magnitude (Amps primary) and phase (degrees)
1028, 102A	I09	float[2]	I09 current magnitude (Amps primary) and phase (degrees)
102C, 102E	I10	float[2]	I10 current magnitude (Amps primary) and phase (degrees)
1030, 1032	I11	float[2]	I11 current magnitude (Amps primary) and phase (degrees)
1034, 1036	I12	float[2]	I12 current magnitude (Amps primary) and phase (degrees)
1038, 103A	I13	float[2]	I13 current magnitude (Amps primary) and phase (degrees)
103C, 103E	I14	float[2]	I14 current magnitude (Amps primary) and phase (degrees)
1040, 1042	I15	float[2]	I15 current magnitude (Amps primary) and phase (degrees)
1044, 1046	I16	float[2]	I16 current magnitude (Amps primary) and phase (degrees)
1048, 104A	I17	float[2]	I17 current magnitude (Amps primary) and phase (degrees)
104C, 104E	I18	float[2]	I18 current magnitude (Amps primary) and phase (degrees)
1050	RSRVD1	float[12]	Reserved for 6 future currents; always report as 0
1068, 106A	V01	float[2]	V01 voltage magnitude (Volts primary) and phase (degrees)

Table 3.21 SEL-487B Communications Card Database Structure—METER Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
106C, 106E	V02	float[2]	V02 voltage magnitude (Volts primary) and phase (degrees)
1070, 1072	V03	float[2]	V03 voltage magnitude (Volts primary) and phase (degrees)
1074	RSRVD2	float[6]	Reserved for 3 future voltages; always report as 0
1080	IOP1	float	Zone 1 Operating Current (per unit)
1082	IOP2	float	Zone 2 Operating Current (per unit)
1084	IOP3	float	Zone 3 Operating Current (per unit)
1086	IOP4	float	Zone 4 Operating Current (per unit)
1088	IOP5	float	Zone 5 Operating Current (per unit)
108A	IOP6	float	Zone 6 Operating Current (per unit)
108C	IRT1	float	Zone 1 Restraint Current (per unit)
108E	IRT2	float	Zone 2 Restraint Current (per unit)
1090	IRT3	float	Zone 3 Restraint Current (per unit)
1092	IRT4	float	Zone 4 Restraint Current (per unit)
1094	IRT5	float	Zone 5 Restraint Current (per unit)
1096	IRT6	float	Zone 6 Restraint Current (per unit)

The TARGET region contains the entire relay word plus the rows designated specifically for the TARGET region. This region is updated every 0.5 seconds. See *Table 3.22* for the Map. See *Appendix A: Relay Word Bits* in the Reference Manual for detailed information on Relay Word bits.

Table 3.22 SEL-487B Communications Card Database Structure—TARGET Region

Address (Hex)	Name	Type	Description
3000	_YEAR	int	4-digit year when data was sampled
3001	DAY_OF_YEAR	int	1–366 day when data was sampled
3002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
3004	TARGET	char[~393]	Entire Relay Word with some bit labels

The HISTORY region contains all information available in a History report for the most recent 10 events. This region is updated within 15 seconds of any new events. See *Table 3.23* for the Map.

Table 3.23 SEL-487B Communications Card Database Structure—HISTORY Region

Address (Hex)	Name	Type	Description
4000	_YEAR	int	4-digit year when data was sampled
4001	DAY_OF_YEAR	int	1–366 day when data was sampled
4002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
4004	REF_NUM	int[10]	Event serial number
400E	MONTH	int[10]	Month of event
4018	DAY	int[10]	Day of event
4022	YEAR	int[10]	Year of event
402C	HOUR	int[10]	Hour of event
4036	MIN	int[10]	Minute of event
4040	SEC	int[10]	Second of event
404A	MSEC	int[10]	Milliseconds of event
4054	EVENT	char[60]	Event type string
4090	GROUP	int[10]	Active group during fault
409A	TARGETS	char[160]	System targets from event

The STATUS region contains complete relay status information. This region is updated every 5 seconds. See *Table 3.24* for the Map.

Table 3.24 SEL-487B Communications Card Database Structure—STATUS Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
6000	_YEAR	int	4-digit year when data was sampled
6001	DAY_OF_YEAR	int	1–366 day when data was sampled
6002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
6004	CH1_24(mV)	int	Channel offsets, use 0 if not measured
601C	MOF(mV)	int	Master offset
601D	MOF2(mV)	int	Master offset 2
601E	OFF_WARN	char[8]	Offset warning string
6026	OFF_FAIL	char[8]	Offset failure string
602E	PS3(V)	float	3.3 Volt power supply voltage
6030	PS5(V)	float	5 Volt power supply voltage
6032	PS_N5(V)	float	–5 Volt regulated voltage
6034	PS15(V)	float	15 Volt power supply voltage
6036	PS_N15(V)	float	–15 Volt power supply voltage
6038	PS_WARN	char[8]	Power supply warning string
6040	PS_FAIL	char[8]	Power supply failure string
6048	HW_FAIL	char[40]	Hardware failure strings
6070	CC_STA	char[40]	Comm. card status strings
6098	PORT_STA	char[160]	Serial port status strings

Table 3.24 SEL-487B Communications Card Database Structure—STATUS Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
6138	TIME_SRC	char[10]	Time source
6142	LOG_ERR	char[40]	SELOGIC error strings
616A	TEST_MD	char[160]	Test mode string

The ANALOGS region contains protection and automation variables. This region is updated every 0.5 seconds. See *Table 3.25* for the Map.

Table 3.25 SEL-487B Communications Card Database Structure—ANALOGS Region

Address (Hex)	Name	Type	Description
7000	_YEAR	int	4-digit year when data was sampled
7001	DAY_OF_YEAR	int	1–366 day when data was sampled
7002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
7004	PMV01_64	float[64]	PMV01–PMV64
7084	AMV001_256	float[256]	AMV001–AMV256

The STATE region contains elements defined with the **SET R** command and an attached SOE queue that holds up to 100 records. The relay updates this region within 0.5 seconds of any new events. Communications card protocols that require state changes with SOE-quality timestamps must retrieve this data from the STATE region. See *Table 3.26* for the Map. See *DNP LAN/WAN Application Example on page R.5.56* for DNP LAN/WAN implementation details.

Table 3.26 SEL-487B Communications Card Database Structure—STATE Region

Address (Hex)	Name	Type	Description
8000	_YEAR	int	4-digit year when data was updated
8001	DAY_OF_YEAR	int	1–366 day when data was updated
8002	TIME(ms)	long int	Time of day in msec when data was updated (0–86,400,000)
8004	ELEMENTS	int[16]	250 Relay Word bits defined to be SER points; SER point 1 goes in first register bit 0,...
8014	CARD_SER	int[8]	128 Relay Word bits defined to be SER points from R CC settings

The D1 region registers map to the relay's Analog Output points (Remote Analogs) RA001–RA256. See *Table 3.27* for the Map.

Table 3.27 SEL-487B Communications Card Database Structure—D1 Region

Address (Hex)	Name	Type	Description
9000–97FF	RA001–RA256	int	Remote Analog Output points from SEL-27*xx* card

The communications card database is virtual device 1 in the relay. You can display the contents of a region using the **MAP 1:region** command (where region is one of the database region names listed in *Table 3.3*). An example of the **MAP** command is shown in *Figure 3.4*.

```
=>>MAP 1:METER <Enter>

Virtual Device 1, Data Region METER Map

Data Item       Starting Address  Type
_YEAR           1000h             int
DAY_OF_YEAR     1001h             int
TIME(ms)        1002h             long int
FREQ            1004h             float
VDC             1006h             float
I01             1008h             float[2]
I02             100Ch             float[2]
I03             1010h             float[2]
I04             1014h             float[2]
I05             1018h             float[2]
I06             101Ch             float[2]
I07             1020h             float[2]
I08             1024h             float[2]
I09             1028h             float[2]
I10             102Ch             float[2]
I11             1030h             float[2]
I12             1034h             float[2]
I13             1038h             float[2]
I14             103Ch             float[2]
I15             1040h             float[2]
I16             1044h             float[2]
I17             1048h             float[2]
I18             104Ch             float[2]
RSRVD1          1050h             float[12]
V01             1068h             float[2]
V02             106Ch             float[2]
V03             1070h             float[2]
RSRVD2          1074h             float[6]
IOP1            1080h             float
IOP2            1082h             float
IOP3            1084h             float
IOP4            1086h             float
IOP5            1088h             float
IOP6            108Ah             float
IRT1            108Ch             float
IRT2            108Eh             float
IRT3            1090h             float
IRT4            1092h             float
IRT5            1094h             float
IRT6            1096h             float
```

Figure 3.4 MAP 1:METER Command Example

Section 4

SEL Communications Protocols

Overview

This section describes features of the SEL-487B Relay communications protocols and includes the following topics:

- ➤ Serial port hardware protocol
- ➤ Software protocol selections
- ➤ SEL ASCII, Compressed ASCII, and Binary protocols
- ➤ Virtual file interface
- ➤ SEL MIRRORED BITS® communications
- ➤ SEL Distributed Port Switch Protocol (LMD) using the SEL-2885 EIA-232 to EIA-485 Transceiver

Serial Port Hardware Protocol

The SEL-487B serial ports comply with the EIA-232 Standard, commonly referred to as EIA-232. The serial ports support RTS/CTS hardware flow control. See also *Software Flow Control on page R.4.7*.

Hardware Flow Control

Hardware handshaking is one form of flow control that two communicating serial devices use to prevent input buffer information overflow and loss of characters. To support hardware handshaking, connect the RTS output pin of each device to the CTS input pin of the other device. To enable hardware handshaking, use the **SET P** ASCII command (or the front-panel sequence `ROTATING DISPLAY`, `MAIN MENU`, `SET/SHOW`, `PORT`, *n*, `Communications Settings`, `RTSCTS`) to set RTSCTS := Y. Disable hardware handshaking by setting RTSCTS := N. *Table 4.1* shows actions the relay takes for the RTSCTS setting values and the conditions relevant to hardware flow control.

Table 4.1 Hardware Handshaking

Setting RTSCTS Value	Condition	Relay Action
N	All	Assert RTS output pin and ignore CTS input pin.
Y	Normal input reception	Assert RTS output pin.
Y	Local input buffer is close to full	Deassert RTS pin to signal remote device to stop transmitting.
Y	Normal transmission	Sense CTS input is asserted, transmit normally.
Y	Remote device buffer is close to full, so remote device deasserts RTS	Sense CTS input is deasserted, stop transmitting

Note that the relay must assert the RTS pin to provide power for some modems, fiber-optic transceivers, and hardware protocol converters that are port powered. Check the documentation for any port-powered device to determine if the device supports hardware handshaking or if you must always assert RTS (RTSCTS := N) for proper operation.

Data Frame

The relay ports use asynchronous data frames to represent each character of data. Four port settings influence the framing: SPEED, DATABIT, PARITY, and STOPBIT. The time allocated for one bit is the reciprocal of the SPEED. For example, at 9600 bits per second, one bit-time is 0.104 milliseconds (ms).

The default port framing uses one start bit, 8 data bits, no parity bit, and one stop bit. The transmitter asserts the TXD line for one data frame, as described in the following steps:

The TXD pin normally is in a deasserted state.

- ➤ To send a character, the transmitter first asserts the TXD pin for one bit time (start bit).
- ➤ For each data bit, if the bit is set, the transmitter asserts TXD for one bit time. If the bit is not set, it deasserts the pin for one bit time (data bits).
- ➤ If the PARITY setting is E, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an even number. If the PARITY setting is O, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an odd number. If the PARITY setting is N, the data frame does not include a parity bit.
- ➤ At the completion of the data bits and parity bit (if any), the transmitter deasserts the line for one bit time (stop bit). If STOPBIT is set to 2, the transmitter deasserts the line for one more bit time (stop bit).
- ➤ Until the relay transmits another character, the TXD pin will remain in the unasserted state.

Software Protocol Selections

The SEL-487B supports the protocols and command sets shown in *Table 4.2*.

Table 4.2 Supported Serial Command Sets

PROTO Setting Value	Command Set	Description
SEL	SEL ASCII	Commands and responses
SEL	SEL Compressed ASCII	Commands and comma-delimited responses
SEL	SEL Fast Meter	Binary meter and digital element commands and responses
SEL	SEL Fast Operate	Binary operation commands
SEL	SEL Fast SER	Binary SER commands and responses
MBA or MBB	SEL MIRRORED BITS communications	Binary high-speed control commands
DNP	DNP3 Slave Level 2	Binary commands and responses See *Section 5: DNP3 Communications*.

Virtual Serial Ports

Actual serial ports are described in *Serial Port Hardware Protocol on page R.4.1*. In addition to actual serial ports, the SEL-487B supports several virtual serial ports. A virtual serial port does the following:

- Transmits and receives characters through a different mechanism than the physical serial port
- Encapsulates characters in virtual terminal messages of a different protocol
- Simulates an actual serial port with setting PROTO := SEL
- May have restrictions imposed by the protocol that encapsulates the virtual serial data

You can set the SEL-487B to use virtual serial ports encapsulated in SEL MIRRORED BITS communications links, DNP3 links, and through the Telnet mechanism of an installed Ethernet card.

Protocol Active When Setting PROTO := SEL

This subsection describes the command sets for the SEL protocols that are active when the port setting PROTO := SEL. You can also access these protocols through virtual serial ports that simulate ports with PROTO := SEL.

SEL ASCII Commands

We originally designed SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands.

The ASCII character set specifies numeric codes that represent printing characters and control characters. The complete ASCII command set is shown in *Section 7: ASCII Command Reference*. *Table 4.3* shows the subset of the ASCII control characters used in this section.

Table 4.3 Selected ASCII Control Characters

Decimal Code	Name	Usage	Keystroke(s)
13	CR	Carriage return	**<Enter>** or **<RETURN>** or **<Ctrl+M>**
10	LF	Line feed	**<Ctrl+J>**
02	STX	Start of transmission	**<Ctrl+B>**
03	ETX	End of transmission	**<Ctrl+C>**
24	CAN	Cancel	**<Ctrl+X>**
17	XON	Flow control on	**<Ctrl+Q>**
19	XOFF	Flow control off	**<Ctrl+S>**

The **<Enter>** key on standard keyboards sends the ASCII character CR for a carriage return. This manual instructs you to press the **<Enter>** key after commands to send the proper ASCII code to the relay. A correctly formatted command transmitted to the relay consists of the command, including optional parameters, followed by either a CR character (carriage return) or CR and LF characters (carriage return and line feed). The following line contains this information in the format this manual uses to describe user input:

<command> <Enter>

You may truncate commands to the first three characters. For example, **EVENT 1 <Enter>** is equivalent to **EVE 1 <Enter>**. You may use upper- and lowercase characters without distinction, except in passwords.

In response to a command, the relay may respond with an additional dialog line or message. The relay transmits dialog lines in the following format:

<STX><MESSAGE LINE 1><CR><LF>

<MESSAGE LINE 2><CR><LF>

•

•

•

<LAST MESSAGE LINE><CR><LF>< ETX>

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX. Each line of the message ends with a carriage return, CR, and line feed, LF.

Send the CAN character to the relay to abort a transmission in progress. For example, if you request a long report and want to terminate transmission of this report, depress the control and X keys (**<Ctrl+X>**) to terminate the report.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII or Compressed ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports may have fewer characters than conventional SEL ASCII reports, because the compressed reports reduce blanks, tabs, and other white space between data fields to a single comma.

Compressed ASCII Message Format

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX:

<STX><MESSAGE LINE 1><CR><LF>

<MESSAGE LINE 2><CR><LF>

•

•

•

<LAST MESSAGE LINE><CR><LF><ETX>

Each line in the message consists of one or more data fields, a checksum field, and a <CR><LF>. Commas separate adjacent fields. Each field is either a number or a string. Number fields contain base-10 numbers using the ASCII characters 0–9, plus (+), minus (–), and period (.). String fields begin and end with quote marks (“ ”)and contain standard ASCII characters. Hexadecimal numbers are contained in string fields.

The checksum consists of four ASCII characters that are the hexadecimal representation of the two-byte binary checksum. The checksum value is the sum of the first byte on a line (first byte following <STX>, <CR>, or <CR><LF>) through the comma preceding the checksum.

If you request data with a Compressed ASCII command and these data are not available, (in the case of an empty history buffer or invalid event request), the relay responds with the following Compressed ASCII format message:

<STX>“No Data Available”,“0668”<CR><ETX>

where:

“No Data Available” is a text string field.

“0668” is the checksum field, which is a hexadecimal number represented by a character string.

Table 4.4 lists the Compressed ASCII commands and contents of the command responses. The Compressed ASCII commands are described in *Section 7: ASCII Command Reference*.

Table 4.4 Compressed ASCII Commands (Sheet 1 of 2)

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CEVENT	Event report	1
CHISTORY	List of events	1
CSER	Sequential Events Recorder report	1
CSTATUS	Self-diagnostic status	1

Table 4.4 Compressed ASCII Commands (Sheet 2 of 2)

Command	Response	Access Level
CSUMMARY	Summary of an event report	1
DNAME X	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

CASCII Configuration Message for Compressed ASCII Commands

The CASCII message provides a block of data for each of the Compressed ASCII commands supported by an SEL device. The block of data for each command provides message description information to allow automatic data extraction. The relay arranges items in the Compressed ASCII configuration message in a predefined order. For the purpose of improving products and services, SEL sometimes changes the items and item order. Contact your local Technical Service Center or the SEL factory for the latest inventory of the items and item order in the Compressed ASCII configuration message. The information presented below explains the message and serves as a guide to the items in Compressed ASCII configuration messages.

NOTE: Compressed ASCII is self-describing and may vary with the firmware version of your relay. Before you program a master device to send and parse Compressed ASCII commands and responses, you should perform a CASCII command on your relay or contact SEL for more detailed information.

A Compressed ASCII command can include multiple header and data configuration lines. The general format of a Compressed ASCII configuration message is the following:

```
<STX>"CAS",n,"yyyy"<CR><LF>
"COMMAND 1",l,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF>
    .
    .
    .
"COMMAND n",l,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF><ETX>
```

Definitions for the items and fields in a Compressed ASCII configuration message are the following:

where:

n is the number of Compressed ASCII command descriptions to follow.

COMMAND is the ASCII name for the Compressed ASCII command that the requesting device (terminal or external software) sends. The naming convention for the Compressed ASCII commands is a C character preceding the typical command. For example, **CSTATUS**, abbreviated to **CST**, is the Compressed ASCII **STATUS** command. Following the command is the minimum access level at which the command can be executed.

#H identifies a header line to precede one or more data lines; the # character represents the number of subsequent ASCII names. For example, 21H identifies a header line with 21 ASCII labels.

xxxxx is an ASCII name for corresponding data on following data lines. Maximum ASCII name width is 10 characters.

#D identifies a data format line; the # character represents the maximum number of data lines in command response.

ddd identifies a format field containing one of the following type designators:

I—Integer data

F—Floating point data

*z*S—String of maximum *z* characters (for example, enter 10S for a 10-character string).

yyyy is the 4-byte hex ASCII representation of the checksum. Every checksum is followed by a new line indication (<CR><LF>).

Software Flow Control

Software handshaking is a form of flow control that two serial devices use to prevent input buffer overflow and loss of characters. The relay uses XON and XOFF control characters to implement software flow control for ASCII commands.

The relay transmits the XOFF character when the input buffer is more than 75 percent full. The connected device should monitor the data it receives for the XOFF character to prevent relay input buffer overflow. The external device should suspend transmission at the end of a message in progress when it receives the XOFF character. When the relay has processed the input buffer so that the buffer is less than 25 percent full, the relay transmits an XON character. The external device should resume normal transmission after receiving the XON character.

The relay also uses XON/XOFF flow control to delay data transmission to avoid overflow of the input buffer in a connected device. When the relay receives an XOFF character during transmission, it pauses transmission at the end of the message in progress. If there is no message in progress when the relay receives the XOFF character, it blocks transmission of any subsequent message. Normal transmission resumes after the relay receives an XON character. Use the **<Ctrl+S>** (XOFF) and the **<Ctrl+Q>** (XON) keystrokes on the keyboard to manually control the data flow to the terminal.

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams in order to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the SEL-487B communicates with an SEL communications processor. The communications processor performs autoconfiguration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the communications processor uses the binary data stream for Fast Meter, Fast Operate, and Fast SER messages to populate a local database and to perform SCADA operations. At the same time, you can use the ASCII data stream to connect transparently to the SEL-487B for ASCII commands and responses.

Automatic Messages

If you enable automatic messages, AUTO = Y, the SEL-487B issues a message any time the relay powers up, asserts a self-test, changes to another settings group, or triggers an event. For virtual ports, the relay issues automatic messages only if the connection is active. Automatic messages contain the following information:

- Power up: On power up, the message provides the terminal ID and the present date and time.
- Self-test failure: When the relay detects an internal failure, the automatic message is the same as the relay response to the **STATUS** command.
- Group switch: Whenever a settings group change occurs, the message contains the relay ID, terminal ID, present date and time, and the selected settings group.
- Events: When the relay triggers an event, the automatic message is the same as the relay response to the **SUMMARY** command.

Timeout

Use the TIMEOUT setting to set the idle time for each port. Idle time is the period when no ASCII characters are transmitted and received (interleaved fast messages do not affect the idle time). When the idle time exceeds the TIMEOUT setting, the following takes place:

- The access level changes to Access Level 0.
- The front-panel targets reset to TAR 0 if the port had previously remapped the targets.
- Virtual connections are disconnected.
- The software flow control state changes to XON.

When set to OFF, the port never times out.

SEL Fast Meter, Fast Operate, and Fast SER Messages

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. The relay can also send unsolicited Fast SER messages automatically. If the relay is connected to an SEL communications processor, these messages provide the mechanism that the communications processor uses for substation control and data acquisition (SCADA) or distributed control system (DCS) functions that occur simultaneously with ASCII interaction. Reference the section, *Interleaved ASCII and Binary Messages on page R.4.7* and *Section 4: SEL Communications Processor Applications in the Applications Handbook.* For more information on the Fast Meter and Fast Operate generic commands and messages that provide configuration messages, see *Application Guide AG95-10* available on the SEL website.

NOTE: The **TEST FM** command overrides normal Fast Meter quantities for testing purposes. Values you enter in Fast Meter storage are "override values." Use the **TEST FM** command to display override values and write override values in the Fast Meter report.

This section summarizes the binary commands and messages and includes our recommendation for using Fast Commands and Compressed ASCII configuration information to communicate with the relay. You need this information to develop or specify the software an external device uses to communicate with the SEL-487B using Fast Messages. To support this type of development, you will also need to contact SEL for Fast Message protocol details.

Table 4.5 lists the two-byte Fast Commands and the actions the relay takes in response to each command.

Table 4.5 Fast Commands and Response Descriptions

Command (Hex)	Name	Description
A5B9h	Status acknowledge message	Clears Fast Meter status byte and sends current status.
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information.
A5C1h	Fast Meter configuration block	Defines contents of Fast Meter data message.
A5CEh	Fast Operate configuration block	Defines available circuit breaker, remote bits, and associated commands, if setting FASTOP := Y for this port.
A5D1h	Fast Meter data message	Defines present values of analog and digital data.

Fast Operate commands use one of the two-byte command types shown in *Table 4.6*. Each Fast Operate command also includes additional bytes that specify a remote bit or circuit breaker bit.

NOTE: Jumper J18C must be in place for the Fast Operate command (**A5E3h**) to operate.

Table 4.6 Fast Operate Command Types

Command (Hex)	Name	Description
A5E0h	Fast Operate command for remote bits	Sends command code that will change the state of a remote bit, if setting FASTOP := Y for this port.
A5E3h	Fast Operate command for circuit breaker bits	Sends command code that will change the state of a circuit breaker control bit, if setting FASTOP := Y for this port.

The Fast Operate messages transfer control commands through the binary data stream. You must enable Fast Operate messages for a port before the relay accepts these messages on that port. In the port settings, when the protocol is set to SEL, the FASTOP setting is visible. Set FASTOP := Y to enable Fast Operate commands or to N to disable Fast Operate commands.

General Fast Messages have a two-byte identifier (A546h) and a function code. Fast SER messages are general Fast Messages that transport Sequential Event Recorder (SER) report information. The Fast SER messages include function codes to accomplish different tasks. *Table 4.7* lists the Fast SER function codes and the actions the relay takes in response to each command.

Table 4.7 Fast Message Command Function Codes Used With Fast SER (A546 Message) and Relay Response Descriptions (Sheet 1 of 2)

Function Code (Hex)	Function	Relay Action
00h	Fast SER message definition block request	Relay transmits Fast SER definition request acknowledge (Function Code 80).
01h	Enable unsolicited transfers	Relay transmits Fast SER command acknowledged message (Function Code 81) and sets relay element bit FSER*x*. Relay will transmit subsequent SER events (Unsolicited SER broadcast, Function Code 18).

Table 4.7 Fast Message Command Function Codes Used With Fast SER (A546 Message) and Relay Response Descriptions (Sheet 2 of 2)

Function Code (Hex)	Function	Relay Action
02h	Disable unsolicited transfers	Relay sends Fast SER command acknowledged message (Function Code 82) and clears relay element bit FSER*x*. Relay will not transmit subsequent SER messages.
05h	Ping; determine channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85).
98h	Fast SER message acknowledge	Relay completes dialog processing for unsolicited message sequence.

Recommended Use of Relay Self-Description Messages for Automatic Configuration

Compressed ASCII and Fast Message commands provide information to allow an external computer-based device to adapt to the special messages for each relay. The SEL communications processor uses the self-description messages to configure a database and name the elements in the database.

Table 4.8 lists commands and command usage in the recommended order of execution for automatic configuration.

Table 4.8 Commands in Recommended Sequence for Automatic Configuration

Command ASCII or hexadecimal (h suffix)	Response	Usage
ID	Relay identification	ID and FID
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information
A5C1h	Fast Meter configuration block	Defines contents of Fast Meter data message
BNAME	Binary names	ASCII names of status bits
DNAME X	Digital I/O name	ASCII names of digital I/O points
SNS	SER names	ASCII names for SER data points
CASCII	Compressed ASCII configuration block	Configuration data for Compressed ASCII commands with access levels > 0
A5CEh	Fast Operate configuration block	Defines available circuit breaker and remote bits, and associated commands, if setting FASTOP :=Y for this port

Virtual File Interface

You can retrieve and send data as files through the SEL-487B virtual file interface. Devices with embedded computers can also use the virtual file interface. When using serial ports or virtual terminal links, use the **FILE DIR** command. When you use a communications card, the file transfer protocol(s) supported by the card can present the file structure and send and receive files.

The SEL-487B has a two-level file structure. There is one file at the root level and three subdirectories or folders. *Table 4.9* shows the directories and the contents of each directory.

Table 4.9 Virtual File Structure

Directory	Usage	Access Level
root	CFG.TXT file, and the SETTINGS, REPORTS, and EVENTS directories (below)	1
SETTINGS	Relay settings	1
REPORTS	SER, circuit breaker, and history reports	1
EVENTS	EVE, CEV, and history reports	1

System Data Format (SDF)

Settings files and CFG.TXT use the SDF (System Data Format). The files may contain keywords to aid external support software parsing. A keyword is defined as a string surrounded by the open and close bracket characters, followed by a carriage return and line feed. Only one keyword is allowed per line in the file. For example, the keyword INFO would look like this in the file:

[INFO]<CR><LF>.

Records are defined as comma-delimited text followed by a carriage return and line feed. One line in a text file equals one record. Fields are defined as comma-delimited text strings.

Comma-Delimited Text Rules

Field strings are separated by commas or spaces and may be enclosed in optional double quotation marks. Double quotes within the field string are repeated to distinguish these double quotes from the quotes that surround the field string. Delimiters are spaces and commas that are not contained within double quotes. Two adjacent commas indicate an empty string, but spaces that appear next to another delimiter are ignored.

Consider the following examples for converting a list of fields to comma-delimited text. Consider the following list of fields:

Stri,ng 1

Stri"ng 2

String 3

String4

The translation to comma-delimited text is:

"Stri,ng 1","Stri""ng 2","String 3","String4"

Root Directory

The root directory contains three subdirectories and one file, CFG.TXT.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each setting class. External support software retrieves the CFG.TXT file to interact automatically with the connected relay.

SETTINGS Directory

You can access the relay settings through files in the SETTINGS directory. We recommend that you use support software to access the settings files, rather than directly accessing the text files. External settings support software functions by reading settings from all of these files. The relay only allows you to write to the individual SET_*cn* files, where *c* is the settings class code and *n* is the settings instance. Changing settings with external support software involves the following steps:

Step 1. The PC software reads the CFG.TXT and SET_ALL.TXT files from the relay.

Step 2. You modify the settings at the PC.

Step 3. For each settings class that you modify, the software sends a SET_*cn*.TXT file to the SEL-487B.

Step 4. The PC software reads the ERR.TXT file. If it is not empty, the relay detects errors in the SET_*cn*.TXT file.

Step 5. For any detected errors, modify the settings and send the settings until the relay accepts your settings.

Step 6. Repeat Steps 3–5 for each settings class that you want to modify.

Step 7. Test and commission the relay.

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains all of the settings for all of the settings classes in the relay.

SET_cn.TXT Files (Read and Write)

There is a file for each instance of each setting class. *Table 4.10* summarizes the settings files. The settings class is designated by *c*, and the settings instance number is *n*.

ERR.TXT (Read-Only)

The ERR.TXT file contents are based on the most recent SET_*cn*.TXT file you wrote to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file.

Table 4.10 Settings Directory Files

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
S	SET_S*p*.TXT[a]	Group *p*	1, B, P, A, O, 2	P, 2
G	SET_G1.TXT	Global	1, B, P, A, O, 2	P, A, O, 2
R	SET_R1.TXT	SER aliases and event settings	1, B, P, A, O, 2	P, A, O, 2
P	SET_P*n*.TXT[b]	Port	1, B, P, A, O, 2	P, A, O, 2
D	SET_D1.TXT	DNP3 remapping (serial)	1, B, P, A, O, 2	P, A, O, 2
F	SET_F1.TXT	Front panel	1, B, P, A, O, 2	P, A, O, 2
O	SET_O1.TXT	Contact outputs	1, B, P, A, O, 2	O, 2
A	SET_A*p*.TXT	Automation	1, B, P, A, O, 2	A, 2
L	SET_L*p*.TXT	Protection logic	1, B, P, A, O, 2	P, 2
T	SET_T1.TXT	Alias settings	1, B, P, A, O, 2	P, A, O, 2
Z	SET_Z*p*.TXT	Zone configuration	1, B, P, A, O, 2	P, 2
All	SET_ALL.TXT	All instances of all settings classes	1, B, P, A, O, 2	NA
All	ERR.TXT	Error log for most recently written settings file	1, B, P, A, O, 2	NA

[a] Parameter p has a range of 1–6.
[b] Parameter n has a range of 1–3, 5, F.

Ethernet Card Subdirectory

If an Ethernet card with the DNP3 protocol is installed into an SEL-487B, the CARD settings directory is accessible as a subdirectory of the SETTINGS directory.

Table 4.11 Ethernet Card Subdirectory

Path and Filename	File Description	Read Access Level	Write Access Level
\CARD\SET_DNP*n*.TXT	DNP custom remapping (Ethernet); *n* in range 1–5	1, B, P, A, O, 2	P, A, O, 2
\CARD\ERR.TXT	List of all error messages from the last write of a settings file (SET_CC1.TXT or SET_DNP*n*.TXT)	1, B, P, A, O, 2	NA

REPORTS Directory

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 4.12*. Note that the relay provides a report file that contains the latest information each time you request the file. You can use the **FILE DIR REPORTS** command to display the contents of the REPORTS directory.

Table 4.12 REPORTS Directory Files

File	Usage: All are read-only files
SER.TXT	ASCII SER report, clears SER when read
CSER.TXT	Compressed ASCII SER report
HISTORY.TXT	History file
CHISTORY.TXT	Compressed ASCII history file

EVENTS Directory

The relay provides history and event report files in the EVENTS directory. Event reports are available in the following formats: SEL ASCII 4-, 12-, or 24-samples/cycle reports and Compressed ASCII 12- or 24-samples/cycle reports. The size of each event report file is determined by the LER setting in effect at the time the event is triggered. You can use the **FILE DIR EVENTS** command to display the contents of the EVENTS directory.

The 4-, 12-, and 24-samples/cycle report files (files with names that begin with C, D, E, or Z) are text files with the same format as the **EVENT** and **CEVENT** command responses. Event file names start with the prefix E4_, E12, E24, D12, C12, C24, or Z24 followed by a unique event serial number. For example, if one event is triggered, with serial number of 10001, the EVENTS directory contains the files shown in *Table 4.13*. For an example of retrieving these files see *Retrieving Event Report Data Files: Terminal Emulation Software on page U.4.36*.

Table 4.13 EVENTS Directory Files (for event 10001)

File	Usage	ASCII Command
HISTORY.TXT	History file; read-only	**HIS**
CHISTORY.TXT	Compressed ASCII History file; read-only	**CHI A**
C1210001.TXT	12-samples/cycle Compressed ASCII filtered event report; read-only	**CEV S12**
C2410001.TXT	24-samples/cycle Compressed ASCII unfiltered event report; read-only	**CEV R**
Z2410000.TXT	24-samples/cycle raw and 12-samples/cycle differential event report; read-only	**CEV RD**
E4_10001.TXT	4-samples/cycle filtered event report; read-only	**EVE**
E1210001.TXT	12-samples/cycle filtered event report; read-only	**EVE S12**
E2410001.TXT	24-samples/cycle unfiltered event report; read-only	**EVE R**
D1210001.TXT	12-samples/cycle differential event report; read-only	**EVE DIFF**

NOTE: Parameter nn is a unique event serial number.

Reports are only available as indicated. For example, the 24-samples/cycle report is only available in an unfiltered format, and filtered reports are only available in 4-samples/cycle (E4_*nn*.TXT) or 12-samples/cycle format.

SEL MIRRORED BITS Communications

Overview

With SEL-patented MIRRORED BITS communications protocol, protective relays and other devices can directly exchange information quickly, securely, and with minimal cost. Use MIRRORED BITS communications for remote control or remote sensing.

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the SEL-487B for compatible operation with SEL-300 series relays, the SEL-2505 Remote I/O Modules, and the SEL-2100 Logic Processors. These devices use MIRRORED BITS communications to exchange the states of eight logic bits. You can also use settings to select extensions of the MIRRORED BITS communications protocols, available only in SEL-400 series relays, to exchange analog values, synchronize clocks, and engage in virtual terminal dialogs. *Table 4.14* summarizes MIRRORED BITS communications features.

Table 4.14 MIRRORED BITS Communications Features

Feature	Compatibility
Transmit and receive logic bits	SEL-300 series relays, SEL-2505, SEL-2100, SEL-400 series relays
Transmit and receive analog values	SEL-400 series relays
Synchronize time	SEL-400 series relays
Send and receive virtual serial port characters	SEL-400 series relays
Support synchronous communications channel	SEL-400 series relays

Communications Channels and Logical Data Channels

NOTE: Complete all of the port settings for a port that you use for MIRRORED BITS communications before you connect an external MIRRORED BITS communications device. If you connect a MIRRORED BITS communications device to a port that is not set for MIRRORED BITS communications operation, the port will be continuously busy.

The SEL-487B supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port; PROTO := MBA for MIRRORED BITS communications Channel A or PROTO := MBB for MIRRORED BITS communications Channel B.

Transmitted bits include TMB1A–TMB8A and TMB1B–TMB8B. The last letter (A or B) designates the channel with which the bits are associated. These bits are controlled by SELOGIC® control equations. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. You can use received bits as arguments in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, DOKA, ANOKA, DOKB, and ANOKB. You can also use these bits as arguments in SELOGIC control equations. Use the **COM** command for additional channel status information.

Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). In operation compatible with other SEL products, you can use the eight logical data channels for TMB1 through TMB8. If you use fewer than eight transmit bits, Data Channel 8 is reserved to support data framing and time synchronization features. You can assign the eight logical data channels as follows:

- **Logic Bits**. Setting MBNUM controls the number of channels used for logic bits, TMB1–TMB8, inclusive.
  - If you set MBNUM to 8, then you cannot use channels for any of the following features.
  - If you set MBNUM less than 8, you can use the remaining channels (up to a total of eight) for the following features.
- **Message and Time Synchronization**. If MBNUM is less than 8, the relay dedicates a logical data channel to message framing and time synchronization.
- **Analog Channels**. Setting MBNUMAN controls the number of Analog Channels.
  - If MBNUM := 8, all channels are used for logic bits and MBNUMAN is forced to 0.
  - If MBNUM := 7, seven channels are used for logic bits and one channel is used for message and time synchronization, and MBNUMAN is forced to 0.
  - If MBNUM is less than 7, you can use the remaining channels for analog channels by setting the desired number of channels in MBNUMAN (1 to 7 – MBNUM).

➤ **Virtual Terminal Sessions**. Setting MBNUMVT controls the number of additional channels available for the virtual terminal session.
  ➢ If MBNUMVT := OFF, the relay does not dedicate any additional channels to the virtual terminal session.
  ➢ If there are spare channels (7 – MBNUM – MBNUMAN > 0), you can use MBNUMVT to dedicate these additional channels to the virtual terminal session.
  ➢ With MBNUM = 7 or less and MBNUMVT = 0, virtual terminal is still possible, because the relay uses the eighth element for time synchronization and virtual terminal.

The virtual terminal session uses channels differently than other data exchange mechanisms. There can only be one active virtual terminal session across a MIRRORED BITS link. One channel, included in the synchronization data, is always dedicated to this virtual terminal session. If you assign additional channels to the virtual terminal session (set MBNUMVT > 0), you will improve the performance of the virtual terminal session. The relay uses the additional channels to exchange data more quickly.

Operation

Message Transmission

MIRRORED BITS communications messages are transmitted as a function of the transmission mode and modem settings, as shown in *Table 4.15*. Each message contains the most recent values of the transmit bits. If you enabled any of the extended features through the settings, note that the relay transmits a portion of the extended data in each message.

If you have specified virtual terminal data channels for this port, the designated data channels are normally idle. If you use the **PORT** command to open a virtual terminal session for this port and type characters, the relay transmits these characters through the virtual terminal logical data channels.

Message Reception Overview

When the devices are synchronized and the MIRRORED BITS communications channel is in a normal state, the relay decodes and checks each received message. If the message is valid, the relay performs the following operations:

➤ Sends each received logic bit (RMB*n*) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*nc* relay element bits.

➤ For 16 out of 18 messages, builds the analog datum for each analog data point; on the 18th message, processes the analog data.

➤ For 16 out of 18 messages, buffers the received characters for each MIRRORED BITS communications virtual serial logical channel; on receiving the 18th message, treats the character exactly as a character from an actual serial port.

Message Decoding and Integrity Checks

The relay provides indication of the status of each MIRRORED BITS communications channel, with element bits ROKA and ROKB. During normal operation, the relay sets the ROK*c* bit. The relay clears the bit upon detecting any of the following conditions:

- Parity, framing, or overrun errors
- Receive data redundancy error
- Receive message identification error
- No message received in the time three messages have been sent

The relay will assert ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below.

While ROK*c* is not set, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, specify the default value with setting RMB*n*FL, as follows:

- 1
- 0
- P (to use last valid value)

Individual pickup and dropout security counters supervise the movement of each received data bit into the corresponding RMB*n* element. You can set each pickup/dropout security counter from 1 to 8. A setting of 1 causes a security counter to pass every occurrence, while a setting of 8 causes a counter to wait for eight consecutive occurrences in the received data before updating the data bits. The pickup and dropout security count settings are separate. Control the security count settings with the settings RMB*n*PU and RMB*n*DO.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of counted received messages instead of time. An SEL-487B communicating with another SEL-487B typically sends and receives MIRRORED BITS communications messages eight times per power system cycle. Therefore, a security counter set to two counts will delay a bit by approximately 1/4 of a power system cycle. Reference *Table 4.18* for the message rates based on the transmission mode and modem settings. You must consider the impact of the security counter settings in the receiving device to determine the channel timing performance.

Channel Synchronization

When an SEL-487B detects a communications error, it deasserts ROKA or ROKB. The relay transmits an attention message until it receives an attention message that includes a match to the TX_ID setting value. If the attention message is successful, the relay has properly synchronized and data transmission will resume. If the attention message is not successful, the relay will repeat the attention message until it is successful.

Loopback Testing

Use the **LOOP** command to verify the communications channel. In this mode, the relay expects the transmitted data to be looped back to the relay to test the data transmissions, including communication data. At the remote end, jumper the send and receive communications channels to complete the path for the test. While in loopback mode, ROK*c* is deasserted, and LBOK*c* asserts and deasserts based on the received data checks.

Channel Monitoring

Based on the results of data checks (described above), the relay collects information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout (See *Message Decoding and Integrity Checks*)

Use the **COM** command to generate a long or summary report of the communications errors.

NOTE: Combine error conditions including RBADA, RBADB, CBADA, and CBADB with other alarm conditions using SELogic control equations. You can use these alarm conditions to program the relay to take appropriate action when it detects a communications channel failure.

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is presently down, the COMM record will only show the initial cause, but the COMM summary will display the present cause of failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay will assert a user-accessible flag, RBADA or RBADB. When channel unavailability exceeds a user-definable threshold for Channel A or B, the relay asserts a user-accessible flag, CBADA or CBADB.

Mirrored Bits Communications Protocol for the Pulsar 9600-BPS Modem

To use a Pulsar MBT modem, set setting MBT:= Y. Setting MBT:= Y hides setting SPEED and forces it to 9600, hides setting PARITY and forces it to a value of O, and hides setting RTSCTS and forces it to a value of N. The relay also injects a delay (idle time) of 3 ms between messages.

NOTE: You must consider the idle time in calculations of data transfer latency through a Pulsar MBT modem system.

The relay sets RTS to a negative voltage at the EIA-232 connector to signify that Mirrored Bits communications matches this specification.

Settings

The SEL-487B Port settings associated with Mirrored Bits communications are shown in *Table 4.15* and *Table 4.17*.

Set PROTO := MBA to enable the Mirrored Bits communications protocol Channel A on this port. Set PROTO := MBB to enable the Mirrored Bits communications protocol Channel B on this port.

Table 4.15 General Port Settings Used With Mirrored Bits Communications

Name	Description	Range	Default
PROTO	Protocol.	None, SEL, DNP[a], MBA, MBB	SEL
MBT	Enable Pulsar 9600 modem. Hidden and set to N if PROTO set to SEL or DNP.	Y, N	N
SPEED	Data speed. Hidden and set to 9600 if MBT := Y.	300, 600, 1200, 2400, 4800, 9600, 19200, 38400, SYNC	9600
DATABIT	Data bits. Hidden and set to 6 if PROTO set to MBA or MBB.	6, 7, 8	8
PARITY	Parity. Forced to O if MBT := Y.	O, E, N	N
STOPBIT	Stop bits. Hidden and set to 1 if MBT := Y.	1, 2	2
RTSCTS	Hardware handshaking enable.	Y, N	N

[a] Optional relay feature.

The relay uses the RBADPU setting to determine how long a channel error must persist before the relay asserts RBADA or RBADB. The relay deasserts RBADA and RBADB immediately when it no longer detects a channel error.

The relay uses the CBADPU setting to determine when to assert CBADA and CBADB. If the short-term channel down time ratio exceeds CBADPU, the relay asserts the appropriate CBAD bit.

NOTE: You must use paced transmission mode (set TXMODE := P) when connecting to an SEL product that is not an SEL-400 series relay.

The TXMODE setting provides compatibility with SEL devices that are not SEL-400 series relays. The SEL-487B can send messages quicker than the SEL-300 series relays and other SEL devices can process these messages. This could lead to loss of data and a failure to communicate properly. When you set TXMODE to P, the relay sends new Mirrored Bits messages no faster than every 3 ms even if the selected data speed (SPEED setting) would allow more frequent messages.

As a function of the settings for SPEED, TXMODE, and MBT, the message transmission periods are shown in *Table 4.18*.

SEL-300 Series Relays and SEL-2100 Compatibility

Use Mirrored Bits communications to exchange information between 300-series and 400-series relays. In addition to the normal Mirrored Bits settings, ensure the 400-series relay has the settings as shown in *Table 4.16*.

Table 4.16 400-Series Relay Prerequisite Settings

Name	Setting
TXMODE	P
MBNUM	8

Table 4.17 Mirrored Bits Communications Protocol Settings

Name	Description	Range	Default
TX_ID	Mirrored Bits communications ID of this device	1–4	2
RX_ID	Mirrored Bits communications ID of device connected to this port	1–4; must be different than TX_ID	1
RBADPU	Outage duration to set RBAD	1–10000 seconds	10
CBADPU	Channel unavailability to set CBAD	1–100000 parts per million	20000
TXMODE	Transmission mode[a]	N (normal), P (paced)	N
MBNUM	Number of Mirrored Bits communications data channels used for logic bits	0–8	8
RMB1FL[b]	RMB1 channel fail state	0, 1, P	P
RMB1PU[b]	RMB1 pickup message count	1–8	1
RMB1DO[b]	RMB1 dropout message count	1–8	1
• • •	• • •		
RMB8FL[b]	RMB8 channel fail state	0, 1, P	P
RMB8PU[b]	RMB8 pickup message count	1–8	1
RMB8DO[b]	RMB8 dropout message count	1–8	1
MBTIME	Mirrored Bits time synchronize enable	Y, N	N
MBNUMAN	Number of analog data channels. Hidden and set to 0 if MBNUM := 7 or 8.	0–n, n=7–MBNUM	0
MBANA1[c]	Selection for Analog Channel 1	Analog quantity label	PMV58
MBANA2[c]	Selection for Analog Channel 2	Analog quantity label	PMV59
MBANA3[c]	Selection for Analog Channel 3	Analog quantity label	PMV60
MBANA4[c]	Selection for Analog Channel 4	Analog quantity label	PMV61
MBANA5[c]	Selection for Analog Channel 5	Analog quantity label	PMV62
MBANA6[c]	Selection for Analog Channel 6	Analog quantity label	PMV63
MBANA7[c]	Selection for Analog Channel 7	Analog quantity label	PMV64
MBNUMVT	Number of virtual terminal channels	OFF,0–n, n=7–MBNUM–MBNUMAN	OFF

[a] Must be P for connections to devices that are not SEL-400 series relays.
[b] Hidden based on MBNUM setting.
[c] Hidden based on MBNUMAN setting.

Table 4.18 MIRRORED BITS Communications Message Transmission Period

Speed in Bits per Second	TXMODE := NORMAL MBT := N	TXMODE := PACED MBT := N	MBT :=Y
38400	1.0 ms	3.0 ms	n/a
19200	2.0 ms	3.0 ms	n/a
9600	4.0 ms	4.0 ms	7.0 ms
4800	8.0 ms	8.0 ms	n/a

Set the RX_ID of the local relay to match the TX_ID of the remote relay. In a three-terminal case, Relay X transmits to Relay Y, Relay Y transmits to Relay Z, and Relay Z transmits to Relay X. *Table 4.19* lists the MIRRORED BITS communications ID settings for Relays X, Y, and Z.

Table 4.19 MIRRORED BITS Communications ID Settings for Three-Terminal Application

Relay	TX_ID	RX_ID
X	1	3
Y	2	1
Z	3	2

SEL Distributed Port Switch Protocol (LMD)

SEL Distributed Port Switch Protocol (LMD) permits multiple devices to share a common communications channel. This protocol is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement. The SEL-487B does not have built-in LMD protocol, but you can connect an SEL-487B to an SEL-2885 EIA-232/485 Protocol Converter and connect the SEL-2885 to an EIA-485 multidrop network. See the SEL-*2885 EIA-232 to EIA-485 Transceiver* product flyer for more information on the settings, configuration, and application of the SEL-2885. (Contact your local Technical Service Center, the SEL factory, or visit our website www.selinc.com for a copy of the SEL-2885 product flyer.)

Initialization

For the first 30 seconds after applying power to the relay, the SEL-2885 listens for an initialization string from the relay. The initialization string must be enclosed in square brackets (“[ ]”). The following table describes the initialization string fields. To send this string automatically, set AUTO to Y and append the initialization string to the relay ID setting so that it is included in the relay power-up header.

Table 4.20 SEL-2885 Initialization String [MODE PREFIX ADDR:SPEED]

Field	Optional or Required	Value	Description
[	Required	[	Opening bracket is start of string
Mode	Optional	Not specified N B	Treat as N, below Addressing for ASCII device Addressing for binary devices
PREFIX	Required	@, #, $, %, or &	Prefix character
ADDR	Required	01–99	Two digit address in the range 01–99
:	Optional; needed if SPEED is specified	Colon ":"	Colon ":", then one of the following codes to match the port SPEED setting
SPEED	Optional	12 24 48 96	1200 bps 2400 bps 4800 bps 9600 bps
]	Required	]	Closing bracket is end of string

Operation

The following steps describe how to use the LMD operation of the SEL-2885:

Step 1. When you send the prefix and address, the SEL-2885 enables echo and message transmission. Wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is ready.

Step 2. You can use the commands that are available for the protocol setting of the port where the SEL-2885 is installed.

Step 3. If the port PROTO setting is set to SEL, you can use the **QUIT** command to terminate the connection. If no data are sent to the relay before the port time-out period, this command automatically terminates the connection.

Step 4. If all relays in the multidrop network do not have the same prefix setting, enter the sequence **<Ctrl+X> QUIT <Enter>** before entering the prefix character to connect to another device.

Section 5
DNP3 Communications

Overview

The SEL-487B Relay provides a DNP3 (Distributed Network Protocol) Level 2 Slave interface for direct serial and Ethernet (LAN/WAN) network connections to the relay. This section covers the following topics:

- *Introduction to DNP3 on page R.5.1*
- *DNP3 (Serial) in the SEL-487B on page R.5.5*
- *DNP3 (Serial) Documentation on page R.5.11*
- *DNP3 (Serial) Application Example on page R.5.31*
- *DNP LAN/WAN Communications on page R.5.37*
- *DNP LAN/WAN Documentation on page R.5.47*
- *DNP LAN/WAN Application Example on page R.5.56*

Introduction to DNP3

A SCADA (Supervisory Control and Data Acquisition) manufacturer developed DNP3 from the lower layers of IEC 60870-5. DNP3 was designed for use in telecontrol applications. The protocol has become popular for both local substation data collection and telecontrol. DNP3 is one of the protocols included in the IEEE® Recommended Practice for Data Communication between Remote Terminal Units and Intelligent Electronic Devices in a Substation.

Rather than individual input and output points wired from the station RTU (remote terminal unit) to the station IEDs (intelligent electronic devices), many stations use DNP3 to convey measurement and control data to and from the RTU. The RTU then forwards data to the off-site master station. By using data communications rather than hard wiring, designers have reduced installation, commissioning, and maintenance costs while increasing remote control and monitoring flexibility.

The DNP User's Group maintains and publishes DNP standards. See the DNP User's Group website, www.dnp.org, for more information on DNP standards, implementers of DNP, and tools for working with DNP.

DNP3 Specifications

DNP3 is a protocol with many features and many ways to accomplish tasks. DNP3 is defined in a series of specifications known as the Basic 4. A companion specification called the Subset Definitions simplifies DNP3 implementation by providing three standard interoperable implementation levels. The levels are listed in *Table 5.1*.

Table 5.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communication requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communication requirements	Large RTUs, SCADA masters

Each level is a proper superset of the next lower-numbered level. A higher subset level device can act as a master to a lower subset level device. For example, a typical SCADA master is a Level 3 device and can poll a Level 2 or Level 1 device by using only the data types and functions that the lower-level device uses. A lower-level device can also poll a higher-level device. For example, a Level 1 device can poll a Level 3 device, but the Level 1 device can only access the features and data available in Level 1.

In addition to the Basic 4 and the Subset Definitions, the protocol is further refined by conformance requirements and a series of technical bulletins. The technical bulletins supplement the specifications with discussion and examples of specific features of DNP.

Data Handling

Objects

DNP3 uses a system of data references called objects, which the Basic 4 standard object library defines. Each subset level specification requires a minimum implementation of object types and also recommends several optional object types. Object types are commonly referred to as objects. DNP objects are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for collections of data or even all data within the DNP device.

If there can be more than one instance of a type of object, then each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15.

Each object also includes multiple versions called variations. For example, Object 1 has three variations: 0, 1, and 2. Variation 0 is a shorthand reference used to request all Object 1 data from a DNP device. Variation 1 is used to specify binary input values only and variation 2 is used to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and defines what data or control points correspond with each index.

A master initiates all DNP message exchanges except unsolicited data. DNP terminology describes all points from the perspective of the master. Binary points for control that move from the master to the remote are called Binary Outputs, while binary status points within the remote are called Binary Inputs.

Function Codes

Each DNP message includes a function code. Each object has a limited set of function codes that a master may use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table 5.2*.

Table 5.2 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the remote
2	Write	Send data to the remote
3	Select	First part of a select-before-execute operation
4	Execute	Second part of a select-before-execute operation
5	Direct operate	One-step operation with reply
6	Direct operate, no reply	One-step operation with no reply

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range, and the range specifies the indices of the objects of interest. DNP masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP remote.

For example, the qualifier code 01 specifies that the request for points will include a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four-hexadecimal byte range field, 00h 04h 00h 10h, that specifies points in the range 4 to 16.

Access Methods

DNP has many features that help it obtain maximum possible message efficiency. Requests are sent with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of data values that are not changing. These features optimize use of bandwidth and maximize performance over any speed connection.

DNP event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are records of when observed measurements changed. For binary points, the remote device logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the remote device logs changes that exceed a dead band. DNP remote devices collect event data in a buffer that the master can either request or the relay can send to the master without a request message. Data sent from the remote to the master without a polling request are called unsolicited data.

DNP data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value data (static data). Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With remotes that contain great amounts of data or in large systems, the three event classes provide a framework for prioritizing different types of data. For example, you can poll once a minute for Class 1 data, once an hour for Class 2 data, and once a day for Class 3 data.

DNP also supports static polling, simple polling of the present value of data points within the remote. By combining event data, unsolicited polling, and static polling, you can operate your system in one of the four access methods shown in *Table 5.3*.

The access methods listed in *Table 5.3* are in order of increasing communication efficiency. With various tradeoffs, each method is less demanding of communication bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communication bandwidth because of the elimination of polling messages from the master required by polled report-by-exception. You must also consider overall system size and the volume of data communication expected in order to properly evaluate which access method provides optimum performance for your application.

Table 5.3 DNP Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data
Unsolicited report-by-exception	Remote devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data
Quiescent	Master never polls and relies on unsolicited reports only

Binary Control Operations

DNP masters use Object 12 control relay output block to perform DNP binary control operations. The control relay output block has both a trip/close selection and a code selection. The trip/close selection allows a single DNP index to operate two related control points such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP master implementations.

The control relay output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP remotes have only a limited subset of the possible combinations of the code field. Sometimes, DNP remotes assign special operation characteristics to the latch and pulse selections. *Table 5.14* and *Table 5.15* describe control point operation for the SEL-487B.

Conformance Testing

In addition to the protocol specifications, the DNP User's Group has approved conformance testing requirements for Level 1 and Level 2 remote devices. Some implementers perform their own conformance specification testing, while some contract with independent companies to perform conformance testing.

Conformance testing does not always guarantee that a master and remote will be fully interoperable (work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP implementers toward a higher level of interoperability. The SEL-487B is certified as having passed DNP3 Slave Level 2 conformance tests by a third-party organization, and the conformance certificate is on file at SEL.

Data Link Layer Operation

DNP employs a three-layer version of the seven-layer OSI (Open Systems Interconnect) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the Data Link Layer, includes several functions for error checking and media access control.

A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP conversation. Consider for your individual application whether you require this link integrity function at the expense of overall system speed and performance.

The DNP technical bulletin (*DNP Confirmation and Retry Guidelines 9804-002*) on confirmation processes recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single network medium, you must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your network as a star topology of point-to-point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before rechecking for a carrier signal. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your network allows for spontaneous data transmission including unsolicited event data transmissions, you also must use application confirmation to provide a retry mechanism for messages lost due to data collisions.

DNP3 (Serial) in the SEL-487B

The SEL-487B is a DNP3 Level 2 remote (slave) device. Additional implementation documentation describing DNP in the relay is in *DNP3 (Serial) Documentation on page R.5.11*.

Data Access

NOTE: Because unsolicited messaging only operates properly in some situations, for maximum performance and minimum risk of configuration problems, use the polled report-by-exception access method. Configure the master to perform at least 10 event polls for every integrity poll.

You can use any of the data access methods listed in *Table 5.4*. *Table 5.4* also lists the SEL-487B DNP3 settings. You must configure the DNP master for the data access method you select.

Table 5.4 DNP Access Methods

Access Method	Master Polling	SEL-487B Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECL-ASSA, ECLASSV to Off, UNSOL to No.
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLSSC, ECL-ASSA, ECLASSV to the desired event class, UNSOL to No.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLSSC, ECL-ASSA, ECLASSV to the desired event class, set UNSOL to Yes and PUNSOL to Yes or No.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLSSC, ECL-ASSA to the desired event class, set UNSOL and PUNSOL to Yes.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table 5.4*, you must make a selection for the PUNSOL setting. This setting enables or disables unsolicited data reporting at power up. If your master can send the DNP message to enable unsolicited reporting from the SEL-487B, you should set PUNSOL to No.

While automatic unsolicited data transmission on power up is convenient, problems can result if your master is not prepared to start receiving data immediately on power up. If the master does not acknowledge the unsolicited data with an Application Confirmation message, the relay will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several relays simultaneously begin sending data and waiting for acknowledgement messages.

Collision Avoidance

If your application uses unsolicited reporting, you must select a polled mode (polled static or polled report-by-exception) or a medium that includes carrier detection to avoid data collisions. EIA-485 two-wire networks are half-duplex. EIA-485 four-wire networks do not provide carrier detection, while EIA-232 systems can support carrier detection.

The relay uses Application Confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The SEL-487B pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. If you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the SEL-487B will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission.

Transmission Control

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your DNP network, you may need to adjust data transmission properties. Use the PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission. For example, an EIA-485 transceiver typically requires 10 to 20 ms to change from receive to transmit. If you set the predelay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

DNP event data objects contain change-of-state and timestamp information that the SEL-487B collects and stores in a buffer. You can configure the SEL-487B to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB, ECLASSC, ECLASSA, and ECLASSV you can set the event class for binary, counter, analog, and virtual terminal information. You can use the classes as a simple priority system for collecting event data. The relay does not treat data of different classes differently with respect to unsolicited messages, but the relay does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP masters perform an event poll that collects event data of all classes simultaneously. Confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-487B.

For event data collection you must also consider and enter appropriate settings for dead-band and scaling operation on analog points shown in *Table 5.6*. You can either set and use default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Configurable Data Mapping on page R.5.9* for a discussion of how to set scaling and dead-band operation on a point-by-point basis.

The settings ANADBA, ANADVB, and ANADBM control default dead-band operation for the specified data type. Because DNP Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

With no scaling, the value of 12.632 would be sent as 13. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

Set the default analog value scaling with the DECPLA, DECPLV, and DECPLM settings. Application of event reporting dead bands occurs after scaling in the DECPLA, DECPLV, and DECPLM. For example, if you set DECPLA to 2 and ANADBA to 10, a measured current of 10.14 amps would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a deadband of 0.2 amps) for the relay to report a new event value.

The relay uses the NUMEVE and AGEEVE settings to decide when to send unsolicited data to the master. The relay sends an unsolicited report when the total number of events accumulated in the event buffer reaches NUMEVE. The relay also sends an unsolicited report if the age of the oldest event in the buffer exceeds AGEEVE. The SEL-487B has the buffer capacities listed in *Table 5.5*.

Table 5.5 SEL-487B Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	256
Counters	128

Binary Controls

The SEL-487B provides more than one way to control individual points within the relay. The relay maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations. *Table 5.14* and *Table 5.15* list control points and control methods available in the SEL-487B.

A DNP technical bulletin (*Control Relay Output Block Minimum Implementation 9701-002*) recommends that you use one point per Object 12, control block output relay. You can use this method to perform Pulse On, Pulse Off, Latch On, and Latch Off operations on selected remote bits.

If your master does not support the single-point-per-index messages or single-operation database points, you can use the trip/close operation or use the code field in the DNP message to specify operation of the points shown in *Control Point Operation on page R.5.26*.

Time Synchronization

The accuracy of DNP time synchronization is insufficient for most protection and oscillography needs. DNP time synchronization provides backup time synchronization in the event the relay loses primary synchronization through the IRIG-B input or some other high accuracy source. Enable time synchronization with the TIMERQ setting and use Object 50, Variation 1, and Object 52, Variation 2, to set the time via a DNP master.

Modem Support

The SEL-487B DNP implementation includes modem support. Your DNP master can dial-in to the SEL-487B and establish a DNP3 connection. The SEL-487B can automatically dial out and deliver unsolicited DNP event data. When the relay dials out, it waits for the “CONNECT” message from the local modem and for assertion of the relay CTS line before continuing the DNP transaction. This requires a connection from the modem DCD to the relay CTS line.

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your SEL-487B to other devices.

Either connect the modem to a computer and configure it before connecting it to the relay, or program the appropriate modem setup string in the modem startup string setting MSTR. Use the PH_NUM setting to set the phone number that you want the relay to call. The relay automatically will send the ATDT modem dial command and then the contents of the PH_NUM setting when dialing the modem. PH_NUM is a text setting that must conform to the AT modem command set dialing string standard. Use a comma (,) for a pause of four seconds. You may need to include a nine to reach an outside line or a one if the number requires long distance access. You can also insert other special codes your telephone service provider designates for block call waiting and other telephone line features.

DNP Settings

The DNP protocol settings that become available when you select DNP on a serial port are shown in *Table 5.6*. The DNP protocol settings are in the port settings for the port that you select for the DNP protocol. You can use DNP on any of the serial ports, Port F and Port 1–Port 3, but you can only enable DNP on one port at a time.

Table 5.6 SEL-487B Port DNP Protocol Settings (Sheet 1 of 2)

Name	Description	Range	Default
DNPADR	DNP address	0–65519	0
ECLASSB	Class for binary event data	OFF, 1–3	1
ECLASSC	Class for counter event data	OFF, 1–3	OFF
ECLASSA	Class for analog event data	OFF, 1–3	2
TIMERQ	Time-set request interval (I, M, 1–32767 minutes)	I, M, 1–32767	I
DECPLA	Current value scaling	0–3	1
DECPLV	Voltage value scaling	0–3	1
DECPLM	Miscellaneous data scaling	0–3	1
STIMEO	Select/operate time-out	0.0–60.0 seconds	1.0
DRETRY	Data link retries	OFF, 1–15	OFF
DTIMEO	Data link time-out; hidden if DRETRY := OFF	0.0–30.0 seconds	1.0
MINDLY	Minimum delay from DCD to TX	0.00–1.00 seconds	0.05
MAXDLY	Maximum delay from DCD to TX	0.00–1.00 seconds	0.10
PREDLY	Settle time from RTS on to TX; OFF disables PSTDLY	OFF, 0.00–30.00 seconds	0.00
PSTDLY	Settle time from TX to RTS off; hidden if PREDLY := OFF	0.00–30.00 seconds	0.00
ANADBA	Analog reporting dead band for current; hidden if ECLASSA := OFF	0–32767	100
ANADBV	Analog reporting dead band for voltages; hidden if ECLASSA := OFF	0–32767	100

Table 5.6 SEL-487B Port DNP Protocol Settings (Sheet 2 of 2)

Name	Description	Range	Default
ANADBM	Analog reporting dead band; hidden if ECLASSC and ECLASSA := OFF	0–32767	100
EVELOCK	Event summary lock period	0–1000 seconds	0
ETIMEO	Event data confirmation time-out	0.1–100.0 seconds	10.0
UNSOL	Enable unsolicited reporting; hidden and set to N if ECLASSB, ECLASSC, ECLASSA, and ECLASSV := OFF	Y, N	N
PUNSOL	Enable unsolicited reporting at power up; hidden if UNSOL := N	Y, N	N
REPADR	DNP address to which the relay reports unsolicited data; hidden if UNSOL := N	0–65519	1
NUMEVE	Number of events on which the relay transmits unsolicited data; hidden if UNSOL := N	1–200	10
AGEEVE	Age of oldest event on which the relay transmits unsolicited data; hidden if UNSOL := N	0.0–60.0 seconds	2.0
MODEM	Modem connected to port	Y, N	N
MSTR	Modem startup string; hidden if MODEM := N	Up to 30 characters	"E0X0& D0S0=4"
PH_NUM	Phone number for unsolicited reporting dial-out; hidden if MODEM := N or UNSOL := N	Up to 30 characters	""
MDTIME	Time to attempt dial	5–300 seconds	60
MDRET	Time between dial-out attempts	5–3600 seconds	120

Configurable Data Mapping

One of the most powerful features of the SEL-487B DNP3 implementation is the ability to remap DNP data. Remapping is the process of selecting data from the default map and organizing it into a smaller data set optimized for your application.

Use the settings Class D to access the SEL-487B DNP Map settings shown in *Table 5.7*. When you are remapping points, the new index will be the row number minus one.

Table 5.7 SEL-487B DNP Map Settings (Sheet 1 of 2)

Name	Description	Range	Default
MAPSEL	Reference Map Selection	B, E	B
DNPBID	Default binary input map enable	Y, N	Y
DNPBOD	Default binary output map enable	Y, N	Y
DNPCOD	Default counters map enable	Y, N	Y
DNPAID	Default analog input map enable	Y, N	Y
DNPAOD	Default analog output map enable	Y, N	Y
Row 1[a]	Custom binary input map	Index number from default map	
• • •			

Table 5.7 SEL-487B DNP Map Settings (Sheet 2 of 2)

Name	Description	Range	Default
Row 400[a]	Maximum custom binary input map		
Row 1[a]	Custom binary output map	Index number from default map	
•			
•			
•			
Row 70[a]	Maximum custom binary output map		
Row 1[a]	Custom counter map, custom counter dead band[b] (Example: 3, 6)	Index number from default map; 1–32767	
•			
•			
•			
Row 10[a]	Last custom counter map; custom counter dead band[b] (Example: 3, 6)	Index number from default map; 1–32767	
Row 1[a]	Custom analog input map; custom analog input scaling[b], custom analog input dead band[b] (Example: 3, 10, 6)	Index number from default map; 0.001–1000.000: 1–32767	
•			
•			
•			
Row 200[a]	Last custom analog input map; custom analog input scaling[b] custom analog input dead band	Index number from default map; 0.001–1000.000: 1–32767	
Row 1[a]	Custom analog output map	Index number from default map	
Row 2[a]	Custom analog output map	Index number from default map	

[a] Free-form setting row hidden if corresponding default map is enabled.
[b] Optional. If not specified, defaults to value associated with point in default map.

The settings shown in *Table 5.7* that follow DNPAOD are entered in a line-based free-form format. An example of these settings is shown in *DNP3 (Serial) Application Example on page R.5.31*. You can program a custom scaling and dead band for each point where indicated. If you do not specify a custom scaling or dead band, the relay will use the default for the type of value you are mapping. For example, if you enter 60 in Row 1 of the custom analog map with no other parameters, the operating current (IOP1) of Differential Element 1 in per unit will be available as Object 30 and 32; index 0 and the relay will use the default scaling DECPLM and default dead band of ANADBM.

Scaling factors allow you to overcome the limitations imposed by the integer nature of Objects 30 and 32. For example, the relay rounds a value of 11.4 amps to 11 amps. Use the scaling to include decimal point values by multiplying by a number larger than one. If you use 10 as a scaling factor, 11.4 amps will be transmitted as 114. You must divide the value by 10 in the master device to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. If you have a value that can reach 157834 you cannot send it using DNP 16-bit analog object variations. Use a scaling factor of 0.1 so that the maximum value reported is 15783. You must multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is rounded in the scaling process, but you can transmit the scaled value using standard DNP Objects 30 and 32.

Warm Start and Cold Start

The DNP function codes for warm start and cold start reset the SEL-487B serial port. These function codes do not interrupt protection processes within the relay.

Testing

Use the **TEST DNP** command to test the data mapping from the relay to your DNP master. You can use the **TEST DNP** command to force DNP values by object and index number. Although the relay reports forced values to the DNP host, these values do not affect protection processing or other protocol interfaces on the SEL-487B. The **TEST DNP** command operates by object and index number, so it works equally well with custom mapping and the default DNP map.

When you are using the **TEST DNP** command to test DNP operation, the Relay Word bit TESTDNP will be asserted to indicate that test mode is active. The DNP status bit will also show forced status for any object variations that include status.

DNP3 (Serial) Documentation

Device Profile

Table 5.8 contains the standard DNP3 device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table 5.8 SEL-487B DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-487B Relay
Highest DNP request level	Level 2
Highest DNP response level	Level 2
Device function	Slave
Notable objects, functions, and/or qualifiers supported	Virtual terminal
Maximum data link frame size transmitted/ received (octets)	292
Maximum data link retries	Configurable, range 0 to 15
Requires data link layer confirmation	Configurable by setting
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None

Table 5.8 SEL-487B DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch On	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary Input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	16 bits
Sends multifragment responses	No

Object List

Table 5.9 lists the objects and variations with supported function codes and qualifier codes as defined in the DNP level 2 documentation. Not all objects listed are supported in the SEL-487B. Objects that are supported include function code and qualifier code information.

Table 5.9 SEL-487B DNP Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
1	0	Binary Input–All Variations	1	0, 1, 6, 7, 8		
1	1	Binary Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
2	0	Binary Input Change–All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28

Table 5.9 SEL-487B DNP Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
2	3[f]	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output–All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block–All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block				
12	3	Pattern Mask				
20	0	Binary Counter–All Variations	1	0, 1, 6, 7, 8		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
20	6[e]	16-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				
21	0	Frozen Counter–All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				

Table 5.9 SEL-487B DNP Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event–All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event–All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Frozen Delta Counter Event With Time				
23	8	16-Bit Frozen Delta Counter Event With Time				
30	0	Analog Input–All Variations	1	0, 1, 6, 7, 8		

Table 5.9 SEL-487B DNP Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
31	0	Frozen Analog Input–All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
32	0	Analog Change Event–All Variations	1	6, 7, 8		
32	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event–All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
40	0	Analog Output Status–All Variations	1	0, 1, 6, 7, 8		
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8

Table 5.9 SEL-487B DNP Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
41	0	Analog Output Block–All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date–All Variations				
50	1	Time and Date	2	7, 8 index=0	129	07, quantity=1
50	2	Time and Date With Interval				
51	0	Time and Date CTO–All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO				07, quantity=1
52	0	Time Delay–All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine			129	07, quantity=1
60	0	All Classes of Data	1, 20, 21	6		
60	1	Class 0 Data	1	6		
60	2	Class 1 Data	1, 20, 21	6, 7, 8		
60	3	Class 2 Data	1, 20, 21	6, 7, 8		
60	4	Class 3 Data	1, 20, 21	6, 7, 8		
70	1	File Identifier	1, 2	6	129	7, 8
80	1	Internal Indications	2	0, 1 index=7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary–Coded Decimal				

Table 5.9 SEL-487B DNP Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
101	2	Medium Packed Binary–Coded Decimal				
101	3	Large Packed Binary–Coded Decimal				
110	All	Octet String				
111	All	Octet String Event				
112	All	Virtual Terminal Output Block	2	6		
113	All	Virtual Terminal Event Data	1, 20, 21	6	129, 130	17, 28
N/A		No object required for the following function codes: 13 cold start 14 warm start 23 delay measurement	13, 14, 23			

[a] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation
[f] Supports request, but response contains no data

Default Data Map

Table 5.10 shows the SEL-487B default DNP3 data map. The default data map makes a wide range of data in the relay available. If your DNP3 master does Class 0 polls, polls of all present value points, the response will be quite large. Use the custom DNP mapping functions of the SEL-487B to reduce the data map to the points that your application requires.

The SEL-487B provides binary input information with one of two reference maps: base or extended. The default map selection is base (MAPSEL := B).

With the base reference map, Object 1 and 2 Indices 0–799 and 800–1599 contain the same data but provide different levels of timestamp accuracy for associated Object 2 DNP events. The SER (sequential events recorder) in the relay controls events for indices 800–1599. The time stamps for these indices have the same accuracy and resolution that the SER provides. The only points available within indices 800–1599 are those that you configure for tracking by the relay SER.

Use indices 800–1599 and corresponding SER settings to track each change of bits in the Relay Word and provide SER quality time stamps via DNP. Event reporting for indices 0–799 uses a slower, less accurate timestamping mechanism, but this reporting operates for all points within the range without additional configuration.

With the extended reference map, Object 1 and 2 Indices 16–265 contain the points available for tracking by the relay SER. SER quality time stamps are available for these points and only the SER settings are needed in order to configure the points available. The entire visible Relay Word (*Table A.2 on page R.A.14*) is available starting at Index 272.

The relay scales analog values by the indicated settings or fixed scaling indicated in the description. Analog dead bands for event reporting use the indicated settings, or ANADBM if you have specified no setting.

Table 5.10 SEL-487B DNP3 Default Data Map (Sheet 1 of 4)

NOTE: See Table 5.14 (trip and close) and Table 5.15 (latch and pulse) for Object 12 operations.

Object	Indices	Description
MAPSEL := B		
01, 02	000–799	Relay Word bits, *Table 5.12*
01, 02	800–1599	SER Points, add 800 to indices in *Table 5.12*
01, 02	1600–1615	Relay front panel targets in *Table 5.13*
01, 02	1616	Relay disabled
01, 02	1617	Relay diagnostic failure
01, 02	1618	Relay diagnostic warning
01, 02	1619	New relay event available
01, 02	1620	Settings change or relay restart
01, 02	1621–1623	Reserved for future status points
01, 02	1624–1631	Relay front-panel targets in *Table 5.13*
MAPSEL := E		
01, 02	0	Relay disabled
01, 02	1	Relay diagnostic failure
01, 02	2	Relay diagnostic warning
01, 02	3	New relay event available
01, 02	4	Settings change or relay restart
01, 02	5–15	Reserved
01, 02	16–265	SER points 1–250
01, 02	266–271	Reserved
01, 02	272–3671	Entire visible Relay Word, starting from bit 0
MAPSEL := B, MAPSEL := E		
10, 12	00–15	Remote bits RB01–RB16
10, 12	16	Pulse Open Circuit Breaker 1 command
10, 12	17	Reserved
10, 12	18	Pulse Open Circuit Breaker 2 command
10, 12	19	Reserved
10, 12	20	Pulse Open Circuit Breaker 3 command
10, 12	21	Reserved
10, 12	22	Pulse Open Circuit Breaker 4 command
10, 12	23	Reserved
10, 12	24–31	Remote bit pairs RB01–RB16
10, 12	32	Open/Close pair for Circuit Breaker 1
10, 12	33	Open/Close pair for Circuit Breaker 2
10, 12	34	Open/Close pair for Circuit Breaker 3
10, 12	35	Open/Close pair for Circuit Breaker 4
10, 12	36–39	Reserved
10, 12	40	Reset front panel targets

Table 5.10 SEL-487B DNP3 Default Data Map (Sheet 2 of 4)

Object	Indices	Description
10, 12	41	Read next relay event
10, 12	42–43	Reserved
10, 12	44–59	Remote bits RB17–RB32
10, 12	60–67	Remote bit pairs RB17–RB32
10, 12	68	Pulse Open Circuit Breaker 5 command
10, 12	69	Reserved
10, 12	70	Pulse Open Circuit Breaker 6 command
10, 12	71	Reserved
10, 12	72	Pulse Open Circuit Breaker 7 command
10, 12	73	Reserved
10, 12	74	Pulse Open Circuit Breaker 8 command
10, 12	75	Reserved
10, 12	76	Pulse Open Circuit Breaker 9 command
10, 12	77	Reserved
10, 12	78	Pulse Open Circuit Breaker 10 command
10, 12	79	Reserved
10, 12	80	Pulse Open Circuit Breaker 11 command
10, 12	81	Reserved
10, 12	82	Pulse Open Circuit Breaker 12 command
10, 12	83	Reserved
10, 12	84	Pulse Open Circuit Breaker 13 command
10, 12	85	Reserved
10, 12	86	Pulse Open Circuit Breaker 14 command
10, 12	87	Reserved
10, 12	88	Pulse Open Circuit Breaker 15 command
10, 12	89	Reserved
10, 12	90	Pulse Open Circuit Breaker 16 command
10, 12	91	Reserved
10, 12	92	Pulse Open Circuit Breaker 17 command
10, 12	93	Reserved
10, 12	94	Pulse Open Circuit Breaker 18 command
10, 12	95	Reserved
10, 12	96–107	Reserved
10, 12	108	Open/Close pair for Circuit Breaker 5
10, 12	109	Open/Close pair for Circuit Breaker 6
10, 12	110	Open/Close pair for Circuit Breaker 7
10, 12	111	Open/Close pair for Circuit Breaker 8
10, 12	112	Open/Close pair for Circuit Breaker 9
10, 12	113	Open/Close pair for Circuit Breaker 10
10, 12	114	Open/Close pair for Circuit Breaker 11
10, 12	115	Open/Close pair for Circuit Breaker 12

Table 5.10 SEL-487B DNP3 Default Data Map (Sheet 3 of 4)

Object	Indices	Description
10, 12	116	Open/Close pair for Circuit Breaker 13
10, 12	117	Open/Close pair for Circuit Breaker 14
10, 12	118	Open/Close pair for Circuit Breaker 15
10, 12	119	Open/Close pair for Circuit Breaker 16
10, 12	120	Open/Close pair for Circuit Breaker 17
10, 12	121	Open/Close pair for Circuit Breaker 18
20, 22	00	Active settings group
20, 22	01	Reserved
20, 22	02	Reserved
20, 22	03	Number of unread event reports
30, 32	00, 01[a]	I01 current magnitude and angle
30, 32	02, 03[a]	I02 current magnitude and angle
30, 32	04, 05[a]	I03 current magnitude and angle
30, 32	06, 07[a]	I04 current magnitude and angle
30, 32	08, 09[a]	I05 current magnitude and angle
30, 32	10, 11[a]	I06 current magnitude and angle
30, 32	12, 13[a]	I07 current magnitude and angle
30, 32	14, 15	I08 current magnitude and angle
30, 32	16, 17[a]	I09 current magnitude and angle
30, 32	18, 19[a]	I10 current magnitude and angle
30, 32	20, 21[a]	I11 current magnitude and angle
30, 32	22, 23[a]	I12 current magnitude and angle
30, 32	24, 25[a]	I13 current magnitude and angle
30, 32	26, 27[a]	I14 current magnitude and angle
30, 32	28, 29[a]	I15 current magnitude and angle
30, 32	30, 31[a]	I16 current magnitude and angle
30, 32	32, 33[a]	I17 current magnitude and angle
30, 32	34, 35[a]	I18 current magnitude and angle
30, 32	36–47	Reserved
30, 32	48, 49[b]	V01 voltage magnitude and angle
30, 32	50, 51[b]	V02 voltage magnitude and angle
30, 32	52, 53[b]	V03 voltage magnitude and angle
30, 32	54–59	Reserved
30, 32	60[c]	IOP1 (per unit) operating current
30, 32	61[c]	IOP2 (per unit) operating current
30, 32	62[c]	IOP3 (per unit) operating current
30, 32	63[c]	IOP4 (per unit) operating current
30, 32	64[c]	IOP5 (per unit) operating current
30, 32	65[c]	IOP6 (per unit) operating current
30, 32	66–67	Reserved
30, 32	68[c]	IRT1 (per unit) restraint current

Table 5.10 SEL-487B DNP3 Default Data Map (Sheet 4 of 4)

Object	Indices	Description
30, 32	69[c]	IRT2 (per unit) restraint current
30, 32	70[c]	IRT3 (per unit) restraint current
30, 32	71[c]	IRT4 (per unit) restraint current
30, 32	72[c]	IRT5 (per unit) restraint current
30, 32	73[c]	IRT6 (per unit) restraint current
30, 32	74–75	Reserved
30, 32	76[c]	IOPCZ1 (per unit) operating current
30, 32	77–78	Reserved
30, 32	79[c]	IRTCZ1 (per unit) restraint current
30, 32	80–99	Reserved
30, 32	100[d]	VDC1 (Volts)
30, 32	101	Reserved
30, 32	102–175	Reserved
30, 32[e]	176	Fault type, *Table 5.11*
30, 32[e]	177	Fault targets (Relay Word rows 0 and 1)
30, 32[e]	178	Fault targets (Relay Word row 421)
30, 32[e]	179	Reserved
30, 32[e]	180	Reserved
30, 32[e]	181	Fault settings group
30, 32[e]	182	Reserved
30, 32[e]	183	Reserved
30, 32[e]	184–186	Fault time in DNP format
30, 32[e]	187–195	Reserved
30, 32	196–227	First 32 automation math variables (AMV001–AMV032)
40, 41	0	Active settings group

[a] Default current scaling DECPLA on magnitudes; angles scaled by 100. Dead band ADADBV on magnitudes and ADADBM on angles.
[b] Default voltage scaling DECPLV on magnitudes; angles scaled by 100. Dead band ADADBV on magnitudes and ANADBM on angles.
[c] Default miscellaneous scaling DECPLM and dead band ANADBM.
[d] Default scale factor of 100.
[e] Event data shall only be generated for the fault summary information if the relay is operating in single event mode.

NOTE: The lower byte is always 0.

Object 30, Index 176 is a 16-bit composite value, where the upper byte value indicates an event cause as shown in *Table 5.11*.

Table 5.11 Object 30, Index 176 Upper Byte—Event Cause

Byte Value	Description
1	Trigger command
2	Pulse command (Not supported)
4	Trip element
8	Event report element

Table 5.11 Object 30, Index 176 Upper Byte—Event Cause

Byte Value	Description
16	Breaker failure trip
32	Differential trip

With the base reference map, the Relay Word bits mapped into Objects 1 and 2 are shown in *Table 5.12*. For non-SER points in the range 0–799, use the Index Range column directly. For SER points in the range 800–1599, add 800 to the indices in *Table 5.12*. The table lists eight bits in each row and the index range for each row. To determine the index for a specific point, add the Relay Word bit number (0 to 7) to the first number in the range listed in the first column. For example, the index of TLED_4 is 12 (the bit number, 4, plus the first number in the range, 8).

Table 5.12 SEL-487B Object 1, 2 Relay Word Bit Mapping (Sheet 1 of 3)

	Relay Word Bits[a]							
Index Range	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
7-0	EN	TRIPLED	*	*	*	*	*	*
15-8	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
23-16	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
31-24	52AL03	52A03	52CL02	52AL02	52A02	52CL01	52AL01	52A01
39-32	52A06	52CL05	52AL05	52A05	52CL04	52AL04	52A04	52CL03
47-40	*	*	ZONE6	ZONE5	ZONE4	ZONE3	ZONE2	ZONE1
55-48	*	*	*	*	ZSWOAL	ZSWOIP	ZSWO	RZSWOAL
63-56	*	87ST	87ST6	87ST5	87ST4	87ST3	87ST2	87ST1
71-64	*	CSL1	ACTRPT1	ACTRP1	CBCLST1	CBCLS1	CB52T1	CB52A1
79-72	*	CSL2	ACTRPT2	ACTRP2	CBCLST2	CBCLS2	CB52T2	CB52A2
87-80	TOS08	TOS07	TOS06	TOS05	TOS04	TOS03	TOS02	TOS01
95-88	TOS16	TOS15	TOS14	TOS13	TOS12	TOS11	TOS10	TOS09
103-96	*	*	*	*	*	*	TOS18	TOS17
111-104	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
119-112	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
127-120	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
135-128	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
143-136	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
151-144	*	IN107	1N106	IN105	IN104	IN103	IN102	IN101
159-152	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
167-160	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
175-168	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
183-176	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
191-184	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
199-192	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
207-200	IN408	IN407	IN406	IN405	IN404	IN403	IN402	IN401
215-208	IN416	IN415	IN414	IN413	IN412	IN411	IN410	IN409
223-216	IN424	IN423	IN422	IN421	IN420	IN419	IN418	IN417

Table 5.12 SEL-487B Object 1, 2 Relay Word Bit Mapping (Sheet 2 of 3)

	Relay Word Bits[a]							
Index Range	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
231–224	IN508	IN507	IN506	IN505	IN504	IN503	IN502	IN501
239–232	IN516	IN515	IN514	IN513	IN512	IN511	IN510	IN509
247–240	IN524	IN523	IN522	IN521	IN520	IN519	IN518	IN517
255–248	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
263–256	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
271–264	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
279–272	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
287–280	PSV40	PSV39	PSV38	PSV37	PSV36	PSV35	PSV34	PSV33
295–288	PSV48	PSV47	PSV46	PSV45	PSV44	PSV43	PSV42	PSV41
303–296	PSV56	PSV55	PSV54	PSV53	PSV52	PSV51	PSV50	PSV49
311–304	PSV64	PSV63	PSV62	PSV61	PSV60	PSV59	PSV58	PSV57
319–312	PLT08	PLT07	PLT06	PLT05	PLT04	PLT03	PLT02	PLT01
327–320	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
335–328	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
343–336	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
351–344	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
359–352	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
367–360	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
375–368	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
383–376	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV00
391–384	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
399–392	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
407–400	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
415–408	ASV040	ASV039	ASV038	ASV037	ASV036	ASV035	ASV034	ASV033
423–416	ASV048	ASV047	ASV046	ASV045	ASV044	ASV043	ASV042	ASV041
431–424	ASV056	ASV055	ASV054	ASV053	ASV052	ASV051	ASV050	ASV049
439–432	ASV064	ASV063	ASV062	ASV061	ASV060	ASV059	ASV058	ASV057
447–440	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
455–448	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
463–456	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
471–464	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
479–472	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
487–480	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
495–488	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
503–496	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
511–504	SALARM	HALARM	BADPASS	CCALARM	CCOK	*	*	*
519–512	*	*	TIRIG	TUPDH	*	*	*	*
527–520	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
535–528	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201

Table 5.12 SEL-487B Object 1, 2 Relay Word Bit Mapping (Sheet 3 of 3)

Relay Word Bits[a]								
Index Range	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
543–536	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
551–544	OUT408	OUT407	OUT406	OUT405	OUT404	OUT403	OUT402	OUT401
559–552	OUT508	OUT507	OUT506	OUT505	OUT504	OUT503	OUT502	OUT501
567–560	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
575–568	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
583–576	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
591–584	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
599–592	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
607–600	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*
615–608	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
623–616	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
631–624	CCIN25	CCIN26	CCIN27	CCIN28	CCIN29	CCIN30	CCIN31	CCIN32
639–632	CCIN17	CCIN18	CCIN19	CCIN20	CCIN21	CCIN22	CCIN23	CCIN24
647–640	CCIN09	CCIN10	CCIN11	CCIN12	CCIN13	CCIN14	CCIN15	CCIN16
655–648	CCIN01	CCIN02	CCIN03	CCIN04	CCIN05	CCIN06	CCIN07	CCIN08
663–656	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
671–664	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
679–672	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
687–680	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
695–688	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
703–696	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
711–704	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
719–712	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
727–720	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*
735–728	*	*	*	*	*	*	*	CZONE1
743–736	*	*	*	*	*	*	*	87CZ1
751–744	*	*	*	*	*	*	*	87STCZ1
759–752	TLED_17	TLED_18	TLED_19	TLED_20	TLED_21	TLED_22	TLED_23	TLED_24
767–760	PB9_LED	PB10_LED	PB11_LED	PB12_LED	*	*	*	*
799–768	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved

[a] An * denotes reserved for future use.

Object 1, 2 indices 1600–1615 represent the front-panel target Relay Word bits as listed in *Table 5.13*.

Table 5.13 Object 1, 2 Front-Panel Targets (Sheet 1 of 2)

Index	Relay Word Bit	Default Function
1600	TLED_8	Busbar Fault in Protective Zone 6
1601	TLED_7	Busbar Fault in Protective Zone 5
1602	TLED_6	Busbar Fault in Protective Zone 4

Table 5.13 Object 1, 2 Front-Panel Targets (Sheet 2 of 2)

Index	Relay Word Bit	Default Function
1603	TLED_5	Busbar Fault in Protective Zone 3
1604	TLED_4	Busbar Fault in Protective Zone 2
1605	TLED_3	Busbar Fault in Protective Zone 1
1606	TLED_2	Breaker Failure
1607	TLED_1	87 Differential element operation
1608	TLED_16	Potential transformer alarm
1609	TLED_15	Disconnect alarm
1610	TLED_14	Disconnect operation in progress
1611	TLED_13	Terminal out of service
1612	TLED_12	87 Differential element blocked
1613	TLED_11	Current transformer alarm
1614	TLED_10	51 Time-delayed overcurrent element operation
1615	TLED_9	50 Instantaneous overcurrent element operation
1624	TLED_24	IRIG Source detected
1625	TLED_23	Circuit Breaker alarm
1626	TLED_22	Busbar Fault in any Zone
1627	TLED_21	Terminal 03 Voltage healthy
1628	TLED_20	Terminal 02 Voltage healthy
1629	TLED_19	Terminal 01 Voltage healthy
1630	TLED_18	59 overvoltage element operation
1631	TLED_17	27 undervoltage element operation

Reading Relay Event Data

The SEL-487B provides protective relay event history information in one of two modes: single event or with a first-in, first-out (FIFO) multi-event access method. The default mode is single event.

Single event mode provides the most recent tripping event. When a trigger with a trip type (Object 30, Index 176 byte value of 4; see *Table 5.11 on page R.5.21*) occurs this data shall be made available in the DNP fault summary area, generating appropriate DNP events. The relay shall then ignore any subsequent events for EVELOCK (port setting) time. This data shall be reset to 0 on a rising edge of RSTDNPE (global SELOGIC equation result). The relay element EVELOCK shall be set when the fault is triggered and reset when EVELOCK time expires.

Multi-event mode shall be initiated if the next event control is operated. The master should monitor binary input point 1619 (MAPSEL := B; see *Table 5.10 on page R.5.18*) or point 3 (MAPSEL := E; see *Table 5.10*), which will be asserted when there is an unread relay event summary. To read the oldest relay event summary, the master should pulse-on binary output point 41 (see *Table 5.14*). This will load the relay event summary analogs (points 176 through 186; see *Table 5.10*) with information from the oldest relay event summary, discarding the values from the previous load.

After reading the analogs, the master should again check binary input point 1619 (point 3 when MAPSEL := E), which will be on if there is another unread relay event summary. The master should continue this process until binary input point 1619 (point 3 when MAPSEL := E) is deasserted. If the master attempts to load values using output point 41 when binary input point

1619 (point 3 when MAPSEL := E) is deasserted, the relay event type analog (point 176) will be loaded with zero. With the FIFO method, the relay event summaries will always be collected in chronological order.

Control Point Operation

Use the Trip and Close operations with Object 12 control relay output block command messages to operate the points shown in *Table 5.14*. Pulse operations provide a pulse with a duration of one protection processing interval.

Table 5.14 SEL-487B Object 12 Trip Operation (Sheet 1 of 3)

Indices	Close	Trip
0–15	Set remote bits RB1–RB16	Clear remote bits RB1–RB16
16	Open Circuit Breaker 1	No action
17	Reserved	Reserved
18	Open Circuit Breaker 2	No action
19	Reserved	Reserved
20	Open Circuit Breaker 3	No action
21	Reserved	Reserved
22	Open Circuit Breaker 4	No action
23	Reserved	Reserved
24	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3
26	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15
32	No action	Pulse OC1, Circuit Breaker 1 open command bit
33	No action	Pulse OC2, Circuit Breaker 2 open command bit
34	No action	Pulse OC3, Circuit Breaker 3 open command bit
35	No action	Pulse OC4, Circuit Breaker 4 open command bit
36–39	Reserved	Reserved
40	Reset front panel targets	Reset front panel targets
41	Read next relay event	Read next relay event
42	Reserved	Reserved
43	Reserved	Reserved
44–59	Set remote bits RB17–RB32	Clear remote bits RB17–RB32
60	Pulse RB18	Pulse RB17
61	Pulse RB20	Pulse RB19
62	Pulse RB22	Pulse RB21
63	Pulse RB24	Pulse RB23
64	Pulse RB26	Pulse RB25

Table 5.14 SEL-487B Object 12 Trip Operation (Sheet 2 of 3)

Indices	Close	Trip
65	Pulse RB28	Pulse RB27
66	Pulse RB30	Pulse RB29
67	Pulse RB32	Pulse RB31
68	Open Circuit Breaker 5	No action
69	Reserved	Reserved
70	Open Circuit Breaker 6	No action
71	Reserved	Reserved
72	Open Circuit Breaker 7	No action
73	Reserved	Reserved
74	Open Circuit Breaker 8	No action
75	Reserved	Reserved
76	Open Circuit Breaker 9	No action
77	Reserved	Reserved
78	Open Circuit Breaker 10	No action
79	Reserved	Reserved
80	Open Circuit Breaker 11	No action
81	Reserved	Reserved
82	Open Circuit Breaker 12	No action
83	Reserved	Reserved
84	Open Circuit Breaker 13	No action
85	Reserved	Reserved
86	Open Circuit Breaker 14	No action
87	Reserved	Reserved
88	Open Circuit Breaker 15	No action
89	Reserved	Reserved
90	Open Circuit Breaker 16	No action
91	Reserved	Reserved
92	Open Circuit Breaker 17	No action
93	Reserved	Reserved
94	Open Circuit Breaker 18	No action
95	Reserved	Reserved
96–107	Reserved	Reserved
108	No action	Pulse OC5, Circuit Breaker 5 open command bit
109	No action	Pulse OC6, Circuit Breaker 6 open command bit
110	No action	Pulse OC7, Circuit Breaker 7 open command bit
111	No action	Pulse OC8, Circuit Breaker 8 open command bit
112	No action	Pulse OC9, Circuit Breaker 9 open command bit

Table 5.14 SEL-487B Object 12 Trip Operation (Sheet 3 of 3)

Indices	Close	Trip
113	No action	Pulse OC10, Circuit Breaker 10 open command bit
114	No action	Pulse OC11, Circuit Breaker 11 open command bit
115	No action	Pulse OC12, Circuit Breaker 12 open command bit
116	No action	Pulse OC13, Circuit Breaker 13 open command bit
117	No action	Pulse OC14, Circuit Breaker 14 open command bit
118	No action	Pulse OC15, Circuit Breaker 15 open command bit
119	No action	Pulse OC16, Circuit Breaker 16 open command bit
120	No action	Pulse OC17, Circuit Breaker 17 open command bit
121	No action	Pulse OC18, Circuit Breaker 18 open command bit
122–127	Reserved	Reserved

The SEL-487B assigns some special operations to the code portion of the control relay output block command. The special operations are shown in *Table 5.15*. Pulse operations provide a pulse duration of one protection-processing interval.

Table 5.15 SEL-487B Object 12 Code Selection Operation (Sheet 1 of 4)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
0–15	Set remote bits RB1–RB16	Clear remote bits RB1–RB16	Pulse remote bits RB1–RB16	Clear remote bits RB1–RB16
16	Pulse	No action	Pulse	No action
17	Reserved	Reserved	Reserved	Reserved
18	Pulse	No action	Pulse	No action
19	Reserved	Reserved	Reserved	Reserved
20	Pulse	No action	Pulse	No action
21	Reserved	Reserved	Reserved	Reserved
22	Pulse	No action	Pulse	No action
23	Reserved	Reserved	Reserved	Reserved
24	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3	Pulse RB4	Pulse RB3
26	Pulse RB6	Pulse RB5	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15	Pulse RB16	Pulse RB15

Table 5.15 SEL-487B Object 12 Code Selection Operation (Sheet 2 of 4)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
32	No action	Pulse OC1, Circuit Breaker 1 open bit	No action	Pulse OC1, Circuit Breaker 1 open bit
33	No action	Pulse OC2, Circuit Breaker 2 open bit	No action	Pulse OC2, Circuit Breaker 2 open bit
34	No action	Pulse OC3, Circuit Breaker 3 open bit	No action	Pulse OC3, Circuit Breaker 3 open bit
35	No action	Pulse OC4, Circuit Breaker 4 open bit	No action	Pulse OC4, Circuit Breaker 4 open bit
36–39	Reserved	Reserved	Reserved	Reserved
40	Reset front panel targets	No action	Reset front-panel targets	No action
41	Read next relay event	No action	Read next relay event	No action
42–43	Reserved	Reserved	Reserved	Reserved
44–59	Set remote bits RB17–RB32	Clear remote bits RB17–RB32	Pulse remote bits RB17–RB32	Clear remote bits RB17–RB32
60	Pulse RB18	Pulse RB17	Pulse RB18	Pulse RB17
61	Pulse RB20	Pulse RB19	Pulse RB20	Pulse RB19
62	Pulse RB22	Pulse RB21	Pulse RB22	Pulse RB21
63	Pulse RB24	Pulse RB23	Pulse RB24	Pulse RB23
64	Pulse RB26	Pulse RB25	Pulse RB26	Pulse RB25
65	Pulse RB28	Pulse RB27	Pulse RB28	Pulse RB27
66	Pulse RB30	Pulse RB29	Pulse RB30	Pulse RB29
67	Pulse RB32	Pulse RB31	Pulse RB32	Pulse RB31
68	Pulse	No action	Pulse	No action
69	Reserved	Reserved	Reserved	Reserved
70	Pulse	No action	Pulse	No action
71	Reserved	Reserved	Reserved	Reserved
72	Pulse	No action	Pulse	No action
73	Reserved	Reserved	Reserved	Reserved
74	Pulse	No action	Pulse	No action
75	Reserved	Reserved	Reserved	Reserved
76	Pulse	No action	Pulse	No action
77	Reserved	Reserved	Reserved	Reserved
78	Pulse	No action	Pulse	No action
79	Reserved	Reserved	Reserved	Reserved
80	Pulse	No action	Pulse	No action
81	Reserved	Reserved	Reserved	Reserved
82	Pulse	No action	Pulse	No action
83	Reserved	Reserved	Reserved	Reserved
84	Pulse	No action	Pulse	No action

Table 5.15 SEL-487B Object 12 Code Selection Operation (Sheet 3 of 4)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
85	Reserved	Reserved	Reserved	Reserved
86	Pulse	No action	Pulse	No action
87	Reserved	Reserved	Reserved	Reserved
88	Pulse	No action	Pulse	No action
89	Reserved	Reserved	Reserved	Reserved
90	Pulse	No action	Pulse	No action
91	Reserved	Reserved	Reserved	Reserved
92	Pulse	No action	Pulse	No action
93	Reserved	Reserved	Reserved	Reserved
94	Pulse	No action	Pulse	No action
95	Reserved	Reserved	Reserved	Reserved
96–107	Reserved	Reserved	Reserved	Reserved
108	No action	Pulse OC5, Circuit Breaker 5 open bit	No action	Pulse OC5, Circuit Breaker 5 open bit
109	No action	Pulse OC6, Circuit Breaker 6 open bit	No action	Pulse OC7, Circuit Breaker 7 open bit
110	No action	Pulse OC8, Circuit Breaker 8 open bit	No action	Pulse OC8, Circuit Breaker 8 open bit
111	No action	Pulse OC9, Circuit Breaker 9 open bit	No action	Pulse OC9, Circuit Breaker 9 open bit
112	No action	Pulse OC10, Circuit Breaker 10 open bit	No action	Pulse OC10, Circuit Breaker 10 open bit
113	No action	Pulse OC11, Circuit Breaker 11 open bit	No action	Pulse OC11, Circuit Breaker 11 open bit
114	No action	Pulse OC12, Circuit Breaker 12 open bit	No action	Pulse OC12, Circuit Breaker 12 open bit
115	No action	Pulse OC13, Circuit Breaker 13 open bit	No action	Pulse OC13, Circuit Breaker 13 open bit
116	No action	Pulse OC14, Circuit Breaker 14 open bit	No action	Pulse OC14, Circuit Breaker 14 open bit
117	No action	Pulse OC15, Circuit Breaker 15 open bit	No action	Pulse OC15, Circuit Breaker 15 open bit
118	No action	Pulse OC16, Circuit Breaker 16 open bit	No action	Pulse OC16, Circuit Breaker 16 open bit
119	No action	Pulse OC17, Circuit Breaker 17 open bit	No action	Pulse OC17, Circuit Breaker 17 open bit

Table 5.15 SEL-487B Object 12 Code Selection Operation (Sheet 4 of 4)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
120	No action	Pulse OC18, Circuit Breaker 18 open bit	No action	Pulse OC18, Circuit Breaker 18 open bit
121	No action	Pulse OC1, Circuit Breaker 1 open bit	No action	Pulse OC1, Circuit Breaker 1 open bit
122–127	Reserved	Reserved	Reserved	Reserved

DNP3 (Serial) Application Example

Application

This example uses an SEL-487B connected to an RTU over an EIA-485 network. The RTU collects basic metering information from the relay. The network for this example is shown in *Figure 5.1*.

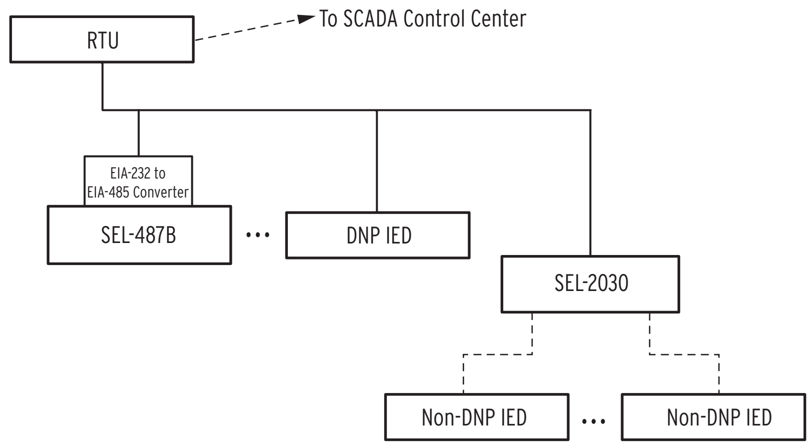

Figure 5.1 DNP Application Network Diagram

The station layout for this example is shown in *Figure 5.2*. The busbar voltage is 230 kV, and the highest expected current on any feeder is 2000 A.

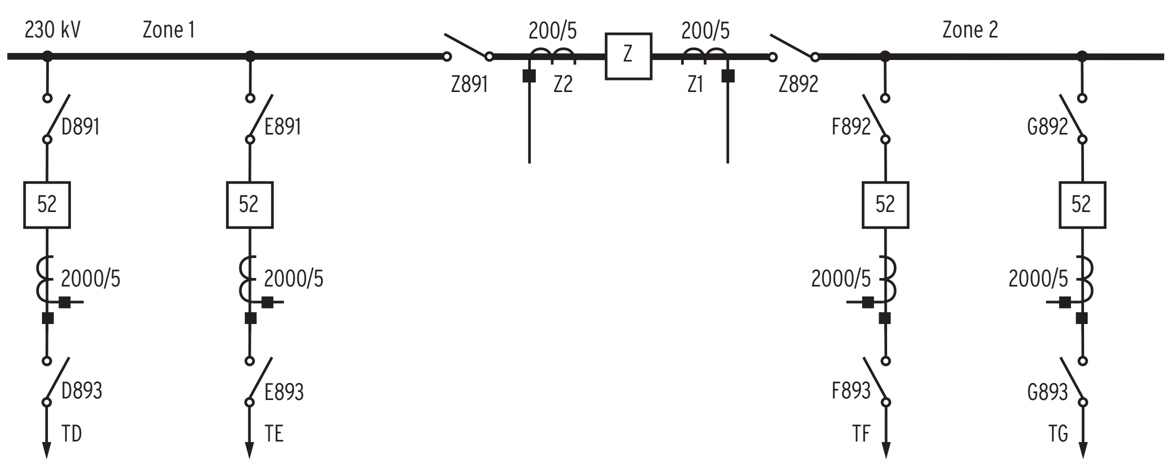

Figure 5.2 Station Layout for the Application Example Showing Four Feeders and a Tie Bus

The metering and status data that the RTU collects from the relay, as well as the default map indices and the new custom indices you can select, are listed in *Table 5.16*.

Table 5.16 DNP3 Application Example Data Map (Sheet 1 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
EN	1, 2	7	0	Relay enabled
52CL01	1, 2	26	1	TD Breaker status
52CL02	1, 2	29	2	TE Breaker status
52CL03	1, 2	32	3	TF Breaker status
52CL04	1, 2	35	4	TG Breaker status
52CL05	1, 2	38	5	TZ Breaker status
TOS01	1, 2	80	6	TD protection status
TOS02	1, 2	81	7	TE protection status
TOS03	1, 2	82	8	TF protection status
TOS04	1, 2	83	9	TG protection status
TOS05	1, 2	84	10	TZ protection status
IN204	1, 2	155	20	D981 disconnect status
IN205	1, 2	156	21	E981 disconnect status
IN206	1, 2	157	22	F981 disconnect status
IN207	1, 2	158	23	G981 disconnect status
IN208	1, 2	159	24	Z981 disconnect status
IN209	1, 2	160	25	Z982 disconnect status
SALARM	1, 2	511	25	Relay software alarm
HALARM	1, 2	510	26	Relay hardware alarm
OUT101	1, 2	520	27	TD breaker tripped
OUT102	1, 2	521	28	TE breaker tripped
OUT103	1, 2	522	29	TF breaker tripped
OUT104	1, 2	523	30	TG breaker tripped
OUT105	1, 2	524	31	TZ breaker tripped
TESTDNP	1, 2	623	32	DNP test mode enabled
RB01	10, 12	00	0	General use control point 1
RB02	10, 12	01	1	General use control point 2
RB03	10, 12	02	2	General use control point 3
RB04	10, 12	03	3	General use control point 4
RB05	10, 12	04	4	General use control point 5
OC1	10, 12	16	5	Circuit Breaker TD open
OC2	10, 12	18	6	Circuit Breaker TE open
OC3	10, 12	20	7	Circuit Breaker TF open
0C4	10, 12	22	8	Circuit Breaker TG open
0C5	10, 12	68	9	Circuit Breaker TZ open
I01FM[a] and I01FA[b]	30	00,01	0,1	I01 magnitude and angle

Table 5.16 DNP3 Application Example Data Map (Sheet 2 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
I02FM[a] and I02FA[b]	30	02,03	2,3	I02 magnitude and angle
I03FM[a] and I01FA[b]	30	04,05	4,5	I03 magnitude and angle
I04FM[a] and I01FA[b]	30	06,07	6,7	I04 magnitude and angle
I05FM[a] and I01FA[b]	30	08,09	8,9	I05 magnitude and angle
V01FM[c] and V01FA[b]	30	48,49	10,11	V01 magnitude and angle
V02FM[c] and V01FA[b]	30	50,51	12,13	V02 magnitude and angle
V03FM[c] and V01FA[b]	30	52,53	14,15	V03 magnitude and angle
IOP1[d]	30	60	16	Zone 1 operating current
IOP2[d]	30	61	17	Zone 2 operating current
IRT1[e]	30	62	18	Zone 1 restraint current
IRT2[e]	30	63	19	Zone 2 restraint current
VDC1[f]	30	100	20	DC1 voltage multiplied by 100
	40	00	0	Active settings group

[a] Because the largest expected current is 2000 A, scale the analog value by a factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of 5 A.

[b] Angles are scaled to 1/100 of a degree. Report change events on a change of 2 degrees.

[c] For a nominal voltage of 230 kV, scale the analog value by a factor of 100 to provide a resolution of 10 V and a maximum value of 327.67 kV. Report 1 kV for change event reporting.

[d] To allow for errors during commissioning, allow an operating current of 1.0 per unit and scale the analog value by a factor of 10000 to provide a resolution of 0.0001 per unit and a maximum value of 3.2767 per unit. Report change events on a change of 0.01 per unit.

[e] Because the largest expected restraint current is 4 per unit, scale the analog value by a factor of 5000 to provide a resolution of 0.0002 per unit, and a maximum value of 6.5534 per unit. Report change events on a change of 0.05 per unit.

[f] VDC1 is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

Settings

Figure 5.3 shows how to enter the new map into the relay. Use the **SET D** command and enter N at the prompts shown in *Figure 5.3* to allow changes to the existing maps. Press **<Enter>** at the line prompt to advance to the next map. For example, press **<Enter>** at line 26 of the Binary Input Map to advance to the Binary Output Map.

```
=>>SET D <Enter>
DNP

DNP Object Default Map Enables

DNP Reference Map Selection

Reference Map Selection (B,E)                      MAPSEL := B        ? <Enter>

Use default DNP map for Binary Inputs (Y/N)        DNPBID  := Y       ?N <Enter>
Use default DNP map for Binary Outputs (Y/N)       DNPBOD  := Y       ?N <Enter>
Use default DNP map for Counters (Y/N)             DNPCOD  := Y       ? <Enter>
Use default DNP map for Analog Inputs (Y/N)        DNPAID  := Y       ?N <Enter>
Use default DNP map for Analog Outputs (Y/N)       DNPAOD  := Y       ? <Enter>

Binary Input Map
(Index Number)

1:
?  7 <Enter>
2:
?  26 <Enter>
3:
?  29 <Enter>
4:
?  32 <Enter>
5:
?  35 <Enter>
6:
?  38 <Enter>
7:
?  80 <Enter>
8:
?  81 <Enter>
9:
?  82 <Enter>
10:
?  83 <Enter>
11:
?  84 <Enter>
12:
?  155 <Enter>
13:
?  156 <Enter>
14:
?  157 <Enter>
15:
?  158 <Enter>
16:
?  159 <Enter>
17:
?  160 <Enter>
18:
?  511 <Enter>
19:
?  510 <Enter>
20:
?  520 <Enter>
21:
?  521 <Enter>
22:
?  522 <Enter>
23:
?  523 <Enter>
24:
?  524 <Enter>
25:
?  623 <Enter>
26:
?<Enter>

Binary Output Map
(Index Number)

1:
?  0 <Enter>
2:
?  1 <Enter>
3:
?  2 <Enter>
4:
?  3 <Enter>
5:
?  4 <Enter>
6:
?  16 <Enter>
7:
?  18 <Enter>
```

```
8:
?  20 <Enter>
9:
?  22 <Enter>
10:
?  68 <Enter>
11:
?<Enter>

Analog Input Map
(Index Number, Scale Factor, Deadband)

1:
?  0 <Enter>
2:
?  1,1,200 <Enter>
3:
?  2 <Enter>
4:
?  3,1,200 <Enter>
5:
?  4 <Enter>
6:
?  5,1,200 <Enter>
7:
?  6 <Enter>
8:
?  7,1,200 <Enter>
9:
?  8 <Enter>
10:
?  9,1,200 <Enter>
11:
?  48 <Enter>
12:
?  49,1,200 <Enter>
13:
?  50 <Enter>
14:
?  51,1,200 <Enter>
15:
?  52 <Enter>
16:
?  53,1,200 <Enter>
17:
?  60,10000,100 <Enter>
18:
?  61,10000,100 <Enter>
19:
?  62,5000,250 <Enter>
20:
?  63,5000,250 <Enter>
21:
?  100,,200 <Enter>
22:
?<Enter>
DNP

DNP Object Default Map Enables

DNPBID  := N        DNPBOD  := N        DNPCOD  := Y        DNPAID  := N
DNPAOD  := Y

Binary Input Map
(Index Number)

1: 7
2: 26
.
.
.
20: 63, 5000, 250
21: 100, 1, 200

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 5.3 SEL-487B Example Settings

Table 5.17 lists the settings for Port 3 for this example. The physical connection between the relay and the DNP master is an EIA-485 network. An SEL-2886 interface converter on the relay Port 3 provides conversion from

EIA-232 to EIA-485. Unsolicited reporting has been disabled because the network is wired as a four-wire connection and does not provide carrier detection or the opportunity to monitor for data traffic on the network.

Table 5.17 SEL-487B Port 3 Example Settings

Setting Name	Setting	Description
PROTO	DNP	Protocol
SPEED	9600	Data speed; hidden and set to 9600 if MBT set to Y
DNPADR	101	DNP address
ECLASSB	1	Event Class 1 for binary event data
ECLASSC	1	Event Class 1 for counter event data
ECLASSA	1	Event Class 1 for analog event data
ECLASSV	OFF	Disable virtual terminal event data because this feature is not supported by master.
TIMERQ	I	Ignore time-set request because IRIG-B is used for time synchronization.
DECPLA	1	Scale current, multiplying by 10 to send amps and tenths of an amp. The relay would report a value of 10.4 as 104, which would remain unscaled at the master.
DECPLV	2	Scale voltage, multiplying by 100 to send kilovolts and tenths of a kilovolt.
DECPLM	2	Not used because custom scaling on all miscellaneous points.
STIMEO	10.0	Select/operate time-out of 10 seconds.
DRETRY	OFF	Turn off data link retries.
MINDLY	0.05	Minimum delay from DCD to TX.
MAXDLY	0.10	Maximum delay from DCD to TX.
PREDLY	0.025	Settle time from RTS on to TX to allow EIA-485 transceiver to switch to transmit mode of 25 milliseconds.
PSTDLY	0.00	Settle time from TX to RTS off; not required in this application.
ANADBA	50	Analog reporting dead band for currents, 5 amps based on DECPLA scaling factor
ANADBV	100	Analog reporting dead band for voltages, 1 kV based on DECPLV scaling factor.
ANADBM	1600	Not used because custom deadbands on all miscellaneous points.
ETIMEO	10	Event data confirmation time-out in seconds.
EVELOCK	0	Event summary lock period (0–1000 seconds)
UNSOL	N	Unsolicited reporting disabled because polling is polled report-by-exception.
MODEM	N	No modem connected to port.

In this example, the polling method employed by the RTU DNP master is polled report-by-exception. The master device normally polls for events only. Once every 25 event polls, the master polls for Class 0 data (status of all points). This polling method allows the master to collect data efficiently from the IEDs by not continuously polling and receiving data that are not changing.

Testing

In this example, we can also use the **TEST DNP** command to substitute each measured value with a static value that you can control. You can then examine received values in the RTU or at the SCADA master to verify that each point is reaching the proper destination.

DNP LAN/WAN Communications

The installation of an Ethernet Card in an SEL-487B Relay provides a DNP3 Level 2 Slave interface for direct Ethernet network connections to the relay. This section covers the following topics:

- *DNP LAN/WAN*
- *DNP LAN/WAN in the SEL-487B*
- *DNP LAN/WAN Documentation on page R.5.47*
- *DNP LAN/WAN Application Example on page R.5.56*

Please refer to *Introduction to DNP3 on page R.5.1* for additional information on DNP3.

DNP LAN/WAN

Because of the benefits that Local- and Wide-Area Networks (LAN/WAN) provide, they have become ubiquitous throughout utilities. Networks are now found in control rooms, substations, and other areas where they were rarely seen until just recently. In line with this trend, the DNP User's Group produced an extension of the DNP3 specification with recommendations for implementing DNP LAN/WAN networks.

The specification contains several key recommendations about DNP3 operation over LAN and WAN links. The most significant recommendations are listed below:

- DNP LAN/WAN will use the TCP/IP and UDP/IP protocol suite, also known as The Internet Protocol Suite.
- Ethernet is the recommended physical layer, but the recommended implementation will function over any link where the TCP/IP and UDP/IP protocol suite is present.
- All devices must support messaging through both TCP (connection oriented) and UDP (connectionless) mechanisms.
- The full DNP3 protocol stack is retained. It is supplemented by the network protocol layers so that major restructuring of DNP3 is unnecessary.
- Link layer confirmations, which are optional but discouraged for serial DNP3, are specifically not allowed for DNP LAN/WAN. The IP Suite already provides a reliable delivery mechanism that is backed up by confirmations at the application layer when required.

DNP LAN/WAN in the SEL-487B

Ethernet Card

Installation of the optional Ethernet card in an SEL-487B provides a high-performance network interface that enables the use of industry-standard SCADA network protocols, including DNP3 Level 2 slave functionality. DNP LAN/WAN incorporates most Serial DNP3 functions, and includes event data reporting with direct time tags, customized data maps and session settings, and operator-initiated control through remote bits.

Configuration and operation of the DNP LAN/WAN interface in the SEL-487B is completely independent of the Serial DNP3 interface. In this section, DNP LAN/WAN is discussed as a function of the SEL-487B, with the implication that this refers to the operation of an optional Ethernet card (with the DNP3 option) installed in an SEL-487B.

Data Access

The data access methods listed for Serial DNP3 in *Table 5.4* are also available for DNP LAN/WAN, with the exception of Virtual Terminal classes. *Table 5.18* lists the appropriate settings for DNP LAN/WAN. The DNP3 master session must be configured for one of the data access methods below.

Table 5.18 DNP LAN/WAN Access Methods

Access Method	Master Polling	SEL-487B/Ethernet Card Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA to Off, UNSL*nn* to No (where *nn* is the session number from 01–10).
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, UNSL*nn* to No.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, set UNSL*nn* to Yes and PUNSL*nn* to Yes or No.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, set UNSL*nn* and PUNSL*nn* to Yes.

As with Serial DNP3, in both the unsolicited report-by-exception and quiescent polling methods shown in *Table 5.18*, you must make a selection for the session's PUNSL*nn* setting. This setting enables or disables unsolicited data reporting at power up for this session. If the master can send the DNP message to enable unsolicited reporting from the SEL-487B, set the session PUNSL*nn* to No.

See *DNP3 Settings on page 5.39* for more information on configuring DNP LAN/WAN sessions.

Event Data

The same serial DNP event data objects are available for DNP LAN/WAN. However, configuration is slightly different. You can still configure the SEL-487B to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. Confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-487B.

With the event class settings ECLASSB, ECLASSC, and ECLASSA, you can set the event class for binary, counter, and analog information. Virtual terminal information is not supported for DNP LAN/WAN since Telnet is available to provide this capability. As with serial DNP3, you can also use the classes as a simple priority system for collecting event data.

For event data collection, you must also consider and enter appropriate settings for dead band and scaling operations on analog points shown in *Table 5.19*. You can set and use either default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Custom Data Mapping on page R.5.43* for a discussion of how to set scaling and dead-band operations on a point-by-point basis.

The setting ANADB defines default dead-band operation for analog events. A DNP3 master may also impose its own default dead band that it will use for event data for a specific channel that override the relay's ANADB setting. Because the default variations of DNP Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value. Scaling on the DNP LAN/WAN connection is subject to the same limitations of the serial interface. The master should also be configured to perform the appropriate arithmetic conversion on the incoming value to display it in proper engineering units.

Set the default analog value scaling with the DECPL setting. Application of event reporting dead bands occurs after scaling the incoming value with 10^{DECPL}. For example, if you set DECPL to 2 and ANADB to 10, a measured current of 10.14 amps would be scaled to the value 1014 (10.14×10^2) and would have to increase to more than 1024 or decrease to less than 1004 (a dead band of 0.2 amps) for the relay to report a new event value.

As with the DNP3 serial connection, the NUMEVE and AGEEVE settings are used to decide when to send unsolicited data to the master. The relay sends an unsolicited report when the total number of events accumulated in the event buffer reaches NUMEVE.

The relay also sends an unsolicited report if the age of the oldest event in the buffer exceeds AGEEVE. The SEL-487B uses the same buffer capacities with DNP LAN/WAN as through the serial DNP3 connection, listed in *Table 5.5*.

Time Synchronization

Time synchronization is not supported for DNP LAN/WAN. However, the relay will accept messages that contain a Record Current Time (Function Code 24) request and return a Null Response.

DNP3 Settings

The protocol settings that become available for DNP LAN/WAN are shown in *Table 5.19*. The DNP3 protocol settings are for the port assigned to the Ethernet card: Port 5. Keep in mind that any settings for the DNP LAN/WAN will not affect any DNP3 serial port configuration or operation and vice-versa.

It may be useful to note a few parameters that are unique to configuring DNP LAN/WAN:

- ➤ The ENDNP setting allows the user to enable or disable all DNP3 sessions on the Ethernet interface.
- ➤ The DNPMAP setting enables the usage of custom DNP3 maps to define the data/control maps for the DNP3 sessions. The DNPMAP setting can have one of two values–AUTO or CUSTOM. AUTO is intended for SEL-2032 and SEL-2030 applications. With the SEL-487B, we recommend that you always use CUSTOM.
- ➤ DECPL indicates an exponential scaling factor, 10^{DECPL}, to multiply by the raw value to calculate engineering units. Thus the default value of DECPL, 0, will still result in the raw value being multiplied by 1 (10^0).

Up to 10 sets of unique master station parameters can be configured for implementation when the relay communicates with a specified DNP3 host. These parameters include: DNPIP*xx*, DNPTR*xx*, DNPUP*xx*, UNSL*xx*, PUNSL*xx*, DNPMP*xx*, and DNPCL*xx*, where *xx* is a master station number from 01–10. These allow you to specify, for all communication sessions with a particular master, whether or not to:

- ➤ enable or disable unsolicited reporting at power-up
- ➤ enable or disable unsolicited reporting for normal operation
- ➤ indicate which custom DNP3 map is associated with it
- ➤ enable or disable controls

Please note that although the SEL-487B supports 10 masters, only five unique configuration files are available. These mapping files follow the naming convention SET_DNP*n*.TXT, where *n* indicates the DNP3 map from 1 to 5. These files reside in the Ethernet card settings subdirectory and are associated with the DNPMP*nn* setting of DNP3 Master *nn*, where *nn* is the master's number of the form 01 to 10. The DNPMP*nn* setting determines which configuration is used for communication sessions with master *nn*. For example, if DNPMP01 is set to 3, DNP3 Ethernet sessions between the SEL-487B and DNP3 Master 01 will employ the custom mapping file named SET_DNP3.TXT. Mapping files may be used by single or multiple sessions, or none at all.

Please see *Custom Data Mapping on page R.5.43* for a discussion of how to configure custom DNP3 maps for Ethernet sessions.

Table 5.19 SEL-487B Ethernet Port DNP3 Protocol Settings (Sheet 1 of 4)

Name	Description	Range	Default
ENDNP	Enable DNP3 (Y, N)	Y, N	N
DNPADR	DNP3 Address (0–65519)	0–65519	0
DNPPNUM	DNP3 Port Number for TCP and UDP (1–65534)	1–65534	20000
DNPMAP	DNP3 map Mode (AUTO, CUSTOM)	AUTO, CUSTOM	AUTO
RPADR01	DNP3 Address for Master 1 (0–65519)	0–65519	1
DNPIP01	IP Address for Master 1 (www.xxx.yyy.zzz)	20 Char String	“”

Table 5.19 SEL-487B Ethernet Port DNP3 Protocol Settings (Sheet 2 of 4)

Name	Description	Range	Default
DNPTR01	Transport Protocol for Master 1 (UDP, TCP)	TCP, UDP	TCP
DNPUP01	UDP Response Port Number for Master 1 (1–65534, REQ)	REQ, 1–65534	20000
UNSL01	Enable Unsolicited Reporting for Master 1 (Y, N)	Y, N	N
PUNSL01	Enable Unsolicited Reporting at Powerup for Master 1 (Y, N)	Y, N	N
DNPMP01	CUSTOM Mode: DNP3 map associated with Master 1 (1–5)	1–5	"1"
DNPCL01	Enable Controls for Master 1 (Y, N)	Y, N	N
RPADR02	DNP3 Address for Master 2 (0–65519)	0–65519	1
DNPIP02	IP Address for Master 2 (www.xxx.yyy.zzz)	20 Char String	""
• • •			
DNPCL02	Enable Controls for Master 2 (Y, N)	Y, N	N
RPADR03	DNP3 Address for Master 3 (0–65519)	0–65519	1
DNPIP03	IP Address for Master 3 (www.xxx.yyy.zzz)	20 Char String	""
• • •			
DNPCL03	Enable Controls for Master 3 (Y,N)	Y, N	N
RPADR04	DNP3 Address for Master 4 (0–65519)	0–65519	1
DNPIP04	IP Address for Master 4 (www.xxx.yyy.zzz)	20 Char String	""
• • •			
DNPCL04	Enable Controls for Master 4 (Y,N)	Y,N	N
RPADR05	DNP3 Address for Master 5 (0–65519)	0–65519	1
DNPIP05	IP Address for Master 5 (www.xxx.yyy.zzz)	20 Char String	""
• • •			
DNPCL05	Enable Controls for Master 5 (Y, N)	Y, N	N
RPADR06	DNP3 Address for Master 6 (0–65519)	0–65519	1
DNPIP06	IP Address for Master 6 (www.xxx.yyy.zzz)	20 Char String	""
• • •			

Table 5.19 SEL-487B Ethernet Port DNP3 Protocol Settings (Sheet 3 of 4)

Name	Description	Range	Default
DNPCL06	Enable Controls for Master 4 (Y, N)	Y, N	N
RPADR07	DNP3 Address for Master 7 (0–65519)	0–65519	1
DNPIP07	IP Address for Master 7 (www.xxx.yyy.zzz)	20 Char String	“”
• • •			
DNPCL07	Enable Controls for Master 7 (Y, N)	Y, N	N
RPADR08	DNP3 Address for Master 8 (0–65519)	0–65519	1
DNPIP08	IP Address for Master 8 (www.xxx.yyy.zzz)	20 Char String	“”
• • •			
DNPCL08	Enable Controls for Master 8 (Y, N)	Y, N	N
RPADR09	DNP3 Address for Master 9 (0–65519)	0–65519	1
DNPIP09	IP Address for Master 9 (www.xxx.yyy.zzz)	20 Char String	“”
• • •			
DNPCL09	Enable Controls for Master 9 (Y, N)	Y, N	N
RPADR10	DNP3 Address for Master 10 (0–65519)	0–65519	1
DNPIP10	IP Address for Master 10 (www.xxx.yyy.zzz)	20 Char String	“”
• • •			
DNPCL10	Enable Controls for Master 10 (Y, N)	Y, N	N
ECLASSA	Class for Analog Event Data (0–3)	0–3	2
ECLASSB	Class for Binary Event Data (0–3)	0–3	1
ECLASSC	Class for Counter Event Data (0–3)	0–3	0
DECPL	Data Scaling Decimal Places (0–3)	0–3	0
ANADB	Data Reporting Deadband Counts (0–32767)	0–32767	100
16BIT	DNP analog input objects default variation size. 16- or 32-bit default variations for analog inputs (16/32)	16, 32	16
STIMEO	Seconds to Select/Operate Time-out (0.0–30.0)	0.0–30.0	1.0
DNPPAIR	AUTO Mode: Enable Use of DNP3 Trip Close Pairs (Y, N)	Y, N	N
DNPINA	Seconds to send Inactive Heartbeat (0=Off, 1–7200)	0–7200	120
NUMEVE	Number of Events to Transmit On (1–200)	1–200	10
AGEEVE	Age of Oldest Event to Transmit On (0–100000 sec)	0–100000	2

Table 5.19 SEL-487B Ethernet Port DNP3 Protocol Settings (Sheet 4 of 4)

Name	Description	Range	Default
ETIMEO	Event Message Confirm Timeout (1–50 sec)	1–50	2
URETRY	Unsolicited Message Max Retry Attempts (2–10)	2–10	3
UTIMEO	Unsolicited Message Offline Timeout (1–5000 sec)	1–5000	60

Custom Data Mapping

Installing an Ethernet card with DNP3 LAN/WAN into an SEL-487B adds the ability to make relay data available over Ethernet to a properly configured DNP3 Master. However, by default, DNPMAP = AUTO, which includes only the relay Digital and Analog Outputs. If Digital or Analog Inputs or Counters need to be available to DNP3, each point must be specified in a custom data map. Setting DNPMAP = CUSTOM enables you to specify the DNP3 data points available for up to 10 unique master sessions using any of 5 distinct DNP3 data maps.

The SEL-487B DNP LAN/WAN interface also maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations. See *Table 5.26* for a list of control points and control methods available in the SEL-487B.

When the Ethernet port has been configured to use custom DNP3 maps, the SEL-487B will obtain these maps from the relay's SETTINGS/CARD subdirectory. Custom setting files have the filename SET_DNP*x*.TXT, where *x* is the map number from 1 to 5.

The settings described in *Table 5.20* are used to define the custom DNP3 maps. Please note that these settings are only accessible as files in the SETTINGS/CARD subdirectory. The best way to operate on these settings is by using the ACSELERATOR QuickSet® SEL-5030 settings assistant.

Table 5.20 SEL-487B DNP LAN/WAN Map Settings (Sheet 1 of 3)

Name	Type	Range	Default	Description
BIM0000–BIM1023	Binary Input Point	String of form "1:addr:bit" where addr must be in range 0–65534 and bit must be in range 0–15.	""	These settings correlate specific database bits with binary input indexes.
BIC0000–BIC1023	Binary Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSB setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
BOM0000–BOM0511	Binary Output Point	OFF, 0–(MAX as defined by *Table 5.2*)	OFF	These settings correlate specific control operations from *Table 5.14* to binary output indexes. A value of OFF indicates no object at that index.

Table 5.20 SEL-487B DNP LAN/WAN Map Settings (Sheet 2 of 3)

Name	Type	Range	Default	Description
CIM0000–CIM0127	Counter Input Point	String of form ”1:addr” where addr must be in range 0–65534.	“”	These settings correlate specific database registers with counter indexes.
CIC0000–CIC0127	Counter Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSC setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
AIM0000–AIM0511	Analog Input Point	String of form “1:addr[,t]” where addr must be in range 0–65534 and t must be i, u, il, ul, or f.	“”	These settings correlate specific database registers with analog input indexes. The optional “treat-as” qualifier (t) is used to indicate that the data at the referenced database address is to be treated as if it is of this type, rather than the type indicated in the database. *i = integer* *u = unsigned integer* *il = long integer* *ul = unsigned long integer* *f = floating point*
AIC0000–AIC0511	Analog Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSA setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
AIS0000–AIS0511	Analog Input Scaling	DFLT, 0.000001–1000000.0	DFLT	A value of DFLT indicates to use the DECPL setting for determining the scaling of a point. The given point will be multiplied by this value before being reported through DNP.

Table 5.20 SEL-487B DNP LAN/WAN Map Settings (Sheet 3 of 3)

Name	Type	Range	Default	Description
AID0000–AID0511	Analog Input Deadband	DFLT, 0–32767	DFLT	This is the deadband to use for the point at the given index. A value of DFLT indicates to use the scaling on the ANADB setting.
AOM0000–AOM0063	Analog Output Point	OFF, 0–255	OFF	These settings correlate addresses within the card-controlled D1 region to analog output indexes. A value of OFF indicates no object at that index.

When DNPMAP = “CUSTOM”, the points that are included in the DNP3 map are defined by the contents of the custom DNP3 map files. The database capacity for each point type per map and system-wide is discussed below:

- ➤ The total number of Binary Input points allowed per map is 1024. The total system capacity (all custom DNP3 maps) is 2048 Digital Input points with unique references.
- ➤ The total number of Analog Input points allowed per map is 512. The total system capacity is 2048 Analog Inputs with unique references.
- ➤ The total number of Binary Output control points allowed per map is 512.
- ➤ The total number of Analog Output control points allowed per map is 64. The total system capacity, for all the custom DNP3 maps, is 256 Analog Output points with unique references.

Binary Inputs

The DNP index for any data point within a custom DNP3 map is assigned based on the associated setting name (i.e., BIM*xxxx* for a Binary Input, where *xxxx* is the DNP index).

In order for Binary Input points to have SOE-quality timestamps, each point must be listed in the SER and the corresponding STATE region points mapped to DNP (see *DNP LAN/WAN Application Example on page R.5.56*).

Analog Inputs

Analog dead bands and scaling factors may be set for each individual point. Use the AID*xxxx* setting to impose a dead band of 0–32767. This may be used in conjunction with a scaling factor of 0.000001–1000000.0 entered in AIS*xxxx*.

Binary Outputs

NOTE: When DNPMAP = CUSTOM, the DNPPAIR setting is ignored. The user must choose the appropriate CPId(s) to select paired or unpaired points for custom BO maps. For example, you may set BOM0000 = 224, BOM0001 = 130 to set the first DNP BO point to the remote bit pair RB02/RB01 and the second to RB03.

A Binary Output manipulates a control point, which is associated to the Binary Output by a Control Point Identifier (CPId). The CPId represents either a non-paired (single) control point or a paired (two control points) control point, where the operation selects the control point. The control points correspond to all paired and unpaired Remote Bits and all breaker controls plus the CCIN*x* bits. CPIds for the SEL-487B, which has 128 CCIN*x* points, 96 Remote Bits, 48 Remote Bit pairs, and controls for 18 Circuit Breakers, are given in *Table 5.21*.

Table 5.21 SEL-487B Binary Output CPId Values

CPId	Description
0–127	CCIN01–CCIN128
128–223	Remote Bits RB01–RB96
224–271	Remote Bit Pairs RB02/RB01–RB96/RB95
272–289	Open/Close Pairs for Circuit Breakers 1–18

Analog Outputs

Any of the 256 Analog Output Quantities in the D1 Region can be included in a custom data map. Up to 64 Analog Outputs can be assigned to a custom map. These are selected using their relative position within the region: 0 to 255. Please note that you must add 1 to the index to find the corresponding Analog Quantity number. For example, if you use index 63, that will correspond to RA064.

DNP Map Command

Use the **POR 5** and Ethernet card **DNPMAP** command to display the data (object types, indices, default variation and source) and controls (object type, indices and destination) that are accessible via DNP LAN/WAN. The output of the **DNPMAP** command documents the DNP3 data map(s) in the Ethernet card to help with the configuration of the DNP3 master.

Specify the desired custom map using an integer parameter corresponding to a DNPMAP number (1–5). For example, the command **DNPMAP 2** would be used to view the custom data map for DNP3 session 2. If a DNPMAP number is not specified, a summary of DNP3 map settings for all configured sessions will be displayed.

Summary and detailed map configurations are also available in the DNPMAP.TXT and DNPMAP*nn*.TXT files from the SEL-487B FTP interface. The individual file names associated with the detailed custom map settings follow the DNPMAP*nn*.TXT naming convention.

Note that if you issue a **DNPMAP** command at the SEL-487B command line, you will get that device's (serial) DNP3 data map. But if you issue a **PORT** command (**PORT 5**) to open a transparent session to the Ethernet port, then a DNPMAP [*x*], you will get the DNPMAP from the Ethernet card. The **PORT** command redirects all input from a serial port away from the command parser for the device and sends the stream of data to the Ethernet port. Also, any data that comes from the Ethernet port is redirected out the serial port.

Testing

Use the **TEST DB** command to test the communications card relay database. The **TEST DB** command can be used to override any value in the relay database. Since the relay database provides data to the communications card interfaces, the **TEST DB** command can also be used to test the data read operations of the DNP3 or IEC 61850 protocols on an installed Ethernet card. Use the **MAP 1** command and the **VIEW 1** command to inspect the relay database (see *MAP on page R.9.26* and *VIEW on page R.9.55*). You must be familiar with the relay database structure to use the **TEST DB** command effectively.

DNP LAN/WAN Documentation

The following section contains information specific to the DNP LAN/WAN implementation.

Device Profile

Table 5.22 contains the standard DNP LAN/WAN device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table 5.22 SEL-487B DNP LAN/WAN Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-487B Relay with Ethernet card
Highest DNP3 request level	Level 2
Highest DNP3 response level	Level 2
Device function	Slave
Notable objects, functions, and/or qualifiers supported	None
Maximum data link frame size transmitted/received (octets)	292
Maximum data link retries	0
Requires data link layer confirmation	Never
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE–NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch On	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary input change with time

Table 5.22 SEL-487B DNP LAN/WAN Device Profile (Sheet 2 of 2)

Parameter	Value
Sends unsolicited responses	Configurable with unsolicited message enable settings
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	N/A
Sends multifragment responses	Yes

Object List

The list of DNP3 objects given in *Table 5.23* includes the additions and exceptions to the list of supported DNP3 objects in *Table 5.9*. Please note the added support of object 34, and removed support of objects 112 and 113.

Table 5.23 SEL-487B DNP LAN/WAN Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
1	1[e]	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2	Binary Input With Status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary Input Change—All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28

Table 5.23 SEL-487B DNP LAN/WAN Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
20	6[e]	16-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				
21	0	Frozen Counter—All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28

Table 5.23 SEL-487B DNP LAN/WAN Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Frozen Delta Counter Event With Time				
23	8	16-Bit Frozen Delta Counter Event With Time				
30	0	Analog Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	5	Short Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6	Long Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				

Table 5.23 SEL-487B DNP LAN/WAN Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	5	Short Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32	6	Long Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
34	0	Analog Input Reporting Dead-Band Setting—All Variations	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	0	Analog Input Reporting Dead-Band Setting—All Variations	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	1[e]	16-Bit Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	1[e]	16-Bit Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28

Table 5.23 SEL-487B DNP LAN/WAN Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
34	2	32-Bit Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	2	32-Bit Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Floating Point Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	3	Floating Point Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog Output Status—All Variations	1	0, 1, 6, 7, 8	139	
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date—All Variations				
50	1	Time and Date			129	07, quantity=1
50	2	Time and Date With Interval				
50	3	Time and Date at Last Recorded Time	1	7, 8 index=0	129	07, quantity=1
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO	07, quan-ity=1			
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine			129	07, quantity=1
60	0	All Classes of Data	1, 20, 21	6		
60	1	Class 0 Data	1	6	129	0, 1
60	2	Class 1 Data	1, 20, 21	6, 7, 8	129	17, 28
60	3	Class 2 Data	1, 20, 21	6, 7, 8	129	17, 28

Table 5.23 SEL-487B DNP LAN/WAN Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
60	4	Class 3 Data	1, 20, 21	6, 7, 8	129	17, 28
70	1	File Identifier				
80	1	Internal Indications	2	0, 1 index=7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary—Coded Decimal				
101	2	Medium Packed Binary—Coded Decimal				
101	3	Large Packed Binary—Coded Decimal				
112	all	Virtual Terminal Output Block				
113	all	Virtual Terminal Event Data				
N/A		No object required for the following function codes: 13 cold start 14 warm start 24 record current time	13, 14, 24			

[a] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation

Control Point Operation

Control point operation for DNP LAN/WAN is functionally identical to Serial DNP3 operation. Use Trip and Close or Code Selection operations with Object 12 control relay output block command messages to operate the points shown in *Table 5.24*. Use the Control Point ID (CPId) shown to select the desired control points to build the Custom Binary Output map. Note that all Binary outputs (paired and non-paired) are available to the DNP LAN/WAN interface. Pulse operations provide a pulse duration of at least one protection-processing interval.

Table 5.24 SEL-487B DNP LAN/WAN Object 12 Control Point Operation (Sheet 1 of 3)

CPId	Control Points	Trip / Close Pairs		Code Selection Operation			
		Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
0–127	CCIN001–CCIN128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128
128	RB01	SET remote bit RB01	CLEAR remote bit RB01	SET remote bit RB01	CLEAR remote bit RB01	SET remote bit RB01	CLEAR remote bit RB01
129	RB02	SET remote bit RB02	CLEAR remote bit RB02	SET remote bit RB02	CLEAR remote bit RB02	SET remote bit RB02	CLEAR remote bit RB02
130	RB03	SET remote bit RB03	CLEAR remote bit RB03	SET remote bit RB03	CLEAR remote bit RB03	SET remote bit RB03	CLEAR remote bit RB03
• • •							
127+*z* [a]	RB(*z*)	SET remote bit RB(*z*)	CLEAR remote bit RB(*z*)	SET remote bit RB(*z*)	CLEAR remote bit RB(*z*)	SET remote bit RB(*z*)	CLEAR remote bit RB(*z*)
• • •							
223	RB96	SET remote bit RB96	CLEAR remote bit RB96	SET remote bit RB96	CLEAR remote bit RB96	SET remote bit RB96	CLEAR remote bit RB96
224	RB02/RB01	PULSE remote bit RB02	PULSE remote bit RB01	PULSE remote bit RB02	PULSE remote bit RB01	PULSE remote bit RB02	PULSE remote bit RB01
225	RB04/RB03	PULSE remote bit RB04	PULSE remote bit RB03	PULSE remote bit RB04	PULSE remote bit RB03	PULSE remote bit RB04	PULSE remote bit RB03
226	RB06/RB05	PULSE remote bit RB06	PULSE remote bit RB05	PULSE remote bit RB06	PULSE remote bit RB05	PULSE remote bit RB06	PULSE remote bit RB05
• • •							
223+*x*/2 [b]	RB(*x*)/RB(*x*–1)	PULSE remote bit RB(*x*)	PULSE remote bit RB(*x*–1)	PULSE remote bit RB(*x*)	PULSE remote bit RB(*x*–1)	PULSE remote bit RB(*x*)	PULSE remote bit RB(*x*–1)
• • •							
271	RB96/RB95	PULSE remote bit RB96	PULSE remote bit RB95	PULSE remote bit RB96	PULSE remote bit RB95	PULSE remote bit RB96	PULSE remote bit RB95
272	CB1	No Action	PULSE OC1, Circuit Breaker 1 open bit	PULSE OC1, Circuit Breaker 1 open bit	No Action	PULSE OC1, Circuit Breaker 1 open bit	No Action

Table 5.24 SEL-487B DNP LAN/WAN Object 12 Control Point Operation (Sheet 2 of 3)

CPId	Control Points	Trip / Close Pairs		Code Selection Operation			
273	CB2	No Action	PULSE OC2, Circuit Breaker 2 open bit	PULSE OC2, Circuit Breaker 2 open bit	No Action	PULSE OC2, Circuit Breaker 2 open bit	No Action
274	CB3	No Action	PULSE OC3, Circuit Breaker 3 open bit	PULSE OC3, Circuit Breaker 3 open bit	No Action	PULSE OC3, Circuit Breaker 3 open bit	No Action
275	CB4	No Action	PULSE OC4, Circuit Breaker 4 open bit	PULSE OC4, Circuit Breaker 4 open bit	No Action	PULSE OC4, Circuit Breaker 4 open bit	No Action
276	CB5	No Action	PULSE OC5, Circuit Breaker 5 open bit	PULSE OC5, Circuit Breaker 5 open bit	No Action	PULSE OC5, Circuit Breaker 5 open bit	No Action
277	CB6	No Action	PULSE OC6, Circuit Breaker 6 open bit	PULSE OC6, Circuit Breaker 6 open bit	No Action	PULSE OC6, Circuit Breaker 6 open bit	No Action
278	CB7	No Action	PULSE OC7, Circuit Breaker 7 open bit	PULSE OC7, Circuit Breaker 7 open bit	No Action	PULSE OC7, Circuit Breaker 7 open bit	No Action
279	CB8	No Action	PULSE OC8, Circuit Breaker 8 open bit	PULSE OC8, Circuit Breaker 8 open bit	No Action	PULSE OC8, Circuit Breaker 8 open bit	No Action
280	CB9	No Action	PULSE OC9, Circuit Breaker 9 open bit	PULSE OC9, Circuit Breaker 9 open bit	No Action	PULSE OC9, Circuit Breaker 9 open bit	No Action
281	CB10	No Action	PULSE OC10, Circuit Breaker 10 open bit	PULSE OC10, Circuit Breaker 10 open bit	No Action	PULSE OC10, Circuit Breaker 10 open bit	No Action
282	CB11	No Action	PULSE OC11, Circuit Breaker 11 open bit	PULSE OC11, Circuit Breaker 11 open bit	No Action	PULSE OC11, Circuit Breaker 11 open bit	No Action
283	CB12	No Action	PULSE OC12, Circuit Breaker 12 open bit	PULSE OC12, Circuit Breaker 12 open bit	No Action	PULSE OC12, Circuit Breaker 12 open bit	No Action
284	CB13	No Action	PULSE OC13, Circuit Breaker 13 open bit	PULSE OC13, Circuit Breaker 13 open bit	No Action	PULSE OC13, Circuit Breaker 13 open bit	No Action
285	CB14	No Action	PULSE OC14, Circuit Breaker 14 open bit	PULSE OC14, Circuit Breaker 14 open bit	No Action	PULSE OC14, Circuit Breaker 14 open bit	No Action
286	CB15	No Action	PULSE OC15, Circuit Breaker 15 open bit	PULSE OC15, Circuit Breaker 15 open bit	No Action	PULSE OC15, Circuit Breaker 15 open bit	No Action

Table 5.24 SEL-487B DNP LAN/WAN Object 12 Control Point Operation (Sheet 3 of 3)

CPId	Control Points	Trip / Close Pairs		Code Selection Operation			
287	CB16	No Action	PULSE OC16, Circuit Breaker 16 open bit	PULSE OC16, Circuit Breaker 16 open bit	No Action	PULSE OC16, Circuit Breaker 16 open bit	No Action
288	CB17	No Action	PULSE OC17, Circuit Breaker 17 open bit	PULSE OC17, Circuit Breaker 17 open bit	No Action	PULSE OC17, Circuit Breaker 17 open bit	No Action
289	CB18	No Action	PULSE OC18, Circuit Breaker 18 open bit	PULSE OC18, Circuit Breaker 18 open bit	No Action	PULSE OC18, Circuit Breaker 18 open bit	No Action

[a] Use this formula to calculate CPId for Remote Bits, where z is the Remote Bit from 1–96.
[b] Use this formula to calculate CPId for Remote Bit pairs, where x is the even-numbered Remote Bit from 2–96.

DNP LAN/WAN Application Example

This example uses an SEL-487B connected to an RTU over an Ethernet (TCP) network. The RTU collects basic metering information from the relay. The network for this example is shown in *Figure 5.4*.

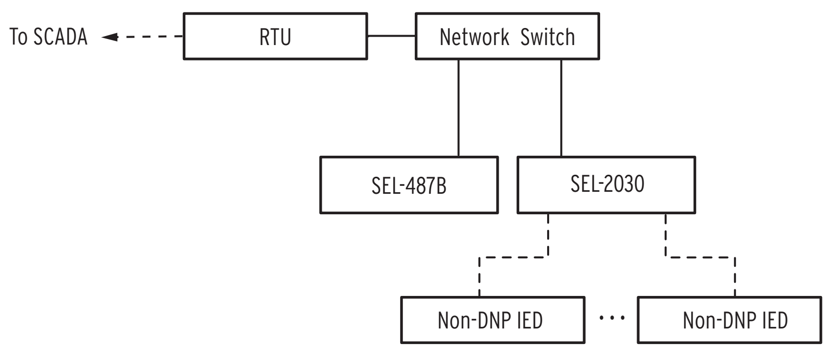

Figure 5.4 DNP LAN/WAN Application Example Ethernet Network

The polling method employed by the RTU DNP3 master is polled report-by-exception, so it normally only does event polls. Once every 25 event polls, the master polls for Class 0 data (status of all points). This polling method allows the master to collect data efficiently from the IEDs by only polling and receiving data that has changed.

The RTU, which will act as the DNP3 master to the SEL-487B slave, has an IP address of 192.9.0.1 and a DNP3 address of 12. The SEL-487B should be assigned a DNP3 address of 101.

All event data (analog, binary, counter) should be assigned to CLASS 1.

All Binary Inputs should have SOE-quality timestamps.

The metering, status data and controls that the RTU will receive and/or send to the relay are listed in *Table 5.25*.

Table 5.25 DNP LAN/WAN Application Example Custom Data Map

Name	Object Type	Custom Map Index	Description
EN	Binary Input	0	Relay enabled
TRIPLED	Binary Input	1	Circuit Breaker tripped
IN101	Binary Input	2	Relay Discrete Input 1
IN102	Binary Input	3	Relay Discrete Input 2
IN103	Binary Input	4	Relay Discrete Input 3
IN104	Binary Input	5	Relay Discrete Input 4
SALARM	Binary Input	6	Relay software alarm
HALARM	Binary Input	7	Relay hardware alarm
TESTDNP	Binary Input	8	DNP3 test mode enabled
RB01	Binary Output	0	General use Control Point (Remote Bit) 1
RB02	Binary Output	1	General use Control Point (Remote Bit) 2
RB03	Binary Output	2	General use Control Point (Remote Bit) 3
RB04	Binary Output	3	General use Control Point (Remote Bit) 4
RB05	Binary Output	4	General use Control Point (Remote Bit) 5
RB06	Binary Output	5	General use Control Point (Remote Bit) 6
OC1	Binary Output	6	Circuit Breaker 1 trip
CB01	Binary Output	6	Circuit Breaker 1 manual trip/close
I01[a][b]	Analog Input	0, 1	Line phase A current magnitude and phase angle
I02[a][b]	Analog Input	2,3	Line phase B current magnitude and phase angle
I03[a][b]	Analog Input	4,5	Line phase C current magnitude and phase angle
V01[b][c]	Analog Input	6, 7	Phase A voltage magnitude and phase angle
V02[b][c]	Analog Input	8, 9	Phase B voltage magnitude and phase angle
V03[b][c]	Analog Input	10, 11	Phase C voltage magnitude and phase angle
VDC[d]	Analog Input	14	DC1 voltage multiplied by 100
ACTGRP	Analog Output	0	Active settings group

[a] Assume the largest expected current is 2000 A, scale the analog value by a factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of 5 A.
[b] Angles are scaled to 1/100 of a degree. Report change events on a change of 2 degrees.
[c] For a nominal voltage of 230 kV, scale the analog value by a factor of 100 to provide a resolution of 10 V and a maximum value of 327.67 kV. Report 1 kV for change event reporting.
[d] VDC is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

To meet the requirement for SOE-quality timestamps, enter all binary inputs into the SER report. See *Figure 5.5* for a screenshot of the process.

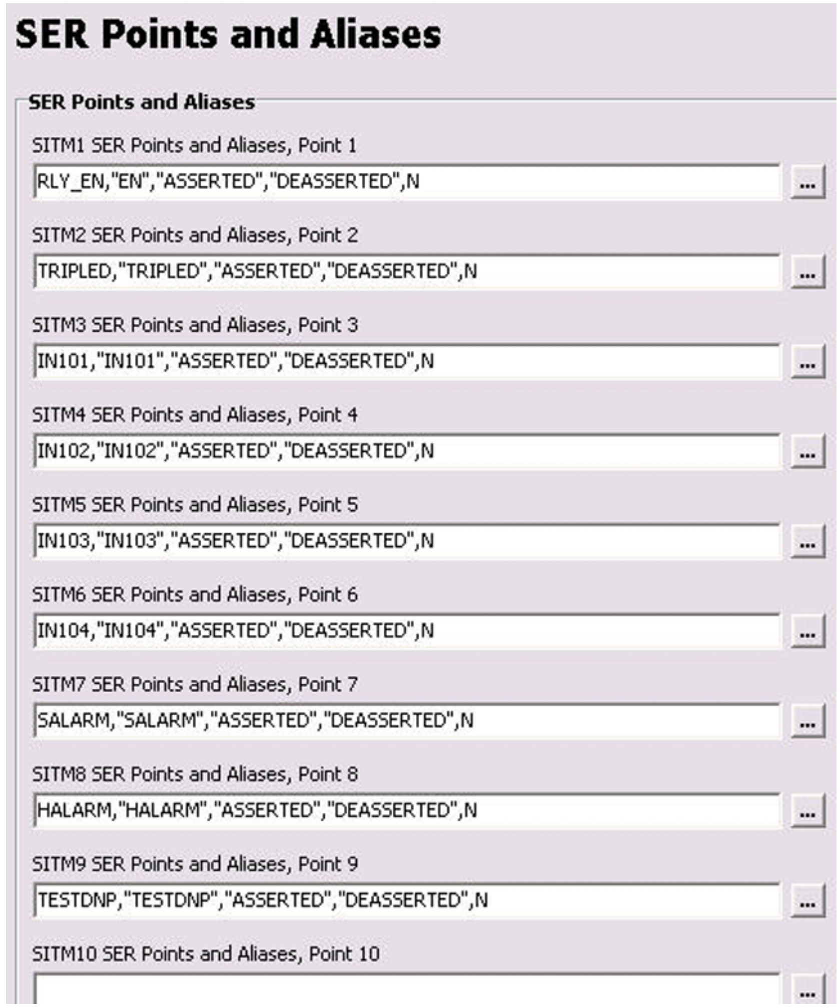

Figure 5.5 Add Binary Inputs to SER Point List

Pass the Binary Input states and timestamps to the DNP master by mapping the SER points from the STATE region, as demonstrated in *Table 5.27*.

Settings

Use the ACSELERATOR QuickSet software to enter the DNP3 protocol settings and new data map into the relay.

Table 5.26 DNP LAN/WAN Application Example Protocol Settings

Setting Name	Setting	Description
ENDNP	Y	Enable DNP3
DNPADR	101	DNP3 Address for Relay is 101
DNPPNUM	20000[a]	DNP3 Port Number for TCP
DNPMAP	CUSTOM	CUSTOM DNP3 map Mode
ECLASSA	1	Analog Event Data = Class 1
ECLASSB	1	Binary Event Data = Class 1
ECLASSC	1	Counter Event Data = Class 1
DECPL	2	Scale analog data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. (10^2=100)
ANADB	200	Analog Deadband Counts, set to 2 engineering units, based on DECPL scaling factor
STIMEO	1.0[a]	1.0 Second to Select/Operate Time-out
DNPPAIR	N[a]	AUTO Mode: Disable Use of DNP3 Trip Close Pairs
DNPINA	120[a]	Wait 120 Seconds to send Inactive Heartbeat
NUMEVE	10[a]	Transmit after 10 Events
AGEEVE	2[a]	Transmit when Age of Oldest Event = 2 sec
ETIMEO	2[a]	Event Message Confirm Timeout (2 sec)
URETRY	3[a]	3 Max Retry Attempts per Unsolicited Message
UTIMEO	60[a]	60 sec for Unsolicited Message Offline Timeout
RPADR01	12	DNP3 Address for Master 1 is 12
DNPIP01	192.9.0.1	IP Address for Master 1 (www.xxx.yyy.zzz)
DNPTR01	TCP	Transport Protocol for Master 1 (UDP, TCP)
DNPUP01	20000[a]	UDP Response Port Number for Master 1
UNSL01	N	Disable Unsolicited Reporting for Master 1
PUNSL01	N	Disable Unsolicited Reporting at Powerup for Master 1
DNPMP01	1	CUSTOM Mode: DNP3 map associated with Master 1 (Map 1)
DNPCL01	Y	Enable Controls for Master 1

[a] Default value

Table 5.27 DNP LAN/WAN Application Example Analog Output Map

Setting Name	Setting	Description
BIM0000 Database Address	1:STATE:ELEMENTS:0	SER Point 1 (EN)
BIM0001 Database Address	1:STATE:ELEMENTS:1	SER Point 2 (TRIPLED)
BIM0002 Database Address	1:STATE:ELEMENTS:2	SER Point 3 (IN101)
BIM0003 Database Address	1:STATE:ELEMENTS:3	SER Point 4 (IN102)
BIM0004 Database Address	1:STATE:ELEMENTS:4	SER Point 5 (IN103)
BIM0005 Database Address	1:STATE:ELEMENTS:5	SER Point 6 (IN104)
BIM0006 Database Address	1:STATE:ELEMENTS:6	SER Point 7 (SALARM)
BIM0007 Database Address	1:STATE:ELEMENTS:7	SER Point 8 (HALARM)
BIM0008 Database Address	1:STATE:ELEMENTS:8	SER Point 9 (TESTDNP)

Table 5.28 DNP LAN/WAN Application Example Binary Output Map

Setting Name	Setting	Description
BOM0000 Database Address	128	Custom BO map position for RB01 Control
BOM0001 Database Address	129	Custom BO map position for RB02 Control
BOM0002 Database Address	130	Custom BO map position for RB03 Control
BOM0003 Database Address	131	Custom BO map position for RB04 Control
BOM0004 Database Address	132	Custom BO map position for RB05 Control
BOM0005 Database Address	133	Custom BO map position for RB06 Control
BOM0006 Database Address	272	Custom BO map position for Circuit Breaker 1 trip/close control

Table 5.29 DNP LAN/WAN Application Example Analog Input Map (Sheet 1 of 2)

Setting Name	Point (Menu Path)	Scale Factor	Dead Band	Description
AIM0000 Database Address	1:METER:I01 (Meter Region > I01_M)	1	50	Custom map position for I01 magnitude, scale by 10 and report 5 amp change events
AIM0001 Database Address	1:100Ah			Custom map position for I01 angle[a], scale by 100 and report 2 degree change events
AIM0002 Database Address	1:METER:I02 (Meter Region > I02_M)	1	50	Custom map position for I02 magnitude[a], scale by 10 and report 5 amp change events
AIM0003 Database Address	1:100Eh			Custom map position for I02 angle[a], scale by 100 and report 2 degree change events
AIM0004 Database Address	1:METER:I03 (Meter Region > I03_M)	1	50	Custom map position for I03 magnitude[a], scale by 10 and report 5 amp change events
AIM0005 Database Address	1:1012h			Custom map position for I03 angle[a], scale by 100 and report 2 degree change events
AIM0006 Database Address	1:METER:V01 (Meter Region > V01_M)	1	10000	Custom map position for V01 magnitude, scale by 10 and report 1 kv change events

Table 5.29 DNP LAN/WAN Application Example Analog Input Map (Sheet 2 of 2)

Setting Name	Point (Menu Path)	Scale Factor	Dead Band	Description
AIM0007 Database Address	1:106Ah			Custom map position for V01 angle[a], scale by 100 and report 2 degree change events
AIM0008 Database Address	1:METER:V02 (Meter Region > V02_M)	1	10000	Custom map position for V02 magnitude, scale by 10 and report 1 kv change events
AIM0009 Database Address	1:106Eh			Custom map position for V02 angle[a], scale by 100 and report 2 degree change events
AIM0010 Database Address	1:METER:V03 (Meter Region > V03_M)	1	10000	Custom map position for V03 magnitude[a], scale by 10 and report 1 kv change events
AIM0011 Database Address	1:1072h			Custom map position for V03 angle[a], scale by 100 and report 2 degree change events
AIM0012 Database Address	1:1METER:VDC (Meter Region > VDC_M)			DC voltage[a] multiplied by 100, with a dead band of 2 volts

[a] Uses default scaling and dead band

Table 5.30 DNP LAN/WAN Application Example Analog Output Map

Setting Name	Setting	Description
AOM0000 Database Address	0	Active Settings Group

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Section 6

IEC 61850 Communications

Features

NOTE: SEL-400 series relays with optional IEC 61850 protocol require the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or if new Ethernet card firmware does not support the current CID file version. If you transfer an invalid CID file, the relay will disable the IEC 61850 protocol, as it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

The SEL-487B Relay supports the following features using Ethernet and IEC 61850:

- **SCADA**—Connect up to six simultaneous client sessions. The SEL-487B also support up to six buffered and six unbuffered report control blocks.
- **Real-Time Status and Control**—Use GOOSE with as many as 24 incoming (receive) and 8 outgoing (transmit) messages.
- **Configuration**—Use FTP client software or ACSELERATOR Architect® SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay.
- **Commissioning and Troubleshooting**—Use software such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc., to browse the relay logical nodes and verify functionality.

This section presents the information you need to use the IEC 61850 features of the SEL-487B:

Introduction to IEC 61850

In the early 1990s, the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) began to define a Utility Communications Architecture (UCA). They initially focused on inter-control center and substation-to-control center communications and produced the Inter-Control Center Communications Protocol (ICCP) specification. This specification, later adopted by the IEC as 60870-6 TASE.2, became the standard protocol for real-time exchange of data between databases.

In 1994, EPRI and IEEE began work on UCA 2.0 for Field Devices (simply referred to as UCA2). In 1997, they combined efforts with Technical Committee 57 of the IEC to create a common international standard. Their joint efforts created the current IEC 61850 standard.

The IEC 61850 standard, a superset of UCA2, contains most of the UCA2 specification, plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards.

The IEC 61850 standard consists of the parts listed in *Table 6.1*.

Table 6.1 IEC 61850 Document Set

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communication requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communication structure for substations and feeder equipment–Principles and models
IEC 61850-7-2	Basic communication structure for substations and feeder equipment–Abstract communication service interface (ACSI)
IEC 61850-7-3	Basic communication structure for substations and feeder equipment–Common data classes
IEC 61850-7-4	Basic communication structure for substations and feeder equipment–Compatible logical node (LN) classes and data classes
IEC 61850-8-1	SCSM–Mapping to Manufacturing Messaging Specification (MMS) (ISO/IEC 9506-1 and ISO/IEC 9506-2 over ISO/IEC 8802-3)
IEC 61850-9-1	SCSM–Sampled values over serial multidrop point-to-point link
IEC 61850-9-2	SCSM–Sampled values over ISO/IEC 8802-3
IEC 61850-10	Conformance testing

The IEC 61850 document set, available directly from the IEC at http://www.iec.ch, contains information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 61850 systems be familiar with the appropriate sections of this standard.

IEC 61850 Operation

Ethernet Networking

IEC 61850 and Ethernet networking model options are available when ordering a new SEL-487B and may also be available as field upgrades to relays equipped with the Ethernet card. In addition to IEC 61850, the Ethernet card provides support protocols and data exchange, including FTP and Telnet, to SEL devices. Access the SEL-487B Port 5 settings to configure all of the Ethernet settings, including IEC 61850 network settings.

The SEL-487B Ethernet card supports IEC 61850 services, including transport of Logical Node objects, over TCP/IP. The Ethernet card can coordinate a maximum of six concurrent IEC 61850 sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) models to define a set of services and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. These abstract models are used to create objects (data items) and services that exist independently of any underlying protocols. These objects are in conformance with the common data class (CDC) specification IEC 61850-7-3, which describes the type and structure of each element within a logical node. CDCs for status, measurements, controllable analogs and statuses, and settings all have unique CDC attributes. Each CDC attribute belongs to a set of functional constraints that groups the attributes into specific categories such as status (ST), description (DC), and substituted value (SV). Functional constraints, CDCs, and CDC attributes are used as building blocks for defining logical nodes.

UCA2 used GOMSFE (Generic Object Models for Substation and Feeder Equipment) to present data from station IEDs as a series of objects called models or bricks. The IEC working group has incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

Logical nodes can be organized into logical devices that are similar to directories on a computer disk. As represented in the IEC 61850 network, each physical device can contain many logical devices and each logical device can contain many logical nodes. Many relays, meters, and other IEC 61850 devices contain one primary logical device where all models are organized.

IEC 61850 devices are capable of self-description. You do not need to refer to the specifications for the logical nodes, measurements, and other components to request data from another IEC 61850 device. IEC 61850 clients can request and display a list and description of the data available in an IEC 61850 server device. This process is similar to the autoconfiguration process used within SEL communications processors (SEL-2032 and SEL-2030). Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also permits extensions to both standard and custom data models. Instead of having to look up data in a profile stored in its database, an IEC 61850 client can simply query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other Supervisory Control and Data Acquisition (SCADA) protocols that present data as a list of addresses or indices, IEC 61850 presents data with descriptors in a composite notation made up of components. *Table 6.2* shows how the A-phase current expressed as MMXUAphsA$cVal is broken down into its component parts.

Table 6.2 Example IEC 61850 Descriptor Components

Component		Description
MMXU	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
PhsA	Sub-Data Object	Phase A
CVal	Data Attribute	Complex value

Data Mapping

Device data is mapped to IEC 61850 logical nodes (LN) according to rules defined by SEL. Refer to IEC 61850-5:2003(E) and IEC 61850-7-4:2003(E) for the mandatory content and usage of these LNs. The SEL-487B logical nodes are grouped under Logical Devices for organization based on function. See *Table 6.3* for descriptions of the Logical Devices in an SEL-487B. See *Logical Nodes on page R.6.18* for a description of the LNs that make up these Logical Devices.

Table 6.3 SEL-487B Logical Devices

Logical Device	Description
ANN	Annunciator elements—alarms, status values
CFG	Configuration elements—datasets and report control blocks
CON	Control elements—remote bits
MET	Metering or Measurement elements—currents, voltages, power, etc.
PRO	Protection elements—protection functions and breaker control

MMS

Manufacturing Messaging Specification (MMS) provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506.

In theory, you can map IEC 61850 to any protocol. However, it can become unwieldy and quite complicated to map objects and services to a protocol that only provides access to simple data points via registers or index numbers. MMS supports complex named objects and flexible services that enable mapping to IEC 61850 in a straightforward manner. This was why the UCA users group used MMS for UCA from the start, and why the IEC chose to keep it for IEC 61850.

GOOSE

The Generic Object Oriented Substation Event (GOOSE) object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE automatically broadcasts messages containing status, controls, and measured values onto the network for use by other devices. IEC 61850 GOOSE sends the message several times, increasing the likelihood that other devices receive the messages.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other network devices with ACSELERATOR Architect. Also, configure outgoing GOOSE messages for SEL devices in ACSELERATOR Architect. See the ACSELERATOR Architect instruction manual or online help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference) in each outgoing message and an Ethernet multicast group address. Devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages.

CCIN (Communications Card Input) bits are control inputs that you can map to GOOSE receive messages using the ACSELERATOR Architect software. See the CCIN*nn* bits in *Table 6.11* for details on which logical nodes and names are used for these bits. This information can be useful when searching through device data with MMS browsers. If you intend to use any SEL-487B CCIN bits for controls, you must create SELOGIC® control equations to define these operations. The CCIN Logical Nodes only contain CCIN status, and only those CCINs that are part of the SER data set will be able to track CCIN transitions (via reporting) between LN data update scans.

File Services

The Ethernet File System allows reading or writing data as files. The File System supports FTP and, for the SEL-487B, the Shared Memory File Transfer service. The File System provides:

- A means for the device to transfer data as files.
- A hierarchal file structure for the device data.

SCL Files

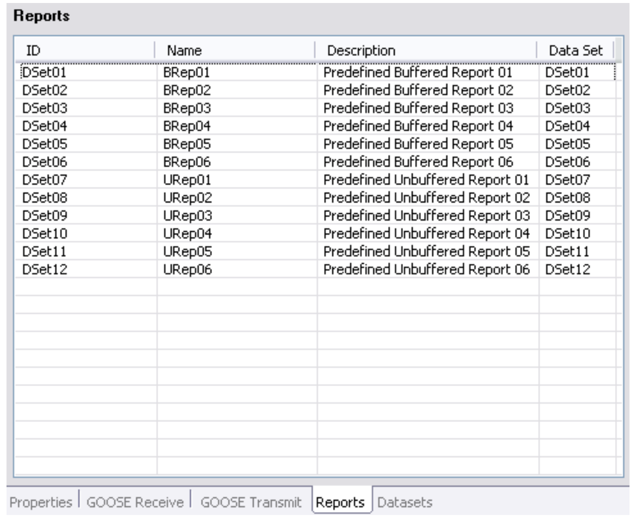
Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- IED Capability Description file (.ICD)
- System Specification Description (.SSD) file
- Substation Configuration Description file (.SCD)
- Configured IED Description file (.CID)

The ICD file describes the capabilities of an IED, including information on LN and GOOSE support. The SSD file describes the single-line diagram of the substation and the required LNs. The SCD file contains information on all IEDs, communications configuration data, and a substation description. The CID file, of which there may be several, describes a single instantiated IED within the project, and includes address information.

Reports

SEL-487B supports buffered and unbuffered report control blocks in the report model as defined in IEC 61850-8-1:2004(E). The predefined reports shown in *Figure 6.1* are available by default via IEC 61850.



Reports

ID	Name	Description	Data Set
DSet01	BRep01	Predefined Buffered Report 01	DSet01
DSet02	BRep02	Predefined Buffered Report 02	DSet02
DSet03	BRep03	Predefined Buffered Report 03	DSet03
DSet04	BRep04	Predefined Buffered Report 04	DSet04
DSet05	BRep05	Predefined Buffered Report 05	DSet05
DSet06	BRep06	Predefined Buffered Report 06	DSet06
DSet07	URep01	Predefined Unbuffered Report 01	DSet07
DSet08	URep02	Predefined Unbuffered Report 02	DSet08
DSet09	URep03	Predefined Unbuffered Report 03	DSet09
DSet10	URep04	Predefined Unbuffered Report 04	DSet10
DSet11	URep05	Predefined Unbuffered Report 05	DSet11
DSet12	URep06	Predefined Unbuffered Report 06	DSet12

Figure 6.1 SEL-487B Predefined Reports

There are twelve report control blocks (six buffered and unbuffered reports). For each report control block, there can be just one client association, i.e., only one client can be associated to a report control block (BRCB or URCB) at any given time. The number of reports (12) and the type of reports (buffered or unbuffered) cannot be changed. However, by using ACSELERATOR Architect, you can reallocate data within each report data set to present different data attributes for each report beyond the predefined datasets.

For buffered reports, connected clients may edit the report parameters shown in *Table 6.4*.

Table 6.4 Buffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		FALSE
RptEna	YES	YES	FALSE
OptFlds	YES		segNum
			timeStamp
			dataSet
			reasonCode
			dataRef
BufTm	YES		500
TrgOp	YES		dchg
			qchg
IntgPd	YES		FALSE
GI	YES[a b]	YES[a]	FALSE
PurgeBuf	YES[a]		FALSE
EntryId	YES		0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.
[b] When disabled, a GI will be processed and the report buffered if a buffer has been previously established. A buffer is established when the report is enabled for the first time.

Similarly, for unbuffered reports, connected clients may edit the report parameters shown in *Table 6.5*.

Table 6.5 Unbuffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		FALSE
RptEna	YES	YES	FALSE
Resv	YES		FALSE
OptFlds	YES		segNum
			timeStamp
			dataSet
			reasonCode
			dataRef
BufTm	YES		250
TrgOps	YES		dchg
			qchg
IntgPd	YES		FALSE
GI		YES[a]	0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

For buffered reports, only one client can enable the RptEna attribute of the BRCB or URCB at a time resulting in a client association for that BRCB or URCB. Once enabled, the associated client has exclusive access to the BRCB or URCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB or URCB.

For unbuffered reports, up to six clients can enable the RptEna attribute of the URCB at a time, resulting in multiple client associations for that URCB. Once enabled, each client has independent access to a copy of that URCB.

The Resv attribute is writable, however, the SEL-487B does not support reservations. Writing any field of the URCB causes the client to obtain their own copy of the URCB-in essence, acquiring a reservation.

Reports are serviced at a 2 Hz rate. The client can set the IntgPd to any value with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The report service rate of 2 Hz results in a report being sent within 500 ms of expiration of the IntgPd. The new IntgPd will begin at the time that the current report is serviced.

Datasets

The list of datasets in *Figure 6.2* are the defaults for an SEL-487B device.

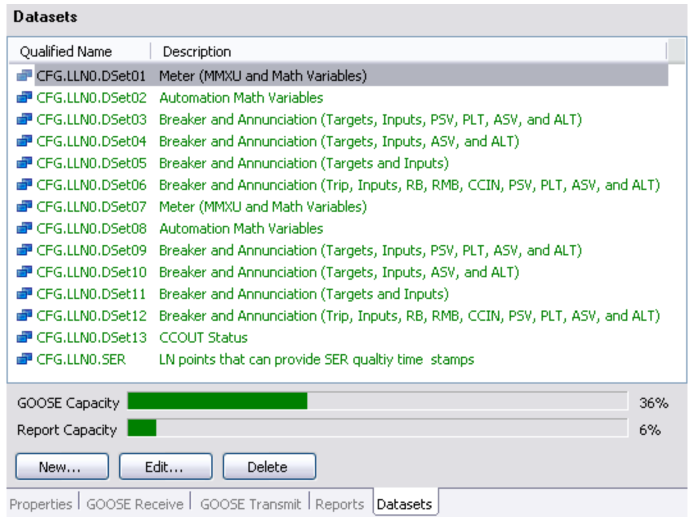


Figure 6.2 SEL-487B Datasets

Within ACSELERATOR Architect, IEC 61850 datasets have two main purposes:

- GOOSE: You can use predefined or edited datasets, or create new datasets for outgoing GOOSE transmission.

NOTE: Do not edit the dataset names used in reports. Changing or deleting any of those dataset names will cause a failure in generating the corresponding report.

- Reports: Twelve predefined datasets (DSet01 to DSet12) correspond to the default six buffered and six unbuffered reports. Note that you cannot change the number (12) or type of reports (buffered or unbuffered) within ACSELERATOR Architect. However, you can alter the data attributes that a dataset contains and so define what data an IEC 61850 client receives with a report.

The SER dataset, CFG.LLN0.SER, is a listing of the predetermined LN data attributes that are available with SER quality timestamps in the SEL-487B. Modifications to this dataset *do not* modify which data attributes have SER quality timestamps. If your application requires SER quality timestamps for data attributes not in this dataset, contact SEL for possible modification to your device IEC 61850 default configuration.

LN data attributes listed in the SER dataset have SER accurate timestamps of 1 ms for data change events. All other LN data attributes are scanned on a 1/2-second interval for data change and have 1/2-second timestamp accuracy.

Supplemental Software

Examine the data structure and values of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc.

The settings needed to browse an SEL-487B with an MMS browser are shown below.

OSI-PSEL (Presentation Selector	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality and t (time stamp) are available at any time. The timestamp is determined when data or quality change is detected. A change in the quality attribute can also be used to issue an internal event.

The timestamp is applied to all data and quality attributes (Boolean, Bstrings, Analogs, etc.) in the same fashion when a data or quality change is detected. However, there is a difference in how the change is detected between the different attribute types. For points that are assigned as SER points, i.e., listed in the SER data set, the change is detected as the receipt of an SER record (which contains the SER timestamp) from the relay to the card. For all other Booleans or Bstrings, the change is detected via the scanner, which compares the last state against the previous state to detect the change. For analogs, the scanner looks at the amount of change relative to the deadband configured for the point to indicate a change and apply the timestamp. In all cases, these timestamps are used for the reporting model.

The SEL-487B has predetermined LN data attributes that are available with SER quality timestamps. These data attributes are listed in the SER data set in the default relay ICD file. Modifications to this data set *do not* modify which data attributes have SER quality timestamps. If your application requires SER quality timestamps on data attributes not in this data set, contact SEL for possible modification to your relay default configuration.

LN data attributes listed in the SER data set have SER accurate timestamps of 1 ms for data change events. All other LN data attributes are scanned on a 1/2-second interval for data change and have 1/2-second timestamp accuracy.

The SEL-487B uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. *Figure 6.3* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from SEL-487B datasets that contain them. Internal status indicators provide the information necessary for the device to set these attributes. For example, if the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the SEL-487B will set the Validity attribute to invalid and the Failure attribute to TRUE. Note that the SEL-487B does not set any of the other quality attributes. These attributes will always indicate FALSE (0). See the ACSELERATOR Architect online help for additional information on GOOSE Quality attributes.

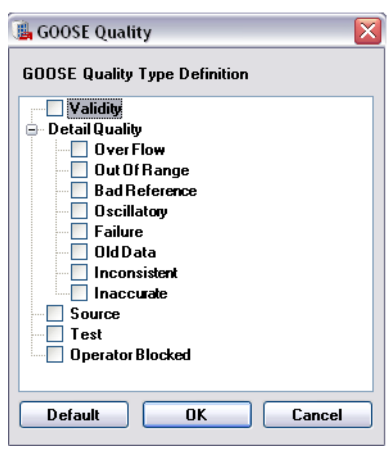


Figure 6.3 GOOSE Quality

GOOSE Processing

SEL-487B devices support GOOSE processing as defined by IEC 61850-7-1:2003(E), IEC 61850-7-2:2003(E), and IEC 61850-8-1:2004(E) via the installed Ethernet card.

Outgoing GOOSE messages are processed in accordance with the following constraints:

- ➤ The user can define up to 8 outgoing GOOSE messages consisting of any Data Attribute (DA) from any Logical Node. A single DA can be mapped to one or more outgoing GOOSE, or one or more times within the same outgoing GOOSE. A user can also map a single GOOSE data set to multiple GOOSE control blocks.
- ➤ High-speed GOOSE messaging (as defined under *GOOSE Performance on page R.6.11*) is only available for CCOUT*n* data.
- ➤ The SEL-487B will transmit all configured GOOSE immediately upon successful initialization. If a GOOSE is not retriggered, then following initial transmission, the SEL-487B will retransmit that GOOSE on a curve. The curve begins at 4 ms and doubles for each retransmission until leveling at the maximum specified in the CID file for that GOOSE. For example, a message with a maximum retransmit interval of 50 ms is retransmitted at intervals of 4 ms, 8 ms, 16 ms, 32 ms and 50 ms, then repeated every 50 ms until a trigger causes the transmission sequence to be repeated. The time-to-live reported in each transmitted message, is three times the current interval, or two times the interval, if the maximum time-to-live has been reached (12 ms, 24 ms, 48 ms, 96 ms and 100 ms for the example above. See IEC 61850-8-1, sec. 18.1).
- ➤ GOOSE transmission is squelched (silenced) if the SEL-487B stops responding to the Ethernet card, or after a permanent (latching) self-test failure.
- ➤ Each outgoing GOOSE includes communication parameters (VLAN, Priority, and Multicast Address) and is transmitted entirely in a single network frame.
- ➤ The SEL-487B will maintain the configuration of outgoing GOOSE through a power cycle and device reset.

Incoming GOOSE messages are processed in accordance with the following constraints:

- ➤ The user can configure the SEL-487B to subscribe to as many as 24 incoming GOOSE messages.
- ➤ Control bits in the SEL-487B get data from incoming GOOSE messages which are mapped to CCIN*n* bits. Note: MMS can independently operate these bits.
- ➤ The SEL-487B will recognize incoming GOOSE messages as valid based on the following content:
  - ➢ Source broadcast MAC address.
  - ➢ Data Set Reference
  - ➢ Application ID
  - ➢ GOOSE Control Reference

  Any GOOSE message that fails these checks shall be rejected.

- Every received and validated GOOSE message that indicates a data change, by an incremented status number, is evaluated as follows:
  - Data within the received GOOSE data set that are mapped to host data bits are identified.
  - Mapped bits are compared against a local version of the available host data bits.
  - If the state of the received bits is different than the local version,
    - Update the local version with the new state for that bit.
    - Pass the new state for the bit to the SEL-487B.
- Reject all DA contained in an incoming GOOSE based on the accumulation of the following error indications created by inspection of the received GOOSE:
  - **Configuration Mismatch.** The configuration number of the incoming GOOSE changes.
  - **Needs Commissioning.** This Boolean parameter of the incoming GOOSE is true.
  - **Test Mode.** This Boolean parameter of the incoming GOOSE is true.
  - **Decode Error.** The format of the incoming GOOSE is not as configured.
- The SEL-487B will discard incoming GOOSE under the following conditions:
  - after a permanent (latching) self-test failure
  - when the host is not responding
  - when EGSE is set to No

Link-layer priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2004(E).

GOOSE Performance

For outgoing high-speed data (CCOUT*n* data, as identified under *GOOSE Processing on page R.6.10*), transmission of GOOSE begins within 2 ms of transition of data within the SEL-487B. For all other data contained in outgoing GOOSE, transmission of GOOSE begins within 500 ms of transition of data within the SEL-487B. Appropriate control commands are issued to the SEL-487B within 2 ms of a GOOSE reception.

IEC 61850 Configuration

Settings

Table 6.6 lists IEC 61850 settings. These settings are only available if your device includes the optional IEC 61850 protocol.

Table 6.6 IEC 61850 Settings

Label	Description	Range	Default
E61850	IEC 61850 interface enable	Y, N	N
EGSE	Outgoing IEC 61850 GSE message enable	Y[a], N	N

[a] Requires E61850 set to Y to send IEC 61850 GSE messages.

Configure all other IEC 61850 settings, including subscriptions to incoming GOOSE messages, with ACSELERATOR Architect software.

ACSELERATOR Architect

The ACSELERATOR Architect software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Engineers can use ACSELERATOR Architect to:

- ➤ Organize and configure all SEL IEDs in a substation project.
- ➤ Configure incoming and outgoing GOOSE messages.
- ➤ Edit and create GOOSE datasets.
- ➤ Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- ➤ Use or edit preconfigured datasets for reports.
- ➤ Load device settings and IEC 61850 CID files into SEL IEDs.
- ➤ Generate ICD files that will provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.
- ➤ Configure protection, logic, control, and communication settings of all SEL IEDs in the substation.

ACSELERATOR Architect provides a Graphical User Interface (GUI) for engineers to select, edit, and create IEC 61850 GOOSE messages important for substation protection, coordination, and control schemes. Typically, the engineer first places icons representing IEDs in a substation container, then edits the outgoing GOOSE messages or creates new ones for each IED. The engineer may also select incoming GOOSE messages for each IED to receive from any other IEDs in the domain. ACSELERATOR Architect has the capability to read other manufacturers' ICD and CID files, enabling the engineer to map the data seamlessly into SEL IED logic. See the ACSELERATOR Architect online help for more information.

SEL ICD File Versions

ACSELERATOR Architect version 1.1.69.0 and higher supports multiple ICD file versions for each IED in a project. Because relays with different Ethernet card firmware may require different CID file versions, this allows users to manage the CID files of all IEDs within a single project.

Please ensure that you work with the appropriate version of ACSELERATOR Architect relative to your current configuration, existing project files, and ultimate goals. If you desire the best available IEC 61850 functionality for your SEL relay, obtain the latest version of ACSELERATOR Architect and select the appropriate ICD version(s) for your needs.

As of this writing, ACSELERATOR Architect comes with two versions of the ICD file for use with the SEL-487B on new or existing projects. These versions are listed below.

- **002 (SEL-487B-0 8-Pushbutton Models):** This file is compatible with Ethernet card firmware R107 to R112 and the 8-pushbutton model of the SEL-487B.
- **002 (SEL-487B-0 12-Pushbutton Models):** Identical in content to the file above, with additional logical nodes for extra pushbuttons made accessible in SEL-487B R116 or higher firmware. Select this file to enable access to these additional logical nodes when using the 12-pushbutton model of the SEL-487B.

NOTE: Using this file with SEL-487B R115 and earlier firmware may cause unexpected behavior.

CID File Conversion

NOTE: If left unmodified, downloading the file will cause CID file parse errors and disable the IEC 61850 protocol.

If you attempt to download a version 001 CID file to a relay with Ethernet card firmware R107 to R112, ACSELERATOR Architect will offer to make the file compatible with version 002. If you agree, ACSELERATOR Architect will modify the existing CID file so that the relay can successfully process it. If you decline, the relay will cancel your request to download the CID file to the relay.

Similarly, if you attempt to download a version 002 CID file to a relay with Ethernet card firmware R113 or higher, ACSELERATOR Architect will offer to convert the file to version 003. Once converted, there will be no difference between version 002 and 003 except for the file version number stored in the CID file. If you agree, ACSELERATOR Architect will change the CID file version so that the relay can successfully process it. If you decline, the relay will cancel your request to download the CID file to the relay. This conversion is the only method ACSELERATOR Architect supports to download a CID file to a relay with Ethernet card firmware R113 or higher.

See *Table 6.7* for a summary of the logical nodes provided with each ICD file version.

Table 6.7 Logical Node Summary (Sheet 1 of 4)

Logical Device	Logical Nodes by ICD Version: Ver 001 Ver 002L	Ver 002 Default	Ver 002 R116+	Description
PRO	D87R1PDIF1	D87RPDIF1[a]	D87RPDIF1	Zone 1 Restraint Differential Element
PRO	D87R2PDIF2	D87RPDIF2[a]	D87RPDIF2	Zone 2 Restraint Differential Element
PRO	D87R3PDIF3	D87RPDIF3[a]	D87RPDIF3	Zone 3 Restraint Differential Element
PRO	D87R4PDIF4	D87RPDIF4[a]	D87RPDIF4	Zone 4 Restraint Differential Element
PRO	D87R5PDIF5	D87RPDIF5[a]	D87RPDIF5	Zone 5 Restraint Differential Element
PRO	D87R6PDIF6	D87RPDIF6[a]	D87RPDIF6	Zone 6 Restraint Differential Element
PRO	T87Z1PTRC1	T87ZPTRC1	T87ZPTRC1	Zone 1 Differential Element
PRO	T87Z2PTRC2	T87ZPTRC2	T87ZPTRC2	Zone 2 Differential Element
PRO	T87Z3PTRC3	T87ZPTRC3	T87ZPTRC3	Zone 3 Differential Element
PRO	T87Z4PTRC4	T87ZPTRC4	T87ZPTRC4	Zone 4 Differential Element
PRO	T87Z5PTRC5	T87ZPTRC5	T87ZPTRC5	Zone 5 Differential Element
PRO	T87Z6PTRC6	T87ZPTRC6	T87ZPTRC6	Zone 6 Differential Element
PRO	TRIP01PTRC7	TRIPPTRC7[a]	TRIPPTRC7	Terminal 1 Trip Output
PRO	TRIP02PTRC8	TRIPPTRC8[a]	TRIPPTRC8	Terminal 2 Trip Output
PRO	TRIP03PTRC9	TRIPPTRC9[a]	TRIPPTRC9	Terminal 3 Trip Output
PRO	TRIP04PTRC10	TRIPPTRC10[a]	TRIPPTRC10	Terminal 4 Trip Output
PRO	TRIP05PTRC11	TRIPPTRC11[a]	TRIPPTRC11	Terminal 5 Trip Output
PRO	TRIP06PTRC12	TRIPPTRC12[a]	TRIPPTRC12	Terminal 6 Trip Output
PRO	TRIP07PTRC13	TRIPPTRC13[a]	TRIPPTRC13	Terminal 7 Trip Output
PRO	TRIP08PTRC14	TRIPPTRC14[a]	TRIPPTRC14	Terminal 8 Trip Output
PRO	TRIP09PTRC15	TRIPPTRC15[a]	TRIPPTRC15	Terminal 9 Trip Output
PRO	TRIP10PTRC16	TRIPPTRC16[a]	TRIPPTRC16	Terminal 10 Trip Output
PRO	TRIP11PTRC17	TRIPPTRC17[a]	TRIPPTRC17	Terminal 11 Trip Output
PRO	TRIP12PTRC18	TRIPPTRC18[a]	TRIPPTRC18	Terminal 12 Trip Output
PRO	TRIP13PTRC19	TRIPPTRC19[a]	TRIPPTRC19	Terminal 13 Trip Output
PRO	TRIP14PTRC20	TRIPPTRC20[a]	TRIPPTRC20	Terminal 14 Trip Output
PRO	TRIP15PTRC21	TRIPPTRC21[a]	TRIPPTRC21	Terminal 15 Trip Output
PRO	TRIP16PTRC22	TRIPPTRC22[a]	TRIPPTRC22	Terminal 16 Trip Output
PRO	TRIP17PTRC23	TRIPPTRC23[a]	TRIPPTRC23	Terminal 17 Trip Output
PRO	TRIP18PTRC24	TRIPPTRC24[a]	TRIPPTRC24	Terminal 18 Trip Output
PRO	-	-	T87CZPTRC25[b]	Check Zone Differential Element
PRO	X52A01XCBR1	X52AXCBR1[a]	X52AXCBR1	Circuit Breaker 01 Closed
PRO	X52A02XCBR2	X52AXCBR2[a]	X52AXCBR2	Circuit Breaker 02 Closed
PRO	X52A03XCBR3	X52AXCBR3[a]	X52AXCBR3	Circuit Breaker 03 Closed
PRO	X52A04XCBR4	X52AXCBR4[a]	X52AXCBR4	Circuit Breaker 04 Closed
PRO	X52A05XCBR5	X52AXCBR5[a]	X52AXCBR5	Circuit Breaker 05 Closed
PRO	X52A06XCBR6	X52AXCBR6[a]	X52AXCBR6	Circuit Breaker 06 Closed
PRO	X52A07XCBR7	X52AXCBR7[a]	X52AXCBR7	Circuit Breaker 07 Closed
PRO	X52A08XCBR8	X52AXCBR8[a]	X52AXCBR8	Circuit Breaker 08 Closed

Table 6.7 Logical Node Summary (Sheet 2 of 4)

Logical Device	Logical Nodes by ICD Version			Description
	Ver 001 Ver 002L	Ver 002 Default	Ver 002 R116+	
PRO	X52A09XCBR9	X52AXCBR9[a]	X52AXCBR9	Circuit Breaker 09 Closed
PRO	X52A10XCBR10	X52AXCBR10[a]	X52AXCBR10	Circuit Breaker 10 Closed
PRO	X52A11XCBR11	X52AXCBR11[a]	X52AXCBR11	Circuit Breaker 11 Closed
PRO	X52A12XCBR12	X52AXCBR12[a]	X52AXCBR12	Circuit Breaker 12 Closed
PRO	X52A13XCBR13	X52AXCBR13[a]	X52AXCBR13	Circuit Breaker 13 Closed
PRO	X52A14XCBR14	X52AXCBR14[a]	X52AXCBR14	Circuit Breaker 14 Closed
PRO	X52A15XCBR15	X52AXCBR15[a]	X52AXCBR15	Circuit Breaker 15 Closed
PRO	X52A16XCBR16	X52AXCBR16[a]	X52AXCBR16	Circuit Breaker 16 Closed
PRO	X52A17XCBR17	X52AXCBR17[a]	X52AXCBR17	Circuit Breaker 17 Closed
PRO	X52A18XCBR18	X52AXCBR18[a]	X52AXCBR18	Circuit Breaker 18 Closed
PRO	X89CL01XSWI1	X89CLXSWI1[a]	X89CLXSWI1	Disconnect 01 Closed
PRO	X89CL02XSWI2	X89CLXSWI2[a]	X89CLXSWI2	Disconnect 02 Closed
PRO	X89CL03XSWI3	X89CLXSWI3[a]	X89CLXSWI3	Disconnect 03 Closed
PRO	X89CL04XSWI4	X89CLXSWI4[a]	X89CLXSWI4	Disconnect 04 Closed
PRO	X89CL05XSWI5	X89CLXSWI5[a]	X89CLXSWI5	Disconnect 05 Closed
PRO	X89CL06XSWI6	X89CLXSWI6[a]	X89CLXSWI6	Disconnect 06 Closed
PRO	X89CL07XSWI7	X89CLXSWI7[a]	X89CLXSWI7	Disconnect 07 Closed
PRO	X89CL08XSWI8	X89CLXSWI8[a]	X89CLXSWI8	Disconnect 08 Closed
PRO	X89CL09XSWI9	X89CLXSWI9[a]	X89CLXSWI9	Disconnect 09 Closed
PRO	X89CL10XSWI10	X89CLXSWI10[a]	X89CLXSWI10	Disconnect 10 Closed
PRO	X89CL11XSWI11	X89CLXSWI11[a]	X89CLXSWI11	Disconnect 11 Closed
PRO	X89CL12XSWI12	X89CLXSWI12[a]	X89CLXSWI12	Disconnect 12 Closed
PRO	X89CL13XSWI13	X89CLXSWI13[a]	X89CLXSWI13	Disconnect 13 Closed
PRO	X89CL14XSWI14	X89CLXSWI14[a]	X89CLXSWI14	Disconnect 14 Closed
PRO	X89CL15XSWI15	X89CLXSWI15[a]	X89CLXSWI15	Disconnect 15 Closed
PRO	X89CL16XSWI16	X89CLXSWI16[a]	X89CLXSWI16	Disconnect 16 Closed
PRO	X89CL17XSWI17	X89CLXSWI17[a]	X89CLXSWI17	Disconnect 17 Closed
PRO	X89CL18XSWI18	X89CLXSWI18[a]	X89CLXSWI18	Disconnect 18 Closed
PRO	X89CL19XSWI19	X89CLXSWI19[a]	X89CLXSWI19	Disconnect 19 Closed
PRO	X89CL20XSWI20	X89CLXSWI20[a]	X89CLXSWI20	Disconnect 20 Closed
PRO	X89CL21XSWI21	X89CLXSWI21[a]	X89CLXSWI21	Disconnect 21 Closed
PRO	X89CL22XSWI22	X89CLXSWI22[a]	X89CLXSWI22	Disconnect 22 Closed
PRO	X89CL23XSWI23	X89CLXSWI23[a]	X89CLXSWI23	Disconnect 23 Closed
PRO	X89CL24XSWI24	X89CLXSWI24[a]	X89CLXSWI24	Disconnect 24 Closed
PRO	X89CL25XSWI25	X89CLXSWI25[a]	X89CLXSWI25	Disconnect 25 Closed
PRO	X89CL26XSWI26	X89CLXSWI26[a]	X89CLXSWI26	Disconnect 26 Closed
PRO	X89CL27XSWI27	X89CLXSWI27[a]	X89CLXSWI27	Disconnect 27 Closed
PRO	X89CL28XSWI28	X89CLXSWI28[a]	X89CLXSWI28	Disconnect 28 Closed
PRO	X89CL29XSWI29	X89CLXSWI29[a]	X89CLXSWI29	Disconnect 29 Closed

Table 6.7 Logical Node Summary (Sheet 3 of 4)

Logical Device	Logical Nodes by ICD Version: Ver 001 Ver 002L	Ver 002 Default	Ver 002 R116+	Description
PRO	X89CL30XSWI30	X89CLXSWI30[a]	X89CLXSWI30	Disconnect 30 Closed
PRO	X89CL31XSWI31	X89CLXSWI31[a]	X89CLXSWI31	Disconnect 31 Closed
PRO	X89CL32XSWI32	X89CLXSWI32[a]	X89CLXSWI32	Disconnect 32 Closed
PRO	X89CL33XSWI33	X89CLXSWI33[a]	X89CLXSWI33	Disconnect 33 Closed
PRO	X89CL34XSWI34	X89CLXSWI34[a]	X89CLXSWI34	Disconnect 34 Closed
PRO	X89CL35XSWI35	X89CLXSWI35[a]	X89CLXSWI35	Disconnect 35 Closed
PRO	X89CL36XSWI36	X89CLXSWI36[a]	X89CLXSWI36	Disconnect 36 Closed
PRO	X89CL37XSWI37	X89CLXSWI37[a]	X89CLXSWI37	Disconnect 37 Closed
PRO	X89CL38XSWI38	X89CLXSWI38[a]	X89CLXSWI38	Disconnect 38 Closed
PRO	X89CL39XSWI39	X89CLXSWI39[a]	X89CLXSWI39	Disconnect 39 Closed
PRO	X89CL40XSWI40	X89CLXSWI40[a]	X89CLXSWI40	Disconnect 40 Closed
PRO	X89CL41XSWI41	X89CLXSWI41[a]	X89CLXSWI41	Disconnect 41 Closed
PRO	X89CL42XSWI42	X89CLXSWI42[a]	X89CLXSWI42	Disconnect 42 Closed
PRO	X89CL43XSWI43	X89CLXSWI43[a]	X89CLXSWI43	Disconnect 43 Closed
PRO	X89CL44XSWI44	X89CLXSWI44[a]	X89CLXSWI44	Disconnect 44 Closed
PRO	X89CL45XSWI45	X89CLXSWI45[a]	X89CLXSWI45	Disconnect 45 Closed
PRO	X89CL46XSWI46	X89CLXSWI46[a]	X89CLXSWI46	Disconnect 46 Closed
PRO	X89CL47XSWI47	X89CLXSWI47[a]	X89CLXSWI47	Disconnect 47 Closed
PRO	X89CL48XSWI48	X89CLXSWI48[a]	X89CLXSWI48	Disconnect 48 Closed
PRO	BKR01CSWI1	BKRCSWI1[a]	BKRCSWI1	Circuit Breaker 01 Open/Close
PRO	BKR02CSWI2	BKRCSWI2[a]	BKRCSWI2	Circuit Breaker 02 Open/Close
PRO	BKR03CSWI3	BKRCSWI3[a]	BKRCSWI3	Circuit Breaker 03 Open/Close
PRO	BKR04CSWI4	BKRCSWI4[a]	BKRCSWI4	Circuit Breaker 04 Open/Close
PRO	BKR05CSWI5	BKRCSWI5[a]	BKRCSWI5	Circuit Breaker 05 Open/Close
PRO	BKR06CSWI6	BKRCSWI6[a]	BKRCSWI6	Circuit Breaker 06 Open/Close
PRO	BKR07CSWI7	BKRCSWI7[a]	BKRCSWI7	Circuit Breaker 07 Open/Close
PRO	BKR08CSWI8	BKRCSWI8[a]	BKRCSWI8	Circuit Breaker 08 Open/Close
PRO	BKR09CSWI9	BKRCSWI9[a]	BKRCSWI9	Circuit Breaker 09 Open/Close
PRO	BKR10CSWI10	BKRCSWI10[a]	BKRCSWI10	Circuit Breaker 10 Open/Close
PRO	BKR11CSWI11	BKRCSWI11[a]	BKRCSWI11	Circuit Breaker 11 Open/Close
PRO	BKR12CSWI12	BKRCSWI12[a]	BKRCSWI12	Circuit Breaker 12 Open/Close
PRO	BKR13CSWI13	BKRCSWI13[a]	BKRCSWI13	Circuit Breaker 13 Open/Close
PRO	BKR14CSWI14	BKRCSWI14[a]	BKRCSWI14	Circuit Breaker 14 Open/Close
PRO	BKR15CSWI15	BKRCSWI15[a]	BKRCSWI15	Circuit Breaker 15 Open/Close
PRO	BKR16CSWI16	BKRCSWI16[a]	BKRCSWI16	Circuit Breaker 16 Open/Close
PRO	BKR17CSWI17	BKRCSWI17[a]	BKRCSWI17	Circuit Breaker 17 Open/Close
PRO	BKR18CSWI18	BKRCSWI18[a]	BKRCSWI18	Circuit Breaker 18 Open/Close

Table 6.7 Logical Node Summary (Sheet 4 of 4)

Logical Device	Logical Nodes by ICD Version: Ver 001 Ver 002L	Ver 002 Default	Ver 002 R116+	Description
MET	METMMXN1	METMMXN1	METMMXN1	Measured Values (Currents and Voltages)
MET	IOPMMXN2	IOPMMXN2	IOPMMXN2[b]	Operating Current Magnitudes
MET	IRTMMXN3	IRTMMXN3	IRTMMXN3[b]	Restraint Current Magnitudes
CON	RBGGIO1	RBGGIO1	RBGGIO1	Remote Bits
ANN	PSVGGIO1	PSVGGIO1	PSVGGIO1	Protection SELOGIC Control Variables
ANN	PLTGGIO2	PLTGGIO2	PLTGGIO2	Protection Latches
ANN	PMVGGIO3	PMVGGIO3	PMVGGIO3	Protection SELOGIC Control Equation Math Variables
ANN	ASVGGIO4	ASVGGIO4	ASVGGIO4	Automation SELOGIC Control Equation Variables
ANN	ALTGGIO5	ALTGGIO5	ALTGGIO5	Automation Latches
ANN	AMVGGIO6	AMVGGIO6	AMVGGIO6	Automation SELOGIC Control Equation Math Variables
ANN	TLEDGGIO7	TLEDGGIO7	TLEDGGIO7[b]	Front-panel target LEDs
ANN	PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8[b]	Pushbutton LEDs
ANN	INPUT1GGIO9	IN1GGIO9[a]	IN1GGIO9	Mainboard inputs
ANN	INPUT2GGIO10	IN2GGIO10[a]	IN2GGIO10	I/O Board 2 inputs, active data only if additional I/O Card(s) installed
ANN	INPUT3GGIO11	IN3GGIO11[a]	IN3GGIO11	I/O Board 3 inputs, active data only if additional I/O Card(s) installed
ANN	INPUT4GGIO12	IN4GGIO12[a]	IN4GGIO12	I/O Board 4 inputs, active data only if additional I/O Card(s) installed
ANN	INPUT5GGIO13	IN5GGIO13[a]	IN5GGIO13	I/O Board 5 inputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT1GGIO14	OUT1GGIO14[a]	OUT1GGIO14	Mainboard outputs
ANN	OUTPUT2GGIO15	OUT2GGIO15[a]	OUT2GGIO15	I/O Board 2 outputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT3GGIO16	OUT3GGIO16[a]	OUT3GGIO16	I/O Board 3 outputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT4GGIO17	OUT4GGIO17[a]	OUT4GGIO17	I/O Board 4 outputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT5GGIO18	OUT5GGIO18[a]	OUT5GGIO18	I/O Board 5 outputs, active data only if additional I/O Card(s) installed
ANN	CCINGGIO19	CCINGGIO19	CCINGGIO19	Communications Card Inputs
ANN	CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Communications Card Outputs
ANN	-	-	RMBAGGIO21[b]	Channel A Receive MIRRORED BITS
ANN	-	-	TMBAGGIO22[b]	Channel A Transmit MIRRORED BITS
ANN	-	-	RMBBGGIO23[b]	Channel B Receive MIRRORED BITS
ANN	-	-	TMBBGGIO24[b]	Channel B Transmit MIRRORED BITS
ANN	-	-	MBOKGGIO25[b]	MIRRORED BITS Communications Status

[a] Indicates that this LN name has been changed in this version and differs from the ICD file version in the adjacent left-hand column.
[b] Indicates that this LN has been added/modified in this version and differs from the ICD file version in the adjacent left-hand column.

Logical Nodes

Table 6.8–Table 6.11 show the logical nodes (LNs) supported in the SEL-487B and the associated Relay Word bits or measured quantities.

Table 6.8 shows the LNs associated with protection elements, defined as Logical Device PRO.

Table 6.8 Logical Device: PRO (Protection) (Sheet 1 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit
Ver 001 Ver 002L	Ver 002	Ver 002 R116+		
D87R1PDIF1	D87RPDIF1	D87RPDIF1	Str.general	P87R1
D87R1PDIF1	D87RPDIF1	D87RPDIF1	Op.general	87R1
D87R2PDIF2	D87RPDIF2	D87RPDIF2	Str.general	P87R2
D87R2PDIF2	D87RPDIF2	D87RPDIF2	Op.general	87R2
D87R3PDIF3	D87RPDIF3	D87RPDIF3	Str.general	P87R3
D87R3PDIF3	D87RPDIF3	D87RPDIF3	Op.general	87R3
D87R4PDIF4	D87RPDIF4	D87RPDIF4	Str.general	P87R4
D87R4PDIF4	D87RPDIF4	D87RPDIF4	Op.general	87R4
D87R5PDIF5	D87RPDIF5	D87RPDIF5	Str.general	P87R5
D87R5PDIF5	D87RPDIF5	D87RPDIF5	Op.general	87R5
D87R6PDIF6	D87RPDIF6	D87RPDIF6	Str.general	P87R6
D87R6PDIF6	D87RPDIF6	D87RPDIF6	Op.general	87R6
T87Z1PTRC1	T87ZPTRC1	T87ZPTRC1	Tr.general	87Z1
T87Z2PTRC2	T87ZPTRC2	T87ZPTRC2	Tr.general	87Z2
T87Z3PTRC3	T87ZPTRC3	T87ZPTRC3	Tr.general	87Z3
T87Z4PTRC4	T87ZPTRC4	T87ZPTRC4	Tr.general	87Z4
T87Z5PTRC5	T87ZPTRC5	T87ZPTRC5	Tr.general	87Z5
T87Z6PTRC6	T87ZPTRC6	T87ZPTRC6	Tr.general	87Z6
TRIP01PTRC7	TRIPPTRC7	TRIPPTRC7	Tr.general	TRIP01
TRIP02PTRC8	TRIPPTRC8	TRIPPTRC8	Tr.general	TRIP02
TRIP03PTRC9	TRIPPTRC9	TRIPPTRC9	Tr.general	TRIP03
TRIP04PTRC10	TRIPPTRC10	TRIPPTRC10	Tr.general	TRIP04
TRIP05PTRC11	TRIPPTRC11	TRIPPTRC11	Tr.general	TRIP05
TRIP06PTRC12	TRIPPTRC12	TRIPPTRC12	Tr.general	TRIP06
TRIP07PTRC13	TRIPPTRC13	TRIPPTRC13	Tr.general	TRIP07
TRIP08PTRC14	TRIPPTRC14	TRIPPTRC14	Tr.general	TRIP08
TRIP09PTRC15	TRIPPTRC15	TRIPPTRC15	Tr.general	TRIP09
TRIP10PTRC16	TRIPPTRC16	TRIPPTRC16	Tr.general	TRIP10
TRIP11PTRC17	TRIPPTRC17	TRIPPTRC17	Tr.general	TRIP11
TRIP12PTRC18	TRIPPTRC18	TRIPPTRC18	Tr.general	TRIP12
TRIP13PTRC19	TRIPPTRC19	TRIPPTRC19	Tr.general	TRIP13
TRIP14PTRC20	TRIPPTRC20	TRIPPTRC20	Tr.general	TRIP14

Table 6.8 Logical Device: PRO (Protection) (Sheet 2 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit
Ver 001 Ver 002L	Ver 002	Ver 002 R116+		
TRIP15PTRC21	TRIPPTRC21	TRIPPTRC21	Tr.general	TRIP15
TRIP16PTRC22	TRIPPTRC22	TRIPPTRC22	Tr.general	TRIP16
TRIP17PTRC23	TRIPPTRC23	TRIPPTRC23	Tr.general	TRIP17
TRIP18PTRC24	TRIPPTRC24	TRIPPTRC24	Tr.general	TRIP18
-	-	T87CZ1PTRC25[a]	Tr.general	87CZ1
X52A01XCBR1	X52AXCBR1	X52AXCBR1	Pos.stVal	52CL01
X52A02XCBR2	X52AXCBR2	X52AXCBR2	Pos.stVal	52CL02
X52A03XCBR3	X52AXCBR3	X52AXCBR3	Pos.stVal	52CL03
X52A04XCBR4	X52AXCBR4	X52AXCBR4	Pos.stVal	52CL04
X52A05XCBR5	X52AXCBR5	X52AXCBR5	Pos.stVal	52CL05
X52A06XCBR6	X52AXCBR6	X52AXCBR6	Pos.stVal	52CL06
X52A07XCBR7	X52AXCBR7	X52AXCBR7	Pos.stVal	52CL07
X52A08XCBR8	X52AXCBR8	X52AXCBR8	Pos.stVal	52CL08
X52A09XCBR9	X52AXCBR9	X52AXCBR9	Pos.stVal	52CL09
X52A10XCBR10	X52AXCBR10	X52AXCBR10	Pos.stVal	52CL10
X52A11XCBR11	X52AXCBR11	X52AXCBR11	Pos.stVal	52CL11
X52A12XCBR12	X52AXCBR12	X52AXCBR12	Pos.stVal	52CL12
X52A13XCBR13	X52AXCBR13	X52AXCBR13	Pos.stVal	52CL13
X52A14XCBR14	X52AXCBR14	X52AXCBR14	Pos.stVal	52CL14
X52A15XCBR15	X52AXCBR15	X52AXCBR15	Pos.stVal	52CL15
X52A16XCBR16	X52AXCBR16	X52AXCBR16	Pos.stVal	52CL16
X52A17XCBR17	X52AXCBR17	X52AXCBR17	Pos.stVal	52CL17
X52A18XCBR18	X52AXCBR18	X52AXCBR18	Pos.stVal	52CL18
X89CL01XSWI1	X89CLXSWI1	X89CLXSWI1	Pos.stVal	89CL01
X89CL02XSWI2	X89CLXSWI2	X89CLXSWI2	Pos.stVal	89CL02
X89CL03XSWI3	X89CLXSWI3	X89CLXSWI3	Pos.stVal	89CL03
X89CL04XSWI4	X89CLXSWI4	X89CLXSWI4	Pos.stVal	89CL04
X89CL05XSWI5	X89CLXSWI5	X89CLXSWI5	Pos.stVal	89CL05
X89CL06XSWI6	X89CLXSWI6	X89CLXSWI6	Pos.stVal	89CL06
X89CL07XSWI7	X89CLXSWI7	X89CLXSWI7	Pos.stVal	89CL07
X89CL08XSWI8	X89CLXSWI8	X89CLXSWI8	Pos.stVal	89CL08
X89CL09XSWI9	X89CLXSWI9	X89CLXSWI9	Pos.stVal	89CL09
X89CL10XSWI10	X89CLXSWI10	X89CLXSWI10	Pos.stVal	89CL10
X89CL11XSWI11	X89CLXSWI11	X89CLXSWI11	Pos.stVal	89CL11
X89CL12XSWI12	X89CLXSWI12	X89CLXSWI12	Pos.stVal	89CL12
X89CL13XSWI13	X89CLXSWI13	X89CLXSWI13	Pos.stVal	89CL13
X89CL14XSWI14	X89CLXSWI14	X89CLXSWI14	Pos.stVal	89CL14
X89CL15XSWI15	X89CLXSWI15	X89CLXSWI15	Pos.stVal	89CL15
X89CL16XSWI16	X89CLXSWI16	X89CLXSWI16	Pos.stVal	89CL16

Table 6.8 Logical Device: PRO (Protection) (Sheet 3 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit
Ver 001 Ver 002L	Ver 002	Ver 002 R116+		
X89CL17XSWI17	X89CLXSWI17	X89CLXSWI17	Pos.stVal	89CL17
X89CL18XSWI18	X89CLXSWI18	X89CLXSWI18	Pos.stVal	89CL18
X89CL19XSWI19	X89CLXSWI19	X89CLXSWI19	Pos.stVal	89CL19
X89CL20XSWI20	X89CLXSWI20	X89CLXSWI20	Pos.stVal	89CL20
X89CL21XSWI21	X89CLXSWI21	X89CLXSWI21	Pos.stVal	89CL21
X89CL22XSWI22	X89CLXSWI22	X89CLXSWI22	Pos.stVal	89CL22
X89CL23XSWI23	X89CLXSWI23	X89CLXSWI23	Pos.stVal	89CL23
X89CL24XSWI24	X89CLXSWI24	X89CLXSWI24	Pos.stVal	89CL24
X89CL25XSWI25	X89CLXSWI25	X89CLXSWI25	Pos.stVal	89CL25
X89CL26XSWI26	X89CLXSWI26	X89CLXSWI26	Pos.stVal	89CL26
X89CL27XSWI27	X89CLXSWI27	X89CLXSWI27	Pos.stVal	89CL27
X89CL28XSWI28	X89CLXSWI28	X89CLXSWI28	Pos.stVal	89CL28
X89CL29XSWI29	X89CLXSWI29	X89CLXSWI29	Pos.stVal	89CL29
X89CL30XSWI30	X89CLXSWI30	X89CLXSWI30	Pos.stVal	89CL30
X89CL31XSWI31	X89CLXSWI31	X89CLXSWI31	Pos.stVal	89CL31
X89CL32XSWI32	X89CLXSWI32	X89CLXSWI32	Pos.stVal	89CL32
X89CL33XSWI33	X89CLXSWI33	X89CLXSWI33	Pos.stVal	89CL33
X89CL34XSWI34	X89CLXSWI34	X89CLXSWI34	Pos.stVal	89CL34
X89CL35XSWI35	X89CLXSWI35	X89CLXSWI35	Pos.stVal	89CL35
X89CL36XSWI36	X89CLXSWI36	X89CLXSWI36	Pos.stVal	89CL36
X89CL37XSWI37	X89CLXSWI37	X89CLXSWI37	Pos.stVal	89CL37
X89CL38XSWI38	X89CLXSWI38	X89CLXSWI38	Pos.stVal	89CL38
X89CL39XSWI39	X89CLXSWI39	X89CLXSWI39	Pos.stVal	89CL39
X89CL40XSWI40	X89CLXSWI40	X89CLXSWI40	Pos.stVal	89CL40
X89CL41XSWI41	X89CLXSWI41	X89CLXSWI41	Pos.stVal	89CL41
X89CL42XSWI42	X89CLXSWI42	X89CLXSWI42	Pos.stVal	89CL42
X89CL43XSWI43	X89CLXSWI43	X89CLXSWI43	Pos.stVal	89CL43
X89CL44XSWI44	X89CLXSWI44	X89CLXSWI44	Pos.stVal	89CL44
X89CL45XSWI45	X89CLXSWI45	X89CLXSWI45	Pos.stVal	89CL45
X89CL46XSWI46	X89CLXSWI46	X89CLXSWI46	Pos.stVal	89CL46
X89CL47XSWI47	X89CLXSWI47	X89CLXSWI47	Pos.stVal	89CL47
X89CL48XSWI38	X89CLXSWI38	X89CLXSWI38	Pos.stVal	89CL48
BKR01CSWI1	BKRCSWI1	BKRCSWI1	Pos.stVal	52CL01
BKR01CSWI1	BKRCSWI1	BKRCSWI1	OpOpn.general	OC01
BKR02CSWI2	BKRCSWI2	BKRCSWI2	Pos.stVal	52CL02
BKR02CSWI2	BKRCSWI2	BKRCSWI2	OpOpn.general	OC02
BKR03CSWI3	BKRCSWI3	BKRCSWI3	Pos.stVal	52CL03
BKR03CSWI3	BKRCSWI3	BKRCSWI3	OpOpn.general	OC03
BKR04CSWI4	BKRCSWI4	BKRCSWI4	Pos.stVal	52CL04

Table 6.8 Logical Device: PRO (Protection) (Sheet 4 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit
Ver 001 Ver 002L	Ver 002	Ver 002 R116+		
BKR04CSWI4	BKRCSWI4	BKRCSWI4	OpOpn.general	OC04
BKR05CSWI5	BKRCSWI5	BKRCSWI5	Pos.stVal	52CL05
BKR05CSWI5	BKRCSWI5	BKRCSWI5	OpOpn.general	OC05
BKR06CSWI6	BKRCSWI6	BKRCSWI6	Pos.stVal	52CL06
BKR06CSWI6	BKRCSWI6	BKRCSWI6	OpOpn.general	OC06
BKR07CSWI7	BKRCSWI7	BKRCSWI7	Pos.stVal	52CL07
BKR07CSWI7	BKRCSWI7	BKRCSWI7	OpOpn.general	OC07
BKR08CSWI8	BKRCSWI8	BKRCSWI8	Pos.stVal	52CL08
BKR08CSWI8	BKRCSWI8	BKRCSWI8	OpOpn.general	OC08
BKR09CSWI9	BKRCSWI9	BKRCSWI9	Pos.stVal	52CL09
BKR09CSWI9	BKRCSWI9	BKRCSWI9	OpOpn.general	OC09
BKR10CSWI10	BKRCSWI10	BKRCSWI10	Pos.stVal	52CL10
BKR10CSWI10	BKRCSWI10	BKRCSWI10	OpOpn.general	OC10
BKR11CSWI11	BKRCSWI11	BKRCSWI11	Pos.stVal	52CL11
BKR11CSWI11	BKRCSWI11	BKRCSWI11	OpOpn.general	OC11
BKR12CSWI12	BKRCSWI12	BKRCSWI12	Pos.stVal	52CL12
BKR12CSWI12	BKRCSWI12	BKRCSWI12	OpOpn.general	OC012
BKR13CSWI13	BKRCSWI13	BKRCSWI13	Pos.stVal	52CL13
BKR13CSWI13	BKRCSWI13	BKRCSWI13	OpOpn.general	OC13
BKR14CSWI14	BKRCSWI14	BKRCSWI14	Pos.stVal	52CL14
BKR14CSWI14	BKRCSWI14	BKRCSWI14	OpOpn.general	OC14
BKR15CSWI15	BKRCSWI15	BKRCSWI15	Pos.stVal	52CL15
BKR15CSWI15	BKRCSWI15	BKRCSWI15	OpOpn.general	OC15
BKR16CSWI16	BKRCSWI16	BKRCSWI16	Pos.stVal	52CL16
BKR16CSWI16	BKRCSWI16	BKRCSWI16	OpOpn.general	OC16
BKR17CSWI17	BKRCSWI17	BKRCSWI17	Pos.stVal	52CL17
BKR17CSWI17	BKRCSWI17	BKRCSWI17	OpOpn.general	OC17
BKR18CSWI18	BKRCSWI18	BKRCSWI18	Pos.stVal	52CL18
BKR18CSWI18	BKRCSWI18	BKRCSWI18	OpOpn.general	OC18

[a] Available only for SEL-487B R116 firmware or later.

Table 6.9 shows the LNs associated with measuring elements, defined as Logical Device MET.

Table 6.9 Logical Device: MET (Metering)

Logical Node (All ICD Versions)	Measurand	Analog Quantity
METMMXN1	Amp01.mag	I01, current magnitude (Amps primary)
METMMXN1	Amp02.mag	I02, current magnitude (Amps primary)
METMMXN1	Amp03.mag	I03, current magnitude (Amps primary)
METMMXN1	Amp04.mag	I04, current magnitude (Amps primary)
METMMXN1	Amp05.mag	I05, current magnitude (Amps primary)
METMMXN1	Amp06.mag	I06, current magnitude (Amps primary)
METMMXN1	Amp07.mag	I07, current magnitude (Amps primary)
METMMXN1	Amp08.mag	I08, current magnitude (Amps primary)
METMMXN1	Amp09.mag	I09, current magnitude (Amps primary)
METMMXN1	Amp10.mag	I10, current magnitude (Amps primary)
METMMXN1	Amp11.mag	I11, current magnitude (Amps primary)
METMMXN1	Amp12.mag	I12, current magnitude (Amps primary)
METMMXN1	Amp13.mag	I13, current magnitude (Amps primary)
METMMXN1	Amp14.mag	I14, current magnitude (Amps primary)
METMMXN1	Amp15.mag	I15, current magnitude (Amps primary)
METMMXN1	Amp16.mag	I16, current magnitude (Amps primary)
METMMXN1	Amp17.mag	I17, current magnitude (Amps primary)
METMMXN1	Amp18.mag	I18, current magnitude (Amps primary)
METMMXN1	Vol01.mag	V01, voltage magnitude (Volts primary)
METMMXN1	Vol02.mag	V02, voltage magnitude (Volts primary)
METMMXN1	Vol03.mag	V03, voltage magnitude (Volts primary)
IOPMMXN2	Amp01.mag	I0P1, Zone 1 Operating Current (per unit)
IOPMMXN2	Amp02.mag	I0P2, Zone 1 Operating Current (per unit)
IOPMMXN2	Amp03.mag	I0P3, Zone 1 Operating Current (per unit)
IOPMMXN2	Amp04.mag	I0P4, Zone 1 Operating Current (per unit)
IOPMMXN2	Amp05.mag	I0P5, Zone 1 Operating Current (per unit)
IOPMMXN2	Amp06.mag	I0P6, Zone 1 Operating Current (per unit)
IOPMMXN2[a]	Amp07.mag	I0PCZ1, Check Zone 1 Operating Current (per unit)
IRTMMXN3	Amp01.mag	IRT1, Zone 1 Restraint Current (per unit)
IRTMMXN3	Amp02.mag	IRT2, Zone 1 Restraint Current (per unit)
IRTMMXN3	Amp03.mag	IRT3, Zone 1 Restraint Current (per unit)
IRTMMXN3	Amp04.mag	IRT4, Zone 1 Restraint Current (per unit)
IRTMMXN3	Amp05.mag	IRT5, Zone 1 Restraint Current (per unit)
IRTMMXN3	Amp06.mag	IRT6, Zone 1 Restraint Current (per unit)
IRTMMXN3[a]	Amp07.mag	IRTCZ1, Check Zone 1 Restraint Current (per unit)

[a] Available only for ICD Ver 002 R116 or newer with SEL-487B R116 firmware or later.

Table 6.10 shows the LNs associated with control elements, defined as Logical Device CON.

Table 6.10 Logical Device: CON (Remote Control) (Sheet 1 of 2)

Logical Node (All ICD Versions)	Control	Relay Word or Database Bit	Comment
RBGGIO1	SPCSO01	RB01	
RBGGIO1	SPCSO02	RB02	
RBGGIO1	SPCSO03	RB03	
RBGGIO1	SPCSO04	RB04	
RBGGIO1	SPCSO05	RB05	
RBGGIO1	SPCSO06	RB06	
RBGGIO1	SPCSO07	RB07	
RBGGIO1	SPCSO08	RB08	
RBGGIO1	SPCSO09	RB09	
RBGGIO1	SPCSO10	RB10	
RBGGIO1	SPCSO11	RB11	
RBGGIO1	SPCSO12	RB12	
RBGGIO1	SPCSO13	RB13	
RBGGIO1	SPCSO14	RB14	
RBGGIO1	SPCSO15	RB15	
RBGGIO1	SPCSO16	RB16	
RBGGIO1	SPCSO17	RB17	
RBGGIO1	SPCSO18	RB18	
RBGGIO1	SPCSO19	RB19	
RBGGIO1	SPCSO20	RB20	
RBGGIO1	SPCSO21	RB21	
RBGGIO1	SPCSO22	RB22	
RBGGIO1	SPCSO23	RB23	
RBGGIO1	SPCSO24	RB24	
RBGGIO1	SPCSO25	RB25	
RBGGIO1	SPCSO26	RB26	
RBGGIO1	SPCSO27	RB27	
RBGGIO1	SPCSO28	RB28	
RBGGIO1	SPCSO29	RB29	
RBGGIO1	SPCSO30	RB30	
RBGGIO1	SPCSO31	RB31	
RBGGIO1	SPCSO32	RB32	
RBGGIO1	SPCSO33	RB33	
RBGGIO1	SPCSO34	RB34	
RBGGIO1	SPCSO35	RB35	
RBGGIO1	SPCSO36	RB36	
RBGGIO1	SPCSO37	RB37	

Table 6.10 Logical Device: CON (Remote Control) (Sheet 2 of 2)

Logical Node (All ICD Versions)	Control	Relay Word or Database Bit	Comment
RBGGIO1	SPCSO38	RB38	
RBGGIO1	SPCSO39	RB39	
RBGGIO1	SPCSO40	RB40	
RBGGIO1	SPCSO41	RB41	
RBGGIO1	SPCSO42	RB42	
RBGGIO1	SPCSO43	RB43	
RBGGIO1	SPCSO44	RB44	
RBGGIO1	SPCSO45	RB45	
RBGGIO1	SPCSO46	RB46	
RBGGIO1	SPCSO47	RB47	
RBGGIO1	SPCSO48	RB48	

Table 6.11 shows the LNs associated with the annunciation element, defined as Logical Device ANN.

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 1 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind01.stVal	PSV01	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind02.stVal	PSV02	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind03.stVal	PSV03	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind04.stVal	PSV04	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind05.stVal	PSV05	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind06.stVal	PSV06	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind07.stVal	PSV07	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind08.stVal	PSV08	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind09.stVal	PSV09	Protection SELOGIC Control Equation Variable
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind10.stVal	PSV10	Protection SELOGIC Control Equation Variable
⋮	⋮	⋮	⋮	⋮	⋮
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind63.stVal	PSV63	Protection SELOGIC Control Equation Variable

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 2 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind64.stVal	PSV64	Protection SELOGIC Control Equation Variable
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind01.stVal	PLT01	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind02.stVal	PLT02	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind03.stVal	PLT03	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind04.stVal	PLT04	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind05.stVal	PLT05	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind06.stVal	PLT06	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind07.stVal	PLT07	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind08.stVal	PLT08	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind09.stVal	PLT09	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind10.stVal	PLT10	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind11.stVal	PLT11	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind12.stVal	PLT12	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind13.stVal	PLT13	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind14.stVal	PLT14	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind15.stVal	PLT15	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind16.stVal	PLT16	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind17.stVal	PLT17	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind18.stVal	PLT18	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind19.stVal	PLT19	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind20.stVal	PLT20	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind21.stVal	PLT21	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind22.stVal	PLT22	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind23.stVal	PLT23	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind24.stVal	PLT24	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind25.stVal	PLT25	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind26.stVal	PLT26	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind27.stVal	PLT27	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind28.stVal	PLT28	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind29.stVal	PLT29	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind30.stVal	PLT30	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind31.stVal	PLT31	Protection Latch
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind32.stVal	PLT32	Protection Latch
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn01.mag	PMV01	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn02.mag	PMV02	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn03.mag	PMV03	Protection SELOGIC Control Equation Math Variable

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 3 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn04.mag	PMV04	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn05.mag	PMV05	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn06.mag	PMV06	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn07.mag	PMV07	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn08.mag	PMV08	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn09.mag	PMV09	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn10.mag	PMV10	Protection SELOGIC Control Equation Math Variable
• • •	• • •	• • •	• • •	• • •	• • •
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn63.mag	PMV63	Protection SELOGIC Control Equation Math Variable
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn64.mag	PMV64	Protection SELOGIC Control Equation Math Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind001.stVal	ASV001	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind002.stVal	ASV002	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind003.stVal	ASV003	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind004.stVal	ASV004	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind005.stVal	ASV005	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind006.stVal	ASV006	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind007.stVal	ASV007	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind008.stVal	ASV008	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind009.stVal	ASV009	Automation SELOGIC Control Equation Variable
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind010.stVal	ASV010	Automation SELOGIC Control Equation Variable
• • •	• • •	• • •	• • •	• • •	• • •
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind127.stVal	ASV127	Automation SELOGIC Control Equation Variable

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 4 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind128.stVal	ASV128	Automation SELOGIC Control Equation Variable
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind01.stVal	ALT01	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind02.stVal	ALT02	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind03.stVal	ALT03	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind04.stVal	ALT04	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind05.stVal	ALT05	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind06.stVal	ALT06	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind07.stVal	ALT07	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind08.stVal	ALT08	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind09.stVal	ALT09	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind10.stVal	ALT10	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind11.stVal	ALT11	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind12.stVal	ALT12	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind13.stVal	ALT13	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind14.stVal	ALT14	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind15.stVal	ALT15	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind16.stVal	ALT16	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind17.stVal	ALT17	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind18.stVal	ALT18	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind19.stVal	ALT19	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind20.stVal	ALT20	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind21.stVal	ALT21	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind22.stVal	ALT22	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind23.stVal	ALT23	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind24.stVal	ALT24	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind25.stVal	ALT25	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind26.stVal	ALT26	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind27.stVal	ALT27	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind28.stVal	ALT28	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind29.stVal	ALT29	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind30.stVal	ALT30	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind31.stVal	ALT31	Automation Latch
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind32.stVal	ALT32	Automation Latch
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn01.mag	AMV001	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn02.mag	AMV002	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn03.mag	AMV003	Automation SELOGIC Control Equation Math Variable

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 5 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn04.mag	AMV004	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn05.mag	AMV005	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn06.mag	AMV006	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn07.mag	AMV007	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn08.mag	AMV008	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn09.mag	AMV009	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn10.mag	AMV010	Automation SELOGIC Control Equation Math Variable
• • •	• • •	• • •	• • •	• • •	• • •
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn63.mag	AMV63	Automation SELOGIC Control Equation Math Variable
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn64.mag	AMV64	Automation SELOGIC Control Equation Math Variable
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind01.stVal	EN	Front-panel target LED “EN”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind02.stVal	TRIPLED	Front-panel target LED “TRIPLED”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind03.stVal	TLED_1	Front-panel target LED “TLED_1”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind04.stVal	TLED_2	Front-panel target LED “TLED_2”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind05.stVal	TLED_3	Front-panel target LED “TLED_3”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind06.stVal	TLED_4	Front-panel target LED “TLED_4”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind07.stVal	TLED_5	Front-panel target LED “TLED_5”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind08.stVal	TLED_6	Front-panel target LED “TLED_6”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind09.stVal	TLED_7	Front-panel target LED “TLED_7”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind10.stVal	TLED_8	Front-panel target LED “TLED_8”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind11.stVal	TLED_9	Front-panel target LED “TLED_9”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind12.stVal	TLED_10	Front-panel target LED “TLED_10”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind13.stVal	TLED_11	Front-panel target LED “TLED_11”

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 6 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind14.stVal	TLED_12	Front-panel target LED "TLED_12"
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind15.stVal	TLED_13	Front-panel target LED "TLED_13"
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind16.stVal	TLED_14	Front-panel target LED "TLED_14"
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind17.stVal	TLED_15	Front-panel target LED "TLED_15"
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind18.stVal	TLED_16	Front-panel target LED "TLED_16"
-	-	TLEDGGIO7[a]	Ind19.stVal	TLED_17	Front-panel target LED "TLED_17"
-	-	TLEDGGIO7[a]	Ind20.stVal	TLED_18	Front-panel target LED "TLED_18"
-	-	TLEDGGIO7[a]	Ind21.stVal	TLED_19	Front-panel target LED "TLED_19"
-	-	TLEDGGIO7[a]	Ind22.stVal	TLED_20	Front-panel target LED "TLED_20"
-	-	TLEDGGIO7[a]	Ind23.stVal	TLED_21	Front-panel target LED "TLED_21"
-	-	TLEDGGIO7[a]	Ind24.stVal	TLED_22	Front-panel target LED "TLED_22"
-	-	TLEDGGIO7[a]	Ind25.stVal	TLED_23	Front-panel target LED "TLED_23"
-	-	TLEDGGIO7[a]	Ind26.stVal	TLED_24	Front-panel target LED "TLED_24"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind01.stVal	PB1_LED	Pushbutton LED "PB1_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind02.stVal	PB2_LED	Pushbutton LED "PB2_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind03.stVal	PB3_LED	Pushbutton LED "PB3_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind04.stVal	PB4_LED	Pushbutton LED "PB4_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind05.stVal	PB5_LED	Pushbutton LED "PB5_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind06.stVal	PB6_LED	Pushbutton LED "PB6_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind07.stVal	PB7_LED	Pushbutton LED "PB7_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind08.stVal	PB8_LED	Pushbutton LED "PB8_LED"
-	-	PBLEDGGIO8[a]	Ind09.stVal	PB9_LED	Pushbutton LED "PB9_LED"
-	-	PBLEDGGIO8[a]	Ind10.stVal	PB10LED	Pushbutton LED "PB10LED"
-	-	PBLEDGGIO8[a]	Ind11.stVal	PB11LED	Pushbutton LED "PB11LED"
-	-	PBLEDGGIO8[a]	Ind12.stVal	PB12LED	Pushbutton LED "PB12LED"
INPUT1GGIO9	IN1GGIO9	IN1GGIO9	Ind01.stVal	IN101	Mainboard input, point 1 value
INPUT1GGIO9	IN1GGIO9	IN1GGIO9	Ind02.stVal	IN102	Mainboard input, point 2 value
INPUT1GGIO9	IN1GGIO9	IN1GGIO9	Ind03.stVal	IN103	Mainboard input, point 3 value
INPUT1GGIO9	IN1GGIO9	IN1GGIO9	Ind04.stVal	IN104	Mainboard input, point 4 value
INPUT1GGIO9	IN1GGIO9	IN1GGIO9	Ind05.stVal	IN105	Mainboard input, point 5 value

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 7 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
INPUT1GGIO9	IN1GGIO9	IN1GGIO9	Ind06.stVal	IN106	Mainboard input, point 6 value
INPUT1GGIO9	IN1GGIO9	IN1GGIO9	Ind07.stVal	IN107	Mainboard input, point 7 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind01.stVal	IN201	I/O Board 2 input, point 1 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind02.stVal	IN202	I/O Board 2 input, point 2 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind03.stVal	IN203	I/O Board 2 input, point 3 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind04.stVal	IN204	I/O Board 2 input, point 4 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind05.stVal	IN205	I/O Board 2 input, point 5 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind06.stVal	IN206	I/O Board 2 input, point 6 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind07.stVal	IN207	I/O Board 2 input, point 7 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind08.stVal	IN208	I/O Board 2 input, point 8 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind09.stVal	IN209	I/O Board 2 input, point 9 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind10.stVal	IN210	I/O Board 2 input, point 10 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind11.stVal	IN211	I/O Board 2 input, point 11 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind12.stVal	IN212	I/O Board 2 input, point 12 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind13.stVal	IN213	I/O Board 2 input, point 13 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind14.stVal	IN214	I/O Board 2 input, point 14 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind15.stVal	IN215	I/O Board 2 input, point 15 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind16.stVal	IN216	I/O Board 2 input, point 16 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind17.stVal	IN217	I/O Board 2 input, point 17 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind18.stVal	IN218	I/O Board 2 input, point 18 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind19.stVal	IN219	I/O Board 2 input, point 19 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind20.stVal	IN220	I/O Board 2 input, point 20 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind21.stVal	IN221	I/O Board 2 input, point 21 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind22.stVal	IN222	I/O Board 2 input, point 22 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind23.stVal	IN223	I/O Board 2 input, point 23 value
INPUT2GGIO10[b]	IN2GGIO10[b]	IN2GGIO10[b]	Ind24.stVal	IN224	I/O Board 2 input, point 24 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind01.stVal	IN301	I/O Board 3 input, point 1 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind02.stVal	IN302	I/O Board 3 input, point 2 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind03.stVal	IN303	I/O Board 3 input, point 3 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind04.stVal	IN304	I/O Board 3 input, point 4 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind05.stVal	IN305	I/O Board 3 input, point 5 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind06.stVal	IN306	I/O Board 3 input, point 6 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind07.stVal	IN307	I/O Board 3 input, point 7 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind08.stVal	IN308	I/O Board 3 input, point 8 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind09.stVal	IN309	I/O Board 3 input, point 9 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind10.stVal	IN310	I/O Board 3 input, point 10 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind11.stVal	IN311	I/O Board 3 input, point 11 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind12.stVal	IN312	I/O Board 3 input, point 12 value

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 8 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind13.stVal	IN313	I/O Board 3 input, point 13 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind14.stVal	IN314	I/O Board 3 input, point 14 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind15.stVal	IN315	I/O Board 3 input, point 15 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind16.stVal	IN316	I/O Board 3 input, point 16 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind17.stVal	IN317	I/O Board 3 input, point 17 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind18.stVal	IN318	I/O Board 3 input, point 18 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind19.stVal	IN319	I/O Board 3 input, point 19 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind20.stVal	IN320	I/O Board 3 input, point 20 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind21.stVal	IN321	I/O Board 3 input, point 21 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind22.stVal	IN322	I/O Board 3 input, point 22 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind23.stVal	IN323	I/O Board 3 input, point 23 value
INPUT3GGIO11[b]	IN3GGIO11[b]	IN3GGIO11[b]	Ind24.stVal	IN324	I/O Board 3 input, point 24 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind01.stVal	IN401	I/O Board 4 input, point 1 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind02.stVal	IN402	I/O Board 4 input, point 2 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind03.stVal	IN403	I/O Board 4 input, point 3 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind04.stVal	IN404	I/O Board 4 input, point 4 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind05.stVal	IN405	I/O Board 4 input, point 5 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind06.stVal	IN406	I/O Board 4 input, point 6 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind07.stVal	IN407	I/O Board 4 input, point 7 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind08.stVal	IN408	I/O Board 4 input, point 8 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind09.stVal	IN409	I/O Board 4 input, point 9 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind10.stVal	IN410	I/O Board 4 input, point 10 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind11.stVal	IN411	I/O Board 4 input, point 11 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind12.stVal	IN412	I/O Board 4 input, point 12 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind13.stVal	IN413	I/O Board 4 input, point 13 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind14.stVal	IN414	I/O Board 4 input, point 14 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind15.stVal	IN415	I/O Board 4 input, point 15 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind16.stVal	IN416	I/O Board 4 input, point 16 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind17.stVal	IN417	I/O Board 4 input, point 17 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind18.stVal	IN418	I/O Board 4 input, point 18 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind19.stVal	IN419	I/O Board 4 input, point 19 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind20.stVal	IN420	I/O Board 4 input, point 20 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind21.stVal	IN421	I/O Board 4 input, point 21 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind22.stVal	IN422	I/O Board 4 input, point 22 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind23.stVal	IN423	I/O Board 4 input, point 23 value
INPUT4GGIO12[b]	IN4GGIO12[b]	IN4GGIO12[b]	Ind24.stVal	IN424	I/O Board 4 input, point 24 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind01.stVal	IN501	I/O Board 5 input, point 1 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind02.stVal	IN502	I/O Board 5 input, point 2 value

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 9 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind03.stVal	IN503	I/O Board 5 input, point 3 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind04.stVal	IN504	I/O Board 5 input, point 4 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind05.stVal	IN505	I/O Board 5 input, point 5 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind06.stVal	IN506	I/O Board 5 input, point 6 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind07.stVal	IN507	I/O Board 5 input, point 7 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind08.stVal	IN508	I/O Board 5 input, point 8 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind09.stVal	IN509	I/O Board 5 input, point 9 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind10.stVal	IN510	I/O Board 5 input, point 10 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind11.stVal	IN511	I/O Board 5 input, point 11 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind12.stVal	IN512	I/O Board 5 input, point 12 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind13.stVal	IN513	I/O Board 5 input, point 13 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind14.stVal	IN514	I/O Board 5 input, point 14 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind15.stVal	IN515	I/O Board 5 input, point 15 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind16.stVal	IN516	I/O Board 5 input, point 16 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind17.stVal	IN517	I/O Board 5 input, point 17 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind18.stVal	IN518	I/O Board 5 input, point 18 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind19.stVal	IN519	I/O Board 5 input, point 19 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind20.stVal	IN520	I/O Board 5 input, point 20 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind21.stVal	IN521	I/O Board 5 input, point 21 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind22.stVal	IN522	I/O Board 5 input, point 22 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind23.stVal	IN523	I/O Board 5 input, point 23 value
INPUT5GGIO13[b]	IN5GGIO13[b]	IN5GGIO13[b]	Ind24.stVal	IN524	I/O Board 5 input, point 24 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind01.stVal	OUT101	Mainboard output, point 1 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind02.stVal	OUT102	Mainboard output, point 2 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind03.stVal	OUT103	Mainboard output, point 3 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind04.stVal	OUT104	Mainboard output, point 4 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind05.stVal	OUT105	Mainboard output, point 5 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind06.stVal	OUT106	Mainboard output, point 6 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind07.stVal	OUT107	Mainboard output, point 7 value
OUTPUT1GGIO14	OUT1GGIO14	OUT1GGIO14	Ind08.stVal	OUT108	Mainboard output, point 8 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind01.stVal	OUT201	I/O Board 2 output, point 1 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind02.stVal	OUT202	I/O Board 2 output, point 2 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind03.stVal	OUT203	I/O Board 2 output, point 3 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind04.stVal	OUT204	I/O Board 2 output, point 4 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind05.stVal	OUT205	I/O Board 2 output, point 5 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind06.stVal	OUT206	I/O Board 2 output, point 6 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind07.stVal	OUT207	I/O Board 2 output, point 7 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind08.stVal	OUT208	I/O Board 2 output, point 8 value

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 10 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind09.stVal	OUT209	I/O Board 2 output, point 9 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind10.stVal	OUT210	I/O Board 2 output, point 10 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind11.stVal	OUT211	I/O Board 2 output, point 11 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind12.stVal	OUT212	I/O Board 2 output, point 12 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind13.stVal	OUT213	I/O Board 2 output, point 13 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind14.stVal	OUT214	I/O Board 2 output, point 14 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind15.stVal	OUT215	I/O Board 2 output, point 15 value
OUTPUT2GGIO15[b]	OUT2GGIO15[b]	OUT2GGIO15[b]	Ind16.stVal	OUT216	I/O Board 2 output, point 16 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind01.stVal	OUT301	I/O Board 3 output, point 1 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind02.stVal	OUT302	I/O Board 3 output, point 2 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind03.stVal	OUT303	I/O Board 3 output, point 3 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind04.stVal	OUT304	I/O Board 3 output, point 4 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind05.stVal	OUT305	I/O Board 3 output, point 5 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind06.stVal	OUT306	I/O Board 3 output, point 6 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind07.stVal	OUT307	I/O Board 3 output, point 7 value
OUTPUT3GGIO16[b]	OUT3GGIO16[b]	OUT3GGIO16[b]	Ind08.stVal	OUT308	I/O Board 3 output, point 8 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind01.stVal	OUT401	I/O Board 4 output, point 1 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind02.stVal	OUT402	I/O Board 4 output, point 2 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind03.stVal	OUT403	I/O Board 4 output, point 3 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind04.stVal	OUT404	I/O Board 4 output, point 4 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind05.stVal	OUT405	I/O Board 4 output, point 5 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind06.stVal	OUT406	I/O Board 4 output, point 6 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind07.stVal	OUT407	I/O Board 4 output, point 7 value
OUTPUT4GGIO17[b]	OUT4GGIO17[b]	OUT4GGIO17[b]	Ind08.stVal	OUT408	I/O Board 4 output, point 8 value
OUTPUT5GGIO18[b]	OUT5GGIO18[b]	OUT5GGIO18[b]	Ind01.stVal	OUT501	I/O Board 5 output, point 1 value
OUTPUT5GGIO18[b]	OUT5GGIO18[b]	OUT5GGIO18[b]	Ind02.stVal	OUT502	I/O Board 5 output, point 2 value
OUTPUT5GGIO18[b]	OUT5GGIO18[b]	OUT5GGIO18[b]	Ind03.stVal	OUT503	I/O Board 5 output, point 3 value
OUTPUT5GGIO18[b]	OUT5GGIO18[b]	OUT5GGIO18[b]	Ind04.stVal	OUT504	I/O Board 5 output, point 4 value
OUTPUT5GGIO18[b]	OUT5GGIO18[b]	OUT5GGIO18[b]	Ind05.stVal	OUT505	I/O Board 5 output, point 5 value
OUTPUT5GGIO18 b	OUT5GGIO18 b	OUT5GGIO18 b	Ind06.stVal	OUT506	I/O Board 5 output, point 6 value
OUTPUT5GGIO18 b	OUT5GGIO18 b	OUT5GGIO18 b	Ind07.stVal	OUT507	I/O Board 5 output, point 7 value
OUTPUT5GGIO18 b	OUT5GGIO18 b	OUT5GGIO18 b	Ind08.stVal	OUT508	I/O Board 5 output, point 8 value
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind001.stVal	CCIN001	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind002.stVal	CCIN002	Communications Card Input

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 11 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind003.stVal	CCIN003	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind004.stVal	CCIN004	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind005.stVal	CCIN005	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind006.stVal	CCIN006	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind007.stVal	CCIN007	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind008.stVal	CCIN008	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind009.stVal	CCIN009	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind010.stVal	CCIN010	Communications Card Input
• • •	CCINGGIO19	CCINGGIO19	• • •	• • •	• • •
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind127.stVal	CCIN127	Communications Card Input
CCINGGIO19	CCINGGIO19	CCINGGIO19	Ind128.stVal	CCIN128	Communications Card Input
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind01.stVal	CCOUT001	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind02.stVal	CCOUT002	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind03.stVal	CCOUT003	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind04.stVal	CCOUT004	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind05.stVal	CCOUT005	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind06.stVal	CCOUT006	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind07.stVal	CCOUT007	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind08.stVal	CCOUT008	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind09.stVal	CCOUT009	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind10.stVal	CCOUT010	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind11.stVal	CCOUT011	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind12.stVal	CCOUT012	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind13.stVal	CCOUT013	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind14.stVal	CCOUT014	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind15.stVal	CCOUT015	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind16.stVal	CCOUT016	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind17.stVal	CCOUT017	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind18.stVal	CCOUT018	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind19.stVal	CCOUT019	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind20.stVal	CCOUT020	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind21.stVal	CCOUT021	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind22.stVal	CCOUT022	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind23.stVal	CCOUT023	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind24.stVal	CCOUT024	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind25.stVal	CCOUT025	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind26.stVal	CCOUT026	Communications Card Output

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 12 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind27.stVal	CCOUT027	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind28.stVal	CCOUT028	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind29.stVal	CCOUT029	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind30.stVal	CCOUT030	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind31.stVal	CCOUT031	Communications Card Output
CCOUTGGIO20	CCOUTGGIO20	CCOUTGGIO20	Ind32.stVal	CCOUT032	Communications Card Output
-	-	RMBAGGIO21[a]	Ind01.stVal	RMB1A	Channel A Receive MIRRORED BIT 1
-	-	RMBAGGIO21[a]	Ind02.stVal	RMB2A	Channel A Receive MIRRORED BIT 2
-	-	RMBAGGIO21[a]	Ind03.stVal	RMB3A	Channel A Receive MIRRORED BIT 3
-	-	RMBAGGIO21[a]	Ind04.stVal	RMB4A	Channel A Receive MIRRORED BIT 4
-	-	RMBAGGIO21[a]	Ind05.stVal	RMB5A	Channel A Receive MIRRORED BIT 5
-	-	RMBAGGIO21[a]	Ind06.stVal	RMB6A	Channel A Receive MIRRORED BIT 6
-	-	RMBAGGIO21[a]	Ind07.stVal	RMB7A	Channel A Receive MIRRORED BIT 7
-	-	RMBAGGIO21[a]	Ind08.stVal	RMB8A	Channel A Receive MIRRORED BIT 8
-	-	TMBAGGIO22[a]	Ind01.stVal	TMB1A	Channel A Transmit MIRRORED BIT 1
-	-	TMBAGGIO22[a]	Ind02.stVal	TMB2A	Channel A Transmit MIRRORED BIT 2
-	-	TMBAGGIO22[a]	Ind03.stVal	TMB3A	Channel A Transmit MIRRORED BIT 3
-	-	TMBAGGIO22[a]	Ind04.stVal	TMB4A	Channel A Transmit MIRRORED BIT 4
-	-	TMBAGGIO22[a]	Ind05.stVal	TMB5A	Channel A Transmit MIRRORED BIT 5
-	-	TMBAGGIO22[a]	Ind06.stVal	TMB6A	Channel A Transmit MIRRORED BIT 6
-	-	TMBAGGIO22[a]	Ind07.stVal	TMB7A	Channel A Transmit MIRRORED BIT 7
-	-	TMBAGGIO22[a]	Ind08.stVal	TMB8A	Channel A Transmit MIRRORED BIT 8
-	-	RMBBGGIO23[a]	Ind01.stVal	RMB1B	Channel B Receive MIRRORED BIT 1
-	-	RMBBGGIO23[a]	Ind02.stVal	RMB2B	Channel B Receive MIRRORED BIT 2
-	-	RMBBGGIO23[a]	Ind03.stVal	RMB3B	Channel B Receive MIRRORED BIT 3
-	-	RMBBGGIO23[a]	Ind04.stVal	RMB4B	Channel B Receive MIRRORED BIT 4

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 13 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
-	-	RMBBGGIO23[a]	Ind05.stVal	RMB5B	Channel B Receive MIRRORED BIT 5
-	-	RMBBGGIO23[a]	Ind06.stVal	RMB6B	Channel B Receive MIRRORED BIT 6
-	-	RMBBGGIO23[a]	Ind07.stVal	RMB7B	Channel B Receive MIRRORED BIT 7
-	-	RMBBGGIO23[a]	Ind08.stVal	RMB8B	Channel B Receive MIRRORED BIT 8
-	-	TMBBGGIO24[a]	Ind01.stVal	TMB1B	Channel B Transmit MIRRORED BIT 1
-	-	TMBBGGIO24[a]	Ind02.stVal	TMB2B	Channel B Transmit MIRRORED BIT 2
-	-	TMBBGGIO24[a]	Ind03.stVal	TMB3B	Channel B Transmit MIRRORED BIT 3
-	-	TMBBGGIO24[a]	Ind04.stVal	TMB4B	Channel B Transmit MIRRORED BIT 4
-	-	TMBBGGIO24[a]	Ind05.stVal	TMB5B	Channel B Transmit MIRRORED BIT 5
-	-	TMBBGGIO24[a]	Ind06.stVal	TMB6B	Channel B Transmit MIRRORED BIT 6
-	-	TMBBGGIO24[a]	Ind07.stVal	TMB7B	Channel B Transmit MIRRORED BIT 7
-	-	TMBBGGIO24[a]	Ind08.stVal	TMB8B	Channel B Transmit MIRRORED BIT 8
-	-	MBOKGGIO25[a]	Ind01.stVal	ROKA	Channel A MIRRORED BIT Normal Status (non-loopback)
-	-	MBOKGGIO25[a]	Ind02.stVal	RBADA	Channel A MIRRORED BIT Outage Too Long
-	-	MBOKGGIO25[a]	Ind03.stVal	CBADA	Channel A MIRRORED BIT Unavailability
-	-	MBOKGGIO25[a]	Ind04.stVal	LBOKA	Channel A MIRRORED BIT Normal Status (loopback)
-	-	MBOKGGIO25[a]	Ind05.stVal	ANOKA	Channel A MIRRORED BIT Analog Transfer OK
-	-	MBOKGGIO25[a]	Ind06.stVal	DOKA	Channel A MIRRORED BIT Communications Normal Status
-	-	MBOKGGIO25[a]	Ind07.stVal	ROKB	Channel B MIRRORED BIT Normal Status (non-loopback)
-	-	MBOKGGIO25[a]	Ind08.stVal	RBADB	Channel B MIRRORED BIT Outage Too Long
-	-	MBOKGGIO25[a]	Ind09.stVal	CBADB	Channel B MIRRORED BIT Unavailability
-	-	MBOKGGIO25[a]	Ind10.stVal	LBOKB	Channel B MIRRORED BIT Normal Status (loopback)

Table 6.11 Logical Device: ANN (Annunciation) (Sheet 14 of 14)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R116+			
-	-	MBOKGGIO25[a]	Ind11.stVal	ANOKB	Channel B MIRRORED BIT Analog Transfer OK
-	-	MBOKGGIO25[a]	Ind12.stVal	DOKB	Channel B MIRRORED BIT Communications Normal Status

[a] Active data only if enhanced front panel installed.
[b] Active data only if additional I/O Card(s) installed.

Protocol Implementation Conformance Statement: SEL-400 Series Devices

The tables below are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that since the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table 6.12 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE management
A3	GSSE	N	N	
A4	Time Sync	N	N	

Table 6.13 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, not GSSE
T4	GSSE	N	N	
T5	Time Sync	N	N	

Refer to the *ACSI Conformance Statements on page R.6.43* for information on the supported services.

MMS Conformance

The Manufacturing Message Specification (MMS) stack provides the basis for many IEC 61850 protocol services. *Table 6.14* defines the service support requirement and restrictions of the MMS services in the SEL-400 series devices. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table 6.14 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
status		Y
getNameList		Y
identify		Y
rename		
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		
deleteVariableAccess		
defineNamedVariableList		
getNamedVariableListAttributes		Y
deleteNamedVariableList		
defineNamedType		
getNamedTypeAttributes		
deleteNamedType		
input		
output		
takeControl		
relinquishControl		
defineSemaphore		
deleteSemaphore		
reportPoolSemaphoreStatus		
reportSemaphoreStatus		
initiateDownloadSequence		
downloadSegment		
terminateDownloadSequence		
initiateUploadSequence		
uploadSegment		
terminateUploadSequence		
requestDomainDownload		
requestDomainUpload		
loadDomainContent		
storeDomainContent		
deleteDomain		
getDomainAttributes		Y
createProgramInvocation		
deleteProgramInvocation		
start		

Table 6.14 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
stop		
resume		
reset		
kill		
getProgramInvocationAttributes		
obtainFile		
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		
reportEventConditionStatus		
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		
acknowledgeEventNotification		
getAlarmSummary		
getAlarmEnrollmentSummary		
readJournal		
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		
fileRead		
fileClose		
fileRename		
fileDelete		
fileDirectory		
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		

Table 6.14 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvocation		

Table 6.15 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table 6.15 MMS Parameter CBB

MMS Parameter CBB	Client-CR	Server-CR
	Supported	Supported
STR1		Y
STR2		Y
VNAM		Y
VADR		Y
VALT		Y
TPY		Y
VLIS		Y
CEI		

The following variable access conformance statements are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table 6.16 AlternateAccessSelection Conformance Statement

AlternateAccessSelection	Client-CR Supported	Server-CR Supported
accessSelection		Y
component		Y
index		
indexRange		
allElements		
alternateAccess		Y
selectAccess		Y
component		Y
index		
indexRange		
allElements		

Table 6.17 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR Supported	Server-CR Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table 6.18 VariableSpecification Conformance Statement

VariableSpecification	Client-CR Supported	Server-CR Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table 6.19 Read Conformance Statement

Read	Client-CR Supported	Server-CR Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table 6.20 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table 6.21 DefineNamedVariableList Conformance Statement

DefineNamedVariableList	Client-CR	Server-CR
	Supported	Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table 6.22 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
ObjectName		
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table 6.23 DeleteNamedVariableList Conformance Statement

DeleteNamedVariableList	Client-CR	Server-CR
	Supported	Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table 6.24 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	Y	Y	
SendGOOSEMessage		Y	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		Y	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		Y	

ACSI Conformance Statements

Table 6.25 ACSI Basic Conformance Statement

		Client/Subscriber	Server/Publisher	SEL-487B Support
Client-Server Roles				
B11	Server side (of Two-Party Application-Association)	–	c1[a]	YES
B12	Client side (of Two-Party Application-Association)	c1[a]	–	
SCMS Supported				
B21	SCSM: IEC 61850-8-1 used			YES
B22	SCSM: IEC 61850-9-1 used			
B23	SCSM: IEC 61850-9-2 used			
B24	SCSM: other			
Generic Substation Event Model (GSE)				
B31	Publisher side	–	O[b]	YES
B32	Subscriber side	O[b]	–	YES
Transmission of Sampled Value Model (SVC)				
B41	Publisher side	–	O[b]	
B42	Subscriber side	O[b]	–	

[a] c1 shall be mandatory if support for LOGICAL-DEVICE model has been declared.
[b] O = optional.

Table 6.26 ACSI Models Conformance Statement (Sheet 1 of 2)

		Client/Subscriber	Server/Publisher	SEL-487B Support
If Server Side (B11) Supported				
M1	Logical device	c2[a]	c2[a]	YES
M2	Logical node	c3[b]	c3[b]	YES
M3	Data	c4[c]	c4[c]	YES
M4	Data set	c5[d]	c5[d]	YES
M5	Substitution	O[e]	O[e]	

Table 6.26 ACSI Models Conformance Statement (Sheet 2 of 2)

		Client/Subscriber	Server/Publisher	SEL-487B Support
M6	Setting group control	O[e]	O[e]	
	Reporting			
M7	**Buffered report control**	O[e]	O[e]	YES
M7-1	sequence-number			YES
M7-2	report-time-stamp			YES
M7-3	reason-for-inclusion			YES
M7-4	data-set-name			YES
M7-5	data-reference			YES
M7-6	buffer-overflow			YES
M7-7	entryID			YES
M7-8	BufTm			YES
M7-9	IntgPd			YES
M7-10	GI			YES
M8	**Unbuffered report control**	O[e]	O[e]	YES
M8-1	sequence-number			YES
M8-2	report-time-stamp			YES
M8-3	reason-for-inclusion			YES
M8-4	data-set-name			YES
M8-5	data-reference			YES
M8-6	BufTm			YES
M8-7	IntgPd			YES
M8-8	GI			
	Logging	O[e]	O[e]	
M9	Log control	O[e]	O[e]	
M9-1	IntgPd			
M10	Log	O[e]	O[e]	
M11	Control	M[f]	M[f]	YES
	If GSE (B31/32) Is Supported			
M12	GOOSE	O[e]	O[e]	YES
M12-1	entryID			YES
M12-2	DataReflnc			YES
M13	GSSE	O[e]	O[e]	
	If GSE (B41/42) Is Supported			
M14	Multicast SVC	O[e]	O[e]	
M15	Unicast SVC	O[e]	O[e]	
M16	Time	M[f]	M[f]	
M17	File Transfer	O[e]	O[e]	

[a] c2 shall be "M" if support for LOGICAL-NODE model has been declared.
[b] c3 shall be "M" if support for DATA model has been declared.
[c] c4 shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time model has been declared.
[d] c5 shall be "M" if support for Report, GSE, or SV models has been declared.
[e] O = optional
[f] M = mandatory

Table 6.27 ACSI Services Conformance Statement (Sheet 1 of 3)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-487B Support
Server (Clause 6)					
S1	ServerDirectory	TP		M[a]	YES
Application Association (Clause 7)					
S2	Associate		M[a]	M[a]	YES
S3	Abort		M[a]	M[a]	YES
S4	Release		M[a]	M[a]	YES
Logical Device (Clause 8)					
S5	LogicalDeviceDirectory	TP	M[a]	M[a]	YES
Logical Node (Clause 9)					
S6	LogicalNodeDirectory	TP	M[a]	M[a]	YES
S7	GetAllDataValues	TP	O[b]	M[a]	YES
Data (Clause 10)					
S8	GetDataValues	TP	M[a]	M[a]	YES
S9	SetDataValues	TP	O[b]	O[b]	YES
S10	GetDataDirectory	TP	O[b]	M[a]	YES
S11	GetDataDefinition	TP	O[b]	M[a]	YES
Data Set (Clause 11)					
S12	GetDataSetValues	TP	O[b]	M[a]	YES
S13	SetDataSetValues	TP	O[b]	O[b]	YES
S14	CreateDataSet	TP	O[b]	O[b]	
S15	DeleteDataSet	TP	O[b]	O[b]	
S16	GetDataSetDirectory	TP	O[b]	O[b]	YES
Substitution (Clause 12)					
S17	SetDataValues	TP	M[a]	M[a]	
Setting Group Control (Clause 13)					
S18	SelectActiveSG	TP	O[b]	O[b]	
S19	SelectEditSG	TP	O[b]	O[b]	
S20	SetSGvalues	TP	O[b]	O[b]	
S21	ConfirmEditSGVal	TP	O[b]	O[b]	
S22	GetSGValues	TP	O[b]	O[b]	
S23	GetSGCBValues	TP	O[b]	O[b]	
Reporting (Clause 14)					
Buffered Report Control Block (BRCB)					
S24	Report	TP	c6[c]	c6[c]	YES
S24-1	data-change (dchg)				YES
S24-2	qchg-change (qchg)				YES
S24-3	data-update (dupd)				
S25	GetBRCBValues	TP	c6[c]	c6[c]	YES
S26	SetBRCBValues	TP	c6[c]	c6[c]	YES

Table 6.27 ACSI Services Conformance Statement (Sheet 2 of 3)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-487B Support
Unbuffered Report Control Block (URCB)					
S27	Report	TP	c6[c]	c6[c]	YES
S27-1	data-change (dchg)				YES
S27-2	qchg-change (qchg)				YES
S27-3	data-update (dupd)				
S28	GetURCBValues	TP	c6[c]	c6[c]	YES
S29	SetURCBValues	TP	c6[c]	c6[c]	YES
Logging (Clause 14)					
Log Control Block					
S30	GetLCBValues	TP	M[a]	M[a]	
S31	SetLCBValues	TP	O[b]	M[a]	
LOG					
S32	QueryLogByTime	TP	c7[d]	M[a]	
S33	QueryLogByEntry	TP	c7[d]	M[a]	
S34	GetLogStatusValues	TP	M[a]	M[a]	
Generic Substation Event Model (GSE) (Clause 14.3.5.3.4.)					
GOOSE-Control-Block					
S35	SendGOOSEMessage	MC	c8[e]	c8[e]	YES
S36	GetReference	TP	O[b]	c9[f]	
S37	GetGOOSEElementNumber	TP	O[b]	c9[f]	
S38	GetGoCBValues	TP	O[b]	O[b]	YES
S39	SetGoCBValues	TP	O[b]	O[b]	Client/Sub ONLY
GSSE-Control-Block					
S40	SendGSSEMessage	MC	c8[e]	c8[e]	
S41	GetReference	TP	O[b]	c9[f]	
S42	GetGSSEElementNumber	TP	O[b]	c9[f]	
S43	GetGsCBValues	TP	O[b]	O[b]	
S44	SetGsCBValues	TP	O[b]	O[b]	
Transmission of Sample Value Model (SVC) (Clause 16)					
Multicast SVC					
S45	SendMSVMessage	MC	c10[g]	c10[g]	
S46	GetMSVCBValues	TP	O[b]	O[b]	
S47	SetMSVCBValues	TP	O[b]	O[b]	
Unicast SVC					
S48	SendUSVMessage	MC	c10[g]	c10[g]	
S49	GetUSVCBValues	TP	O[b]	O[b]	
S50	SetUSVCBValues	TP	O[b]	O[b]	
Control (Clause 16.4.8)					
S51	Select		M[a]	O[b]	
S52	SelectWithValue	TP	M[a]	O[b]	
S53	Cancel	TP	O[b]	M[a]	YES

Table 6.27 ACSI Services Conformance Statement (Sheet 3 of 3)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-487B Support
S54	Operate	TP	M[a]	M[a]	YES
S55	Commmand-Termination	TP	M[a]	M[a]	
S56	TimeActivated-Operate	TP	O[b]	O[b]	
File Transfer (Clause 20)					
S57	GetFile	TP	O[b]	M[a]	
S58	SetFile	TP	O[b]	O[b]	
S59	DeleteFile	TP	O[b]	O[b]	
S60	GetFileAttributeValues	TP	O[b]	M[a]	
Time (Clause 5.5)					
T1	Time resolution of internal clock (nearest negative power of 2 in seconds)			2–10 (1 ms)	T1
T2	Time accuracy of internal clock				10/9
	T1				YES
	T2				YES
	T3				YES
	T4				YES
	T5				YES
T3	Supported TimeStamp resolution (nearest negative power of 2 in seconds)			2–10 (1 ms)	10

[a] M = Mandatory
[b] O = Optional
[c] c6 shall declare support for at least one (BRCB or URCB).
[d] c7 shall declare support for at least one (QueryLogByTime or QueryLogAfter).
[e] c8 shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage).
[f] c9 shall declare support if TP association is available.
[g] c10 shall declare support for at least one (SendMSVMessage or SendUSVMessage).

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Section 7
ASCII Command Reference

Overview

You can use a communications terminal or terminal emulation program to set and operate the SEL-487B Relay. This section explains the commands that you send to the SEL-487B using SEL ASCII (American National Standard Code for Information Interchange) communications protocol. The relay responds to commands such as settings, metering, and control operations.

This section lists ASCII commands alphabetically. Commands, command options, and command variables that you enter are shown in bold. Lowercase italic letters and words in a command represent command variables that you determine based on the application (for example, Zone *n* = 1–6, remote bit number *nn* = 01–96, and *level*).

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the relay function corresponding to the command or examples of the relay response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters (upper- or lowercase); for example, **ACCESS** becomes **ACC**. Always send a carriage return <CR> character, or a carriage return character followed by a line feed character <CR><LF>, to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the Enter key as a <CR>. For example, to send the **ACCESS** command, type **ACC <Enter>**. For more information on SEL ASCII protocol, including handshaking, see *Section 4: SEL Communications Protocols*.

Tables in this section show the access level(s) where the command or command option is active. Access levels in the SEL-487B are Access Level 0, Access Level 1, Access Level B (breaker), Access Level P (protection), Access Level A (automation), Access Level O (output), and Access Level 2. For information on access levels see *Changing the Default Passwords on page U.4.6*.

Description of Commands

2ACCESS

Use the **2AC** command to gain access to Access Level 2 (full relay control). See *Access Levels on page U.4.6* for more information.

Table 7.1 2AC Command

Command	Description	Access Level
2AC	Go to Access Level 2 (full relay control).	1, B, P, A, O, 2

AACCESS

Use the **AAC** command to gain access to Access Level A (automation). See *Access Levels* for more information.

Table 7.2 AAC Command

Command	Description	Access Level
AAC	Go to Access Level A (automation).	1, B, P, A, O, 2

ACCESS

Use the **ACC** command to gain access to Access Level 1 (monitor). See *Access Levels* for more information.

Table 7.3 ACC Command

Command	Description	Access Level
ACC	Go to Access Level 1 (monitoring).	0, 1, B, P, A, O, 2

BACCESS

Use the **BAC** command to gain access to Access Level B (breaker). See *Access Levels* for more information.

Table 7.4 BAC Command

Command	Description	Access Level
BAC	Go to Access Level B (breaker).	1, B, P, A, O, 2

BNAME

In response to the **BNA** command, the relay displays the ASCII names of all relay status bits for Fast Meter Compressed ASCII. See *Section 4: SEL Communications Protocols* for more information on Fast Meter and the Compressed ASCII command set.

Table 7.5 BNA Command

Command	Description	Access Level
BNA	Display ASCII names of all relay status bits for Fast Meter.	0, 1, B, P, A, O, 2

CAL

Use the **CAL** command to gain access to Access Level C. See *Access Levels on page U.4.6* for more information. Only go to Level C to modify the default password or under the direction of an SEL employee. The additional commands available at Level C are not intended for normal operational purposes.

Table 7.6 CAL Command

Command	Description	Access Level
CAL	Go to Access Level C.	2, C

CASCII

In response to the **CAS** command, the relay displays the Compressed ASCII configuration message. This configuration instructs an external computer on the method for extracting data from other Compressed ASCII commands. See *Section 4: SEL Communications Protocols* for an example of the **CAS** command configuration message and for further information on the Compressed ASCII command set.

Table 7.7 CAS Command

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0, 1, B, P, A, O, 2

CEVENT

Three **CEVENT** commands **CEV**, **CEV R**, and **CEV RD**, each with options and combinations of the options, provide different formats of the same event data in the relay. *Table 7.8* defines the differences among the three commands.

Table 7.8 CEV Commands

Command	Definition
CEV	Display filtered analog and digital data at 4-samples/cycle in Compressed ASCII format.
CEV R	Display unfiltered analog and digital data at 24-samples/cycle in Compressed ASCII format.
CEV RD	Display a combination of unfiltered analog and digital data at 24-samples/cycle and filtered differential element analog data at 12-samples/cycle in Compressed ASCII format.

Table 7.9 CEV Command Options

Command	Options
CEV	***n***[a], **ACK**, **C**, **L**, **L*y***, **NEXT**, **NSET**, **S*x***, **TERSE**

[a] Parameter n indicates event order or serial number; see EVENT on page R.7.14.

When parameter *n* is 1 through 100, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the unique serial number of the event report. For example, event number 10475 keeps this unique number. The position of event 10475 could be anywhere between 1 and 100.

Except for the **CEV ACK** command, all other command options may be grouped when using the **CEV** command.

Table 7.10 CEV Command Options Description (Sheet 1 of 2)

Command	Description	Access Level
CEV	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a]	Return particular *n* event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

Table 7.10 CEV Command Options Description (Sheet 2 of 2)

Command	Description	Access Level
CEV ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2
CEV C	Return the most recent event report at full length with 12-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV L	Return the most recent event report at full length with 12-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV L*y*	Return *y* cycles of the most recent event report (including settings) with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] L	Return particular *n* event report (including settings and summary) as full-length with 12-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV NEXT	Return the oldest unacknowledged event report with 4-samples/cycle sampling in Compressed ASCII format.	1, B, P, A, O, 2
CEV NSET	Return the most recent event report without settings at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV S*x*[b]	Return the most recent event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV TERSE	Return the most recent event report at full length without the report labels with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVENT on page R.7.14.
[b] x = 4 or 12.

CEVENT R

Use the **CEV R** command to display an unfiltered 24-samples/cycle event report. *Table 7.11* shows the **CEV R** command options. You can combine options ***n***, **L*y***, **NSET**, and **TERSE** in one command, entered in any order.

Table 7.11 CEV R Command Options

Command	Options
CEV R	***n***[a], **Ly**, **NSET**, **TERSE**

[a] Parameter n indicates event order or serial number; see EVENT on page R.7.14.

Table 7.12 CEV R Command Options Description

Command	Description	Access Level
CEV R	Return the most recent unfiltered event report at full length with 24-samples/cycle data.	1, B, P, A, O, 2
CEV R *n*[a]	Return a particular *n* unfiltered event report at full length with 24-samples/cycle.	1, B, P, A, O, 2
CEV R L*y*	Return *y* cycles of the most recent event report with 24-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV R NSET	Return the most recent event report without settings at full length with 24-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV R TERSE	Return the most recent event report at full length without the report labels with 24-samples/cycle data in Compressed ASCII format	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVENT on page R.7.14.

CEVENT RD

Use the **CEV RD** command to display unfiltered 24-samples/cycle analog and digital values and 12-samples/cycle differential data. You can combine options ***n***, **L*y***, **NSET**, and **TERSE** in one command, entered in any order. *Table 7.13* shows the **CEV RD** command options.

Table 7.13 CEV RD Command Options

Command	Options
CEV RD	***n***[a], **L*y***, **NSET**, **TERSE**

[a] Parameter n indicates event order or serial number; see EVENT on page R.7.14.

Table 7.14 CEV RD Command Options Description

Command	Description	Access Level
CEV RD	Return the most recent unfiltered event report at full length with 24-samples/cycle analog and digital data and 12-samples/cycle analog differential data in Compressed ASCII format.	1, B, P, A, O, 2
CEV RD *n*	Return event number *n* unfiltered event report at full length with 24-samples/cycle analog and digital data and 12-samples/cycle analog differential data in Compressed ASCII format.	1, B, P, A, O, 2
CEV RD L*y*	Return the first *y* cycles of the most recent unfiltered event report with 24-samples/cycle analog and digital data and 12-samples/cycle analog differential data in Compressed ASCII format.	1, B, P, A, O, 2
CEV RD NSET	Return the most recent unfiltered event report without settings at full length with 24-samples/cycle analog and digital data and 12-samples/cycle analog differential data in Compressed ASCII format.	1, B, P, A, O, 2
CEV RD TERSE	Return the most recent unfiltered event report without report labels at full length with 24-samples/cycle analog and digital data and 12-samples/cycle analog differential data in Compressed ASCII format.	1, B, P, A, O, 2

CHISTORY

The **CHISTORY** command is the **HISTORY** command for the Compressed ASCII command set. See *Section 4: SEL Communications Protocols* for information on the Compressed ASCII command set. For a detailed example of the items in the Compressed ASCII history report, see *Section 3: Analyzing Data in the Applications Handbook*.

CHI

Use the **CHI** command to gather one-line descriptions of event reports. Combine parameters **A** and ***k*** to display the summary description of event number ***k***, for example, **CHI A 3**.

Table 7.15 CHI Command

Command	Description	Access Level
CHI	Return the data as contained in the History report for the most recent 20 event reports in Compressed ASCII format (for SEL-2030/2032 compatibility).	1, B, P, A, O, 2
CHI *k*	Return one-line descriptions of the most recent *k* number of event reports in Compressed ASCII format.	1, B, P, A, O, 2
CHI A	Return summary descriptions of available event reports in Compressed ASCII format (returns long form report).	1, B, P, A, O, 2

CHI TERSE

The **CHI TERSE** command returns a Compressed ASCII event report without the event report header label lines. Combine parameters **A** and ***k*** to display the summary description of event number ***k***.

Table 7.16 CHI TERSE Command

Command	Description	Access Level
CHI TERSE	Return one-line descriptions for the most recent 20 event reports without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CHI *k* TERSE	Return one-line descriptions for the most recent *k* number of event reports without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CHI A TERSE	Return summary descriptions of all available event reports without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2

COMMUNICATIONS

The **COMMUNICATIONS** command displays communications statistics for the MIRRORED BITS® communications channels. For more information on MIRRORED BITS communications, see *SEL MIRRORED BITS Communications on page R.4.14*.

COM c

Use the **COM *c*** command to view records in the communications buffers for specific relay communications channels.

Table 7.17 COM c Command[a]

Command	Description	Access Level
COM A	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1, B, P, A, O, 2
COM B	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1, B, P, A, O, 2
COM M	Return a summary report of the last 255 records in the communications buffer for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	1, B, P, A, O, 2

[a] Parameter c is A, B, or M for Channel A, Channel B, and MIRRORED BITS communications channels, respectively.

The *c* option in the **COM** command is **A** for MIRRORED BITS communications Channel A, **B** for MIRRORED BITS communications Channel B, and **M** for the MIRRORED BITS communications channels in general. If both MIRRORED BITS communications channels are in use, then the **M** option does not function and you must specify **A** or **B**.

COM c C and COM c R

The **COM *c* C** and **COM *c* R** commands clear the communications buffer data for the specified channel ***c***. Options **C** and **R** are identical.

Table 7.18 COM c C and COM c R Command[a]

Command	Description	Access Level
COM A C	Clear communications buffer data for MIRRORED BITS communications Channel A.	P, A, O, 2
COM B R	Clear communications buffer data for MIRRORED BITS communications Channel B.	P, A, O, 2
COM M C	Clear communications buffer data for both MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	P, A, O, 2

[a] Parameter c is A, B, or M for Channel A, Channel B, and MIRRORED BITS communications channels, respectively.

COM c L m n and COM c L date1 date2

Use **COM *c* L** to list the records in the communications buffer in a specified manner. The relay returns the list of records in rows. You can specify a range of buffer records in forward or reverse chronological order or in forward or reverse date order. Date parameter entries depend on the setting DATE_F format you chose in the relay Global settings. See *Section 8: Settings* for more information.

The relay displays the records based on the last 255 records in newest to oldest time order. The relay puts the newest record in the buffer and discards the oldest record if the buffer is full.

Table 7.19 is a representative list of options for listing records in the communications buffer.

Table 7.19 COM c L Command[a]

Command	Description	Access Level
COM A L	Display all available records from MIRRORED BITS communications Channel A; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM B L *k*[b]	Display the first *k* records for MIRRORED BITS communications Channel B; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM M L *m n*[c]	Display the records for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled; show the records with Record *m* at the top of the report through Record *n* at the bottom of the report.	1, B, P, A, O, 2
COM A L *date1*[d]	Display the records from MIRRORED BITS communications Channel A on *date1*.	1, B, P, A, O, 2
COM B L *date1 date2*[d]	Display the records from MIRRORED BITS communications Channel B between *date1* and *date2*. The date listed first, *date1*, is at the top of the report; the date listed second, *date2*, is at the bottom of the report.	1, B, P, A, O, 2

[a] Parameter c is A, B, or M for Channel A, Channel B, and MIRRORED BITS communications channels, respectively.
[b] Parameter k indicates a specific number of communications buffer records.
[c] Parameters m and n are communications buffer row numbers.
[d] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

CONTROL nn

Use the **CONTROL *nn*** command to set, clear, or pulse internal Relay Word bits RB01 through RB96 (Remote Bit 1 through Remote Bit 96). Remote bits in SELOGIC control equations are similar to hardwired control inputs, in that you use these bits to affect relay operation from outside sources. For hard-wired control inputs, external input to the relay comes through the rear panel; in the case of the **CON *nn*** command, external control signals come through the communications ports. See *Section 4: SEL Communications Processor Applications in the Applications Handbook* for information on remote bits.

Table 7.20 CON nn Command[a]

Command	Description	Access Level
CON *nn* C	Clear Remote Bit *nn*.	P, A, O, 2
CON *nn* P	Pulse Remote Bit *nn* for one processing cycle.	P, A, O, 2
CON *nn* S	Set Remote Bit *nn*.	P, A, O, 2

[a] Parameter nn is a number from 01 to 96 representing Remote Bit 01 through Remote Bit 96.

If you enter **CON *nn*** with no set, clear, or pulse option specified, the relay responds:

```
Control RBnn:
```

You must then provide the control action (set, clear, or pulse) that you want to perform. (The relay checks only the first character; you can type **Set** and **Clear**.) When you issue a valid **CON** command, the relay performs the control action immediately and displays the following:

```
Remote Bit Operated
```

COPY

The **COPY** command copies the settings from one class instance to another instance in the same class. For example, you can copy Group settings from Group 1 to Group 2. You cannot copy Group settings to Port settings.

This command is limited to the same access level as the **SET** command for the class of settings you are copying. Use the command order specified in *Table 7.21*.

Table 7.21 COPY Command

Command	Description	Access Level
COPY *m n*[a]	Copy settings from instance *m* of the Group settings to instance *n* of the Group settings.	P, A, O, 2
COPY *class m n*[b]	Copy settings from instance *m* of Class *class* to instance *n* of Class *class*.	P, A, O, 2

[a] Parameters m and n are 1 to 6 for the Group class and 1, 2, 3, and F for the Port class.
[b] Parameter class is S, P, L, and Z for group settings, port settings, protection SELOGIC® control equations, and zone settings, respectively.

The parameters *m* and *n* must be valid and distinct (not the same) instance numbers. The *class* parameter is the class that you can choose from group (S), port (P), protection SELOGIC control equations (L), and zone (Z). The **COPY** command is not available within the Automation class.

In addition, port settings instances must be compatible; you cannot copy from/to Port 5 and the other communications ports settings. You cannot copy to a port that is presently in transparent communication. In addition, you cannot copy to the present port (the port you are using to communicate with the relay).

When you enter the **COPY** command with valid parameters, the relay responds as follows:

```
Are you sure (Y/N)?
```

Answer **Y <Enter>** (for yes) to complete copying.

If the copy is successful, the relay pulses the SALARM Relay Word bit for one second.

CSER

The **CSER** command is the **SER** command for the Compressed ASCII command set. See *SEL Compressed ASCII Commands on page R.4.4* for information on the Compressed ASCII command set. The default order of the **CSER** command (chronologically newest to oldest from list top to list bottom) is the reverse of the **SER** command (oldest to newest from list top to list bottom). For a detailed example of the items in the Compressed ASCII SER report, see *SER (Sequential Events Recorder) on page A.3.31*.

CSE

Use the **CSE** command to gather Sequential Events Recorder records. You can sort these records in numerical or date order.

Table 7.22 CSE Command

Command	Description	Access Level
CSE	Return all records from the Sequential Events Recorder in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *k*[a]	Return the *k* most recent records from the Sequential Events Recorder in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *m n*[b]	Return the Sequential Events Recorder records in Compressed ASCII format from *m* to *n*. If *m* is greater than *n*, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If *m* is less than *n*, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1*[c]	Return the Sequential Events Recorder records in Compressed ASCII format on *date1*.	1, B, P, A, O, 2
CSE *date1 date2*[c]	Return the Sequential Events Recorder records in Compressed ASCII format from *date1* to *date2*.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of SER records.
[b] Parameters m and n indicate an SER record number.
[c] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

CSE TERSE

The **CSE TERSE** command returns a Sequential Events Recorder report in Compressed ASCII format without labels; the relay sends only the data. You can apply the **TERSE** option with any of the **CSE** commands.

Table 7.23 CSE TERSE Command (Sheet 1 of 2)

Command	Description	Access Level
CSE TERSE	Return all Sequential Events Recorder records without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *k* TERSE[a]	Return the *k* most recent Sequential Events Recorder records without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2

Table 7.23 CSE TERSE Command (Sheet 2 of 2)

Command	Description	Access Level
CSE *m n* TERSE[b]	Return the Sequential Events Recorder records in Compressed ASCII format from *m* to *n* without the header label lines in Compressed ASCII format. If *m* is greater than *n*, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If *m* is less than *n*, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1* TERSE[c]	Return the Sequential Events Recorder records in Compressed ASCII format on *date1* without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *date1 date2* TERSE[c]	Return the Sequential Events Recorder records in Compressed ASCII format from *date1* to *date2* without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of SER records.
[b] Parameters m and n indicate an SER record number.
[c] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

CSTATUS

The **CSTATUS** command is the **STATUS** command for the Compressed ASCII command set. The **TERSE** option eliminates the report header label lines. See *Section 4: SEL Communications Protocols* for information on the Compressed ASCII command set. For an example of the **CST** command, see *Figure 6.34 on page U.6.35*.

Table 7.24 CST Command

Command	Description	Access Level
CST	Return the relay status in Compressed ASCII.	1, B, P, A, O, 2
CST TERSE	Return the relay status in Compressed ASCII; suppress the header label lines and transmit only the data lines.	1, B, P, A, O, 2

CSUMMARY

The **CSUMMARY** command is the **SUMMARY** command for the Compressed ASCII command set. **CSUMMARY** supports the following parameters: **ACK**, **MB**, ***n***, **NEXT**, and **TERSE**. See *Section 4: SEL Communications Protocols* for information on the Compressed ASCII command set. For a detailed example of the items in the Compressed ASCII summary report, see *Figure 3.14 on page A.3.27*.

CSU

Use the **CSU** command to gather event report summaries.

Table 7.25 CSU Command

Command	Description	Access Level
CSU	Return the most recent event summary (with header label lines) in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n*[a]	Return a particular *n* event summary (with header label lines) in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

When parameter *n* is 1 through 100, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

CSU ACK

Use the **CSU ACK** command to acknowledge an event summary that you recently retrieved with the **CSU NEXT** command on the present communications port.

Table 7.26 CEV ACK Command

Command	Description	Access Level
CSU ACK	Acknowledge the oldest unacknowledged event summary at the present communications port for Compressed ASCII format.	1, B, P, A, O, 2

CSU MB

The **CSU MB** command causes the relay to output the labels for the MIRRORED BITS communications channel data in Compressed ASCII format.

Table 7.27 CSU MB Command

Command	Description	Access Level
CSU MB	Return the MIRRORED BITS communications channel labels.	1, B, P, A, O, 2

CSU NEXT

Use the **CSU NEXT** command to view the oldest unacknowledged event summary in Compressed ASCII format.

Table 7.28 CSU NEXT Command

Command	Description	Access Level
CSU NEXT	View the oldest unacknowledged event summary.	1, B, P, A, O, 2

CSU TERSE

The **TERSE** command option returns an event summary report in Compressed ASCII format without header labels; the relay sends only the data.

Table 7.29 CSU TERSE Command

Command	Description	Access Level
CSU TERSE	Return the most recent event summary report without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n* TERSE[a]	Return a particular *n* event summary report without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU N TERSE	View the oldest unacknowledged event summary without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event number or serial order.

You can apply the **TERSE** option with any of the **CSU** commands except **CSU ACK** and **CSU MB**.

DATE

Use the **DATE** command to view and set the relay date. The relay can overwrite the date that you enter by using other time sources such as IRIG and DNP; see *Configuring Timekeeping on page U.4.49* for information. Enter the **DATE** command with a date to set the internal clock date. You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

Set the year in 2-digit form (for dates 2000–2099) or 4-digit form. If you enter the year as 12, the relay date is 2012. Global setting DATE_F sets the date format; see *Section 8: Settings* for more information.

Table 7.30 DATE Command

Command	Description	Access Level
DATE	Display the internal clock date.	1, B, P, A, O, 2
DATE *date*[a]	Set the internal clock date.	1, B, P, A, O, 2

[a] Enter date setting in the same format as specified by Global setting DATE_F.

DNAME X

The **DNA X** command produces the ASCII names of all relay digital I/O (input/output) quantities reported in a Fast Meter message in Compressed ASCII format. See *SEL Fast Meter, Fast Operate, and Fast SER Messages on page R.4.8* for more information on SEL Fast Meter.

Table 7.31 DNA X Command

Command	Description	Access Level
DNA X	Display ASCII names of all relay digital I/O.	0, 1, B, P, A, O, 2

DNP

The **DNP** command is only available if DNP3 has been selected as the protocol on one of the serial ports. Use the **DNP** command to access the DNP3 settings. The **DNP** command is similar to the **SHOW D** and **SET D** commands. Type **DNP <Enter>** to show the relay DNP3 map beginning at the first setting label. Issue the **DNP** command with any parameter *param* to set the DNP3 settings; the relay begins at the first DNP3 setting. For more information, see the **SET D** command and *Section 5: DNP3 Communications*.

Table 7.32 DNP Command

Command	Description	Access Level
DNP	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP VIEW	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP *param*	Set the serial port DNP3 settings (same as **SET D**); begin at the first DNP3 setting.	P, A, O, 2

EVENT

Two **EVENT** commands **EVE** and **EVE R**, each with options and combinations of the options, provide reports in different formats of the same event data in the relay.

Table 7.33 EVE Command Options

Command	Options
EVE	***n***, **A**, **ACK**, **C**, **D**, **DIF**, **L**, **L*y***, **NEXT**, **NSET**, **NSUM**, **S*x***

When parameter *n* is 1 through 100, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

Except for the **EVE ACK** command, all other command options may be grouped when using the **EVE** command. Enter the options according to the following guidelines:

- The **L*y*** option overrides the **C** option.
- The **S*x*** option overrides the **L** option.
- When choosing option **A** or option **D** as a report type, you cannot use option **C** to specify the report length at 15 cycles. Use option **L*y*** at L15 to specify a 15-cycle report.
- Enter the options in any order.

Table 7.34 EVE Command Options Description (Sheet 1 of 2)

Command	Description	Access Level
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2
EVE *n*	Return a particular *n* event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE A	Return only the analog information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE C	Return the most recent event report at full length with 12-samples/cycle data.	1, B, P, A, O, 2
EVE D	Return only the digital information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE DIF	Return the differential information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2

Table 7.34 EVE Command Options Description (Sheet 2 of 2)

Command	Description	Access Level
EVE L	Return the most recent event report at full length with 12-samples/cycle data.	1, B, P, A, O, 2
EVE L*y*	Return *y* cycles of the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE NEXT	Return the oldest unacknowledged event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE NSET	Return the most recent event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE S*x*[a]	Return the most recent event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2

[a] Where x = 4 or 12.

EVENT R

Use the **EVE R** command to display an unfiltered 24-samples/cycle event report. *Table 7.35* shows the **EVE R** command options.

Table 7.35 EVE R Command Options

Command	Options
EVE R	***n***, **A**, **D**, **L*y***, **NSET**, **NSUM**

Table 7.36 EVE R Command Options Description

Command	Description	Access Level
EVE R	Return the most recent unfiltered event report at full length with 24-samples/cycle data	1, B, P, A, O, 2
EVE R *n*[a]	Return a particular *n* unfiltered event report at full length with 24-samples/cycle data.	1, B, P, A, O, 2
EVE R A	Return only the analog information for the most recent event report with 24-samples/cycle data.	1, B, P, A, O, 2
EVE R D	Return only the digital information for the most recent event report with 24-samples/cycle data.	1, B, P, A, O, 2
EVE R L*y*	Return *y* cycles of the most recent event report with 24-samples/cycle data.	1, B, P, A, O, 2
EVE R NSET	Return the most recent event report without settings at full length with 24-samples/cycle data.	1, B, P, A, O, 2
EVE R NSUM	Return the most recent event report without the event summary at full length with 24-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVENT on page R.7.14

FILE

Use the Ymodem protocol with the **FILE** command to transfer files between intelligent electronic devices (IEDs) and external support software (ESS). For more information on the **FILE** command, see *Virtual File Interface on page R.4.11*.

Table 7.37 FILE Command

Command	Description	Access Level
FILE DIR [*directory1* [*directory2*]]	Returns a list of filenames in specified directory (*directory1*) and subdirectory (*directory2*). If neither parameter is specified, then the list of files and directories in the root directory is returned.	1, B, P, A, O, 2
FILE READ [*directory1* [*directory2*]] *filename*	Initiates a file transfer of the file *filename* (in the folder *directory1,* subdirectory *directroy2*) from the relay to external support software. The *filename* parameter is required.	1, B, P, A, O, 2
FILE WRITE SETTINGS [*directory1* [*directory2*]] [*filename*]	Initiates a file transfer of the file *filename* (in the folder SETTINGS, subdirectory *directory*) from external support software to the relay. If the *filename* parameter is not specified, the file name must be given in the Ymodem header.	P, A, O, 2

All text enclosed in [brackets] indicate optional command line parameters. The **FILE** command allows access to second level subdirectories as the optional *directory2* parameter.

File directories in the SEL-487B are the EVENTS directory, the REPORTS directory, and the SETTINGS directory. For FILE READ operations, specify the *directory1* (and *directory2*) parameters as needed. The **FILE WRITE** command is available only for the SETTINGS directory and its second level subdirectories. Parameter filename is optional for **FILE WRITE** operations. When using the **FILE WRITE** command, use only file names that already exist in the relay.

GROUP

Use the **GROUP** command to view the present group number or to change the active group.

Table 7.38 GROUP Command

Command	Description	Access Level
GROUP	Display the presently active group.	1, B, P, A, O, 2
GROUP *n*[a]	Change the active group to Group *n*.	B, P, A, O, 2

[a] Parameter n indicates group numbers 1–6.

When you change the active group, the relay sends the following confirmation prompt:

```
Are you sure (Y/N)?
```

Answer **Y <Enter>** to change the active group. The relay asserts the Relay Word bit SALARM for one second when you change the active group.

If any of the SELOGIC control equations SS1–SS6 are set when you issue the **GROUP *n*** command, the group change will fail, because the SS1–SS6 settings have priority. For information on SELOGIC control equations SS1 through SS6, see *Settings Structure on page U.4.12*.

HELP

The **HELP** command gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for help on each command. For information on access levels and passwords, see *Access Levels on page U.4.6*.

Table 7.39 HELP Command

Command	Description	Access Level
HELP	Display a list of each command available at the present access level with a one-line description.	1, B, P, A, O, 2
HELP *command*	Display information on the command *command*.	1, B, P, A, O, 2

HISTORY

The **HISTORY** command displays a quick synopsis of the last 100 events that the relay has captured. The rows in the **HISTORY** report contain the event number, date, time, event, active group, and targets. See *Event History on page A.3.27* for the **HISTORY** report format.

HIS

Use the **HIS** command to list one-line descriptions of relay events. You can list event histories by number or by date.

Table 7.40 HIS Command

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *k*[a]	Return the *k* most recent event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *date1*[b]	Return the event histories on *date1*.	1, B, P, A, O, 2
HIS *date1 date2*[b]	Return the event histories from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.	1, B, P, A, O, 2

[a] Parameter k indicates number of events.
[b] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

HIS C and HIS R

The **HIS C** and **HIS R** commands clear the history data and corresponding event report data on the present port. Options **C** and **R** are identical.

Table 7.41 HIS C and HIS R Commands

Command	Description	Access Level
HIS C	Clear event data on the present port only.	1, B, P, A, O, 2
HIS R	Clear event data on the present port only.	1, B, P, A, O, 2

When you issue the **HIS C** and **HIS R** commands, the relay sends the following prompt:

```
Are you sure (Y/N)?
```

If you answer **Y <Enter>**, the relay clears the present port history data.

HIS CA and HIS RA

The **HIS CA** and **HIS RA** commands clear all history data and event reports from memory. Use these commands to completely delete event report data captures.

Table 7.42 HIS CA and HIS RA Commands

Command	Description	Access Level
HIS CA	Clear all event data for all ports.	P, A, O, 2
HIS RA	Clear all event data for all ports.	P, A, O, 2

If you issue the **HIS CA** and **HIS RA** commands, the relay sends the following prompt:

```
Are you sure (Y/N)?
```

If you answer **Y <Enter>**, the relay clears all history data and event reports. The relay resets the event report number to 10000.

ID

Use the **ID** command to extract relay identification codes.

Table 7.43 ID Command

Command	Description	Access Level
ID	Return a list of relay identification codes.	0, 1, B, P, A, O, 2

Each line of the **ID** command report contains an identification code and a line checksum. The relay presents these codes in the following order:

FID: the Firmware Identification string

BFID: the Boot Firmware Identification string

CID: the checksum of the firmware

DEVID: the RID string as stored in the relay settings

DEVCODE: a unique Device Code (for SEL-2020/2030/2032 Modbus® identification purposes)

PARTNO: the Part Number

CONFIG: abcdef (a0c000)

The designator positions indicate a specific relay configuration:
"a" represents the nominal frequency; where 1 = 60 Hz, and 2 = 50 Hz.
"b" represents the phase rotation; where 0 = N/A.
"c" represents the phase input current scaling; where 1 = 5 A, and 2 = 1 A.
"d" represents the neutral input current scaling; where 0 = N/A.
"e" represents the voltage input connection; where 0 = N/A.
"f" represents the current input connection; where 0 = N/A.

SPECIAL: the Special Configuration Designators—a mechanism for anticipating future product enhancements

CARD5FID: the Ethernet card Firmware Identification string

CARD5BFID: the Ethernet card Boot Firmware Identification string

CARD5PARTNO: the Ethernet card Part Number

A sample **ID** command response is shown in *Figure 7.1*.

```
"FID=SEL-487B-R102-V0-Z001001-D20030724","08E1"
"BFID=SLBT-4XX-R100-V0-Z001001-D20030703","0972"
"CID=88D0","0261"
"DEVID=Relay 1","0467"
"DEVCODE=42","030D"
"PARTNO=0487B06512XEXXXXH","06E4"
"CONFIG=101000","0385"
"SPECIAL=00000","039E"
"CARD5FID=SEL-2702-R103-V0-Z001001-D20070223","0A1B"
"CARD5BFID=SLBT-2701-R102-V0-Z000000-D20051107","0AAA"
"CARD5PARTNO=2702A0P","055C"
```

Figure 7.1 Sample ID Command Response

If the device supports IEC 61850 ICD or CID files and the IEC 61850 protocol is enabled, the ID command will display the following additional information:

- iedName: the IED name (e.g., SEL-487B_OtterTail)
- type: the IED type (e.g., SEL-487B)
- configVersion: the CID file configuration version (e.g., ICD-487B-R100-V0-Z001001-20060512

The optional Ethernet card provides support for IEC 61850 in the SEL-487B. You must first use the **POR 5** command to establish a transparent session to the Ethernet card, then issue the ID command to view the IEC 61850 ID data.

A sample ID command response from the optional Ethernet card (with IEC 61850 enabled) is shown in *Figure 7.2*.

```
"FID=SEL-2702-R100-V2-Z000000-D20060524","08DA"
"BFID=SLBT-2701-R102-V0-Z000000-D20051107","095B"
"CID=9689h","02C5"
"DEVID=ETHERNET PROCESSOR WITH IEC 61850 AND DNP","0CBE"
"PARTNO=2702C4P","0413"
"CONFIG=000000","0383"
"iedName=SEL_487B_OtterTail","05BC"
"type=SEL_487B","04A4"
"configVersion=ICD-487B-R117-V0-Z001001-D20060524","0698"
```

Figure 7.2 Sample ID Command Response from Ethernet Card

LOOPBACK

Use the **LOOP** command to verify the communications channel. In this mode, the relay expects the transmitted data to be looped back to the relay to test the data transmissions, including communication data. See *SEL MIRRORED BITS Communications on page R.4.14* for more information on MIRRORED BITS communications.

LOOP

The **LOOP** command puts the relay serial port in loopback if you have previously configured the port for MIRRORED BITS communications. If you have enabled both of the MIRRORED BITS communications channels (A and B), then you must specify the channel parameter. If you have only one of the channels enabled, the relay uses that channel, if you do not specify that channel in the command. If you do not specify a timeout period, the relay provides a five-minute timeout.

Table 7.44 LOOP Command

Command	Description	Access Level
LOOP	Begin loopback of a single enabled MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *c*[a]	Begin loopback of MIRRORED BITS communications channel *c* for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *t*	Begin loopback of a singleMIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after timeout *t* minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2
LOOP *t c*	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after timeout *t* minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2

[a] Parameter c is A or B, representing Channel A or Channel B.

You can enter the options in any order. If you operate the relay using both MIRRORED BITS communications channels (A and B), then you must specify the channel parameter by using the **LOOP A** command and the **LOOP B** command.

When you issue the **LOOP** command, the relay responds with statements about the loopback time, status of the RMB (Receive MIRRORED BITS), and a confirmation prompt:

```
Are you sure (Y/N)?
```

If you answer **Y <Enter>**, the relay responds as follows:

```
Loopback Mode Started
```

In the loopback mode, Relay Word bit ROK (data valid, loopback disabled) drops out and the relay uses Relay Word bit LBOK (data valid, loopback enabled) to indicate whether the data transmissions are satisfactory. The relay collects COM data as usual. Time synchronization and virtual terminal modes are not available during loopback. The relay continues passing analog quantities.

LOOP DATA

The **LOOP DATA** command results in the input MIRRORED BITS communications data being passed through to the receive (RMB) bits, as in the nonloopback mode.

Table 7.45 LOOP DATA Command

Command	Description	Access Level
LOOP DATA	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA	Begin loopback of MIRRORED BITS communications channel *c* only for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA *t*	Begin loopback of MIRRORED BITS communications channel *c* only for *t* minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2

The relay ignores received values if you do not specify the **DATA** option. You can enter the options in any order.

LOOP R

The **LOOP R** command terminates the loopback condition on MIRRORED BITS communications channels in loopback. If you do not specify a channel *c*, the relay disables loopback on both channels. If you specify a channel, you can enter the options in any order.

Table 7.46 LOOP R Command

Command	Description	Access Level
LOOP R	Cease loopback on all MIRRORED BITS communications channels. (Reset the channels to normal use.)	P, A, O, 2
LOOP *c* R	Cease loopback on MIRRORED BITS communications channel *c*. (Reset channel c to normal use.)	P, A, O, 2

MAP

Use the **MAP** command to view the organization of the relay database. The **MAP** command in the SEL-487B is very similar to the **MAP** command in the SEL-2020 and SEL-2030 Communications Processors. See *Section 4: SEL Communications Protocols* for more information on the relay database regions and data types.

MAP 1

The **MAP 1** command lists the relay database regions. Database region names are LOCAL, METER, TARGET, HISTORY, STATUS, ANALOGS, STATE and D1.

Table 7.47 MAP 1 Command

Command	Description	Access Level
MAP 1	List the database regions in the relay.	1, B, P, A, O, 2

MAP 1 region and MAP 1 region BL

Use the **MAP 1** command with the *region* option to view the layout of a specific region. Database region names are LOCAL, METER, TARGET, HISTORY, STATUS, ANALOGS, STATE and D1.

Table 7.48 MAP 1 Region Command

Command	Description	Access Level
MAP 1 *region*	List the data labels, database address, and data type.	1, B, P, A, O, 2
MAP 1 *region* BL	List the data labels, database address, and data type; list the Bit Labels, if assigned.	1, B, P, A, O, 2

The *region* option is the database region name shown in the simple **MAP 1** command response. The region map consists of columns for data item labels, database address, and data type.

If you specify the **BL** option and the region contains items with bit labels, the relay lists these bit labels in MSB (most significant bit) to LSB (least significant bit) order. Examples of database bit label names are P87R1, 27P32, and ASV256.

METER

The **METER** command displays reports about quantities the relay measures in the power system and internal relay operating quantities. For more information on power system measurements, see *Section 2: Monitoring and Metering in the Applications Handbook*.

MET

NOTE: Data obtained with the **MET** command during dynamic zone selection may be unreliable.

Use the **MET** command to view fundamental metering quantities. The relay filters harmonics to present only measured quantities at the power system fundamental operating frequency.

Table 7.49 MET Command

Command	Description	Access Level
MET	Display fundamental metering data.	1, B, P, A, O, 2
MET *k*	Display fundamental metering data successively for *k* times.	1, B, P, A, O, 2

Some situations require that you repeatedly monitor the power system for a brief period; specify a number after any **MET** command to automatically repeat the command.

MET AMV

The **MET AMV** command lists automation math variables.

Table 7.50 MET AMV Command

Command	Description	Access Level
MET AMV	Display the last 16 automation math variables.	1, B, P, A, O, 2
MET AMV *k*	Display the last 16 automation math variables successively for *k* times.	1, B, P, A, O, 2
MET AMV A	Display all the automation math variables.	1, B, P, A, O, 2
MET AMV A *k*	Display all the automation math variables successively for *k* times.	1, B, P, A, O, 2

The last 16 automation math variables are AMV241 through AMV256. The relay displays three places after the decimal point for these numerals.

MET ANA

Use the **MET ANA** command to view the analog quantities from the MIRRORED BITS communications channels.

Table 7.51 MET ANA Command

Command	Description	Access Level
MET ANA	Display the MIRRORED BITS communications analog quantities.	1, B, P, A, O, 2
MET ANA *k*	Display the MIRRORED BITS communications analog quantities successively for *k* times.	1, B, P, A, O, 2

If you have not enabled the MIRRORED BITS communications channels and the remote sources, the relay responds with the following:

```
Option not available.
```

MET BAT

Use the **MET BAT** command to view the station dc quantities.

Table 7.52 MET BAT Command

Command	Description	Access Level
MET BAT	Display station battery measurements.	1, B, P, A, O, 2
MET BAT *k*	Display station battery measurements successively for *k* times.	1, B, P, A, O, 2
MET RBM	Reset station battery measurements.	P, A, O, 2

If you have not enabled the Station DC Battery Monitor, the relay responds as follows:

```
DC Monitor Is Not Enabled
```

(Enable the dc monitor with the Global setting EDCMON; see *Section 8: Settings*.)

The reset command, **MET RBM**, resets the dc monitor maximum/minimum metering quantities. When you issue the **MET RBM** command, the relay responds as follows:

```
Reset Max/Min Battery Metering (Y/N)?
```

If you answer **Y <Enter>**, the relay responds as follows:

```
Max/Min Battery Reset
```

MET CZ1

Use the **MET CZ1** command to view the current magnitude, angle, and polarity of each terminal in Check Zone 1 and the voltage in primary values.

Table 7.53 MET CZ1 Command

Command	Description	Access Level
MET CZ1	Display primary metering data.	1, B, P, A, O, 2
MET CZ1 *k*	Display primary metering data successively for *k* times.	1, B, P, A, O, 2

If an alias name for the terminal exists, the relay displays the alias name.

MET DIF

Use the **MET DIF** command to view the operate and restraint differential currents in the active zones in per unit values as well as the reference current (IREF).

Table 7.54 MET DIF Command

Command	Description	Access Level
MET DIF	Display the operate and restraint differential currents and IREF metering data.	1, B, P, A, O, 2
MET DIF *k*	Display the operate and restraint differential currents and IREF metering data successively for *k* times.	1, B, P, A, O, 2

MET PMV

Use the **MET PMV** command to view the protection math variables.

Table 7.55 MET PMV Command

Command	Description	Access Level
MET PMV	Display the last 16 protection math variables.	1, B, P, A, O, 2
MET PMV *k*	Display the last 16 protection math variables successively for *k* times.	1, B, P, A, O, 2
MET PMV A	Display all the protection math variables	1, B, P, A, O, 2
MET PMV A *k*	Display all the protection math variables successively for *k* times.	1, B, P, A, O, 2

The last 16 protection math variables are PMV49 through PMV64. The relay displays three places after the decimal point for these numerals.

MET SEC

Use the **MET SEC** command to view the current magnitude, angle, and CT ratio of each terminal. The view also includes voltage magnitudes in secondary values.

Table 7.56 MET SEC Command

Command	Description	Access Level
MET SEC	Display secondary metering data.	1, B, P, A, O, 2
MET SEC *k*	Display secondary metering data successively for *k* times.	1, B, P, A, O, 2

If an alias name for the terminal exists, the relay displays the alias name.

MET SEC CZ1

Use the **MET SEC CZ1** command to view the current magnitude, angle, CT ratio, and polarity of each terminal in check zone and the voltage in secondary values.

Table 7.57 MET SEC CZ1 Command

Command	Description	Access Level
MET SEC CZ1	Display secondary metering data.	1, B, P, A, O, 2
MET SEC CZ1 *k*	Display secondary metering data successively for *k* times.	1, B, P, A, O, 2

If an alias name for the terminal exists, the relay displays the alias name.

MET SEC Zn

Use the **MET SEC Z*n*** command to view the current magnitude, angle, CT ratio, and polarity of each terminal in a particular protection zone (*n* = 1–6), the bus-zones in Protection Zone *n*, and the voltage in secondary values.

Table 7.58 MET SEC Zn Command

Command	Description	Access Level
MET SEC Z*n*	Display secondary metering data.	1, B, P, A, O, 2
MET SEC Z*n*[a] *k*	Display secondary metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter n is 1 or 6 to indicate 6 zones.

If an alias name for the terminal exists, the relay displays the alias name.

MET Zn

Use the **MET Z*n*** command to view the current magnitude, angle, and polarity of each terminal in a particular protection zone (*n* = 1–6), the bus-zones in Protection Zone *n*, and the voltage in primary values.

Table 7.59 MET Zn Command

Command	Description	Access Level
MET Z*n*	Display primary metering data.	1, B, P, A, O, 2
MET Z*n*[a] *k*	Display primary metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter n is 1 or 6 to indicate 6 zones.

If an alias name for the terminal exists, the relay displays the alias name.

OACCESS

Use the **OACCESS** command to gain access to Access Level O (output). See *Access Levels on page U.4.6* for more information.

Table 7.60 OAC Command

Command	Description	Access Level
OAC	Go to Access Level O (output).	1, B, P, A, O, 2

OPEN n

Use the **OPEN *n*** (*n* = 1–18) command to open a circuit breaker(s). The **OPEN 1** command pulses Relay Word bit OC01, and the **OPEN 2** command pulses Relay Word bit OC02. Usually, you configure these Relay Word bits as part of the SELOGIC control equations that trip the appropriate circuit breaker. See *Breaker Trip Logic on page R.1.55* for information on trip SELOGIC control equations.

Table 7.61 OPEN k Command

Command	Description	Access Level
OPEN 1	Pulse Relay Word bit OC01 to logical 1.	B, P, A, O, 2
OPEN 2	Pulse Relay Word bit OC02 to logical 1.	B, P, A, O, 2
• • •	• • •	B, P, A, O, 2
OPEN 18	Pulse Relay Word bit OC18 to logical 1.	B, P, A, O, 2

To open a breaker, the breaker number (1–18) must be within the range specified by the global setting, NUMBK; the relay must be enabled; and the breaker control enable jumper, J18C, must be in place.

For information on placing relay jumpers, see *Password and Circuit Breaker Jumpers on page U.2.16*.

When you issue the **OPEN *n*** command, and the circuit breaker control enable jumper is in place, the relay responds as follows:

```
Open breaker (Y/N)?
```

If you answer **Y <Enter>**, the relay responds as follows:

```
Are you sure (Y/N)?
```

If you answer **Y <Enter>**, the relay asserts the appropriate OC bit (OC01–OC18) for one processing interval. Circuit Breaker 1 opens if you have programmed Relay Word bit OC01 in the TR01 SELOGIC control equation.

If you have assigned auxiliary contact 52A inputs for this circuit breaker (based on settings 52A01 through 52A18), the relay waits 0.5 seconds, checks the state of the breaker auxiliary contacts, and returns one of the following responses:

```
Breaker OPEN
```

or

```
Breaker CLOSED
```

PACCESS

Use the **PACCESS** command to gain access to Access Level P (protection). See *Access Levels on page U.4.6* for more information.

Table 7.62 PAC Command

Command	Description	Access Level
PAC	Go to Access Level P (protection).	1, B, P, A, O, 2

PASSWORD

Use the **PASSWORD** command to control password protection for relay access levels. For information on access levels and passwords, see *Changing the Default Passwords on page U.4.6*.

PAS level new_password

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

The relay changes the existing password for the specified access level to a *new_password* that you specify when you issue the **PAS *level new_password*** command.

Table 7.63 PAS level new_password Command

Command	Description	Access Levels
PAS *level*[a] *new_password*	Set a password *new_password* for Access Level *level*.	2

[a] Parameter level represents the relay access levels 1, B, P, A, O, or 2.

Relay access levels that have passwords are 1, B, P, A, O, and 2. Valid passwords are character sequences of as many as 12 characters. Valid characters are any printable ASCII character. HMI password entry is limited to upper- and lower-case letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel.

All passwords are case sensitive. See *Changing the Default Passwords on page U.4.6* for information on setting strong passwords. When you successfully enter a new password, the relay pulses the Relay Word bit SALARM for one second, and responds as follows:

```
Set
```

PAS level DISABLE

Issuing the **PAS *level* DISABLE** command disables password checking for the specified access level. You must type **DISABLE** in uppercase.

Table 7.64 PAS level DISABLE Command

Command	Description	Access Levels
PAS *level* DISABLE	Disable password protection for the Access Level *level*.[a]	2

[a] Parameter level represents the relay access Levels 1, B, P, A, O, or 2.

When you successfully disable password checking, the relay pulses the SALARM Relay Word bit for one second, and responds as follows:

```
Password Disabled
```

SEL does not recommend disabling passwords. See *Changing the Default Passwords*.

PORT

The **PORT** command can be used to connect to either an installed Ethernet card or a remote relay.

In the SEL-487B, serial port virtual terminal capability is available in MIRRORED BITS communications. You must have previously configured the serial port for MIRRORED BITS communications operation, set port setting MBNUM less than 8, and have at least one virtual terminal session available (set MBNUMVT to 0 or greater). Choosing MBNUMVT to 0 uses virtual terminal within the synchronization channel only. See *SEL MIRRORED BITS Communications on page R.4.14* for information on the MIRRORED BITS communications protocol.

PORT p

The **PORT *p*** command connects a relay serial or Ethernet port to another device through a virtual terminal session.

If an Ethernet card is installed, you can use the **PORT** command to initiate a virtual terminal session with the communications card by specifying port number *p* as 5.

Table 7.65 PORT p Command

Command	Description	Access Level
PORT *p*[a]	Connect to a remote device through Port *p* (over MIRRORED BITS communications virtual terminal mode).	1, B, P, A, O, 2

[a] Parameter p is 1, 2, 3, 5, and F to indicate Communications Port 1 through Port 3, Port 5, and Port F.

When the relay establishes a connection, the relay responds as follows:

```
Transparent session to Port p established
```

To quit the transparent connection, type the control string that you specify in port setting TERSTRN; the default is **<Ctrl+E>**. Only one transparent port connection to each MIRRORED BITS communications port is possible at one time. If you issue a **PORT *p*** command when the selected session is already active, the relay responds as follows:

```
Transparent session already in use
```

If you issue the **PORT *p*** command to ports 1, 2, 3, or F and you have not properly configured the MIRRORED BITS communications port or the MBNUMVT is not set to 1 or larger, then the relay responds `Invalid destination port` as follows:

```
Invalid destination port
```

PORT KILL n

It is possible to forcefully disconnect a transparent session from another port (a port not involved in the present transparent connection) by using the **PORT KILL *n*** command.

Table 7.66 PORT Kill *n* Command

Command	Description	Access Level
PORT KILL *n*[a]	Terminate the virtual terminal connection with a remote device through Port *n* by using a port not involved in the connection.	P, A, O, 2

[a] Parameter n is 1, 2, 3, 5, and F to indicate Communications Port 1 through Port 3, Port 5, and Port F; *n* is not the present port.

The port parameter *n* can refer to either of the ports involved in the session you want to kill. When you issue the **PORT KILL *n*** command, the relay responds as follows:

```
Kill connection between ports m and n (Y/N)?
```

Answer **Y <Enter>** to terminate the connection. The relay sends a character sequence to the remote relay (to make sure the remote device is left in a known state) and responds, `Connection between ports m and n disconnected`.

PULSE

Use the **PULSE OUT*nnn*** command to pulse any of the relay control outputs for a specified time. This function aids you in relay testing and commissioning. If the output is open, the **PUL** command momentarily closes the output; if the output is closed, the **PUL** command momentarily opens the output. See *Test Commands on page U.6.5* for information on using the **PULSE OUT*nnn*** command. The control outputs are **OUT*nnn***, where ***nnn*** represents the 100-series, 200-series, 300-series, 400-series, and 500-series addresses.

Table 7.67 PUL OUTnnn Command

Command	Description	Access Level
PUL OUT*nnn*[a]	Pulse output OUT*nnn* for 1 second.	B, P, A, O, 2
PUL OUT*nnn s*[b]	Pulse output OUT*nnn* for *s* seconds.	B, P, A, O, 2

[a] Parameter nnn is a control output number.
[b] Parameter s is time in seconds, with a range of 1 through 30.

If the circuit breaker control enable jumper J18C is not in place, the relay aborts the command and responds as follows:

```
Aborted: the breaker jumper is not installed
```

See *Jumpers on page U.2.16* for more information on relay jumpers.

When you issue the **PUL** command and the breaker jumper is in place, the relay responds as follows:

```
Pulse contact OUTnnn for s seconds (Y/N)?
```

If you answer **Y <Enter>**, the relay asserts OUT*nnn* for the time you specify.

During the **PUL** operation, the Relay Word bit corresponding to the control output you specified (OUT*nnn*) asserts; Relay Word bit TESTPUL asserts also during any **PUL** command, so you can monitor pulse operation by programming TESTPUL into event triggers and alarm outputs. See *Section 3: Analyzing Data in the Applications Handbook* for more information on pulsing relay outputs.

QUIT

Use the **QUIT** command to revert to Access Level 0 (exit relay control). See *Section 4: Basic Relay Operations in the User's Guide* for more information.

Table 7.68 QUIT Command

Command	Description	Access Level
QUIT	Go to Access Level 0 (exit relay control).	0, 1, B, P, A, O, 2

Access Level 0 is the lowest access level; the relay performs no password check to descend to this level (or remain at this level).

In a Telnet session, **QUIT** terminates the connection; see *Section 5: Direct Network Communications in the Applications Handbook*.

SER

The **SER** command retrieves SER (Sequential Events Recorder) records. The relay SER captures state changes of Relay Word bit elements and relay conditions. Relay conditions include power up, relay enable/disable, group changes, settings changes, memory queue overflow, and SER autoremoval/reinsertion. For more information on the Sequential Events Recorder, see *Section 3: Analyzing Data in the Applications Handbook*.

SER

The default order of the **SER** command is oldest to newest from list top to list bottom. You can view the SER records in numerical or date order.

Table 7.69 SER Command (Sheet 1 of 2)

Command	Description	Access Level
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2

Table 7.69 SER Command (Sheet 2 of 2)

Command	Description	Access Level
SER *m n*[a]	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.	1, B, P, A, O, 2
SER *date1*[b]	Return the SER records on *date1*.	1, B, P, A, O, 2
SER *date1 date2*[b]	Return the SER records from *date1* at the top of the list, to *date2* at the bottom of the list.	1, B, P, A, O, 2

[a] Parameters m and n indicate an SER event number, where 1 is the latest event.
[b] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

SER C and SER R

The **SER C** and **SER R** commands clear the SER records for the present port. Options **C** and **R** are identical.

Table 7.70 SER C and SER R Commands

Command	Description	Access Level
SER C	Clear SER records on the present port.	1, B, P, A, O, 2
SER R	Clear SER records on the present port.	1, B, P, A, O, 2

When you issue the **SER C** or **SER R** command, the relay prompts as follows:

```
Clear the sequential events recorder.
Are you sure (Y/N)?
```

If you answer **Y <Enter>**, the relay clears the SER for that port. The data are still visible to other ports and to file transfer accesses, and they must be cleared independently for those ports.

SER CA and SER RA

The **SER CA** and **SER RA** commands are identical and clear all SER records from memory.

Table 7.71 SER CA or SER RA Commands

Command	Description	Access Level
SER CA or **SER RA**	Clear SER data for all ports.	P, A, O, 2

If you issue the **SER CA** or **SER RA** command, the relay prompts as follows:

```
Clear the sequential events recorder for all ports.
Are you sure (Y/N)?
```

If you answer **Y <Enter>**, the relay clears all SER records in nonvolatile memory.

SER CV and SER RV

The **SER CV** and **SER RV** commands clear any SER data records that have been viewed from the present port. The two commands are equivalent.

Table 7.72 SER CV or SER RV Commands

Command	Description	Access Level
SER CV or **SER RV**	Clear viewed SER data for this port.	1, B, P, A, O, 2

If you issue the **SER CV** or **SER RV** command, the relay prompts as follows:

```
Clear viewed SER records for this port.
Are you sure (Y/N)?
```

If you answer **Y <Enter>**, the relay clears all SER records viewed from this port. The data are still visible to other ports and to file transfer accesses, and they must be cleared independently for those ports. Data not yet viewed remain available.

SER D

The **SER D** command shows a list of SER items that the relay has automatically removed. These are chattering elements. You can automatically remove chattering SER elements in the SER Chatter Criteria category of the Report settings; the enable setting is ESERDEL. See *Section 3: Analyzing Data in the Applications Handbook* for more information on SER automatic deletion and reinsertion.

Table 7.73 SER D Command

Command	Description	Access Level
SER D	List chattering SER elements that the relay is removing from the SER records.	1, B, P, A, O, 2

If you issue the **SER D** command and you have not enabled automatic removal of chattering SER elements (Report setting ESERDEL), the relay responds as follows:

```
Automatic removal of chattering SER elements not enabled.
```

SET

Use the **SET** command to change relay settings. The SEL-487B settings structure is ordered and contains these items (in structure order): classes, instances, categories, and settings. An outline of the relay settings structure is as follows:

Classes (Global, Group, Zone Configuration, Protection, Automation, Outputs, Front Panel, Report, DNP, and Ports)

Instances (some classes have instances: Group = 1–6; Protection = 1–6; Zone Configuration = 1–6; Automation = 1–10; Ports = 1–3, F, 5)

Categories (collections of similar settings)

Settings (specific relay settings with values)

The **SET** and **SHOW** commands contain these settings structure items, which you must specify in order from class to instance (if applicable) to setting. For more information and a tutorial on setting the relay, see *Making Simple Settings Changes on page U.4.12*.

The order that specific settings appear in the relay settings structure is factory programmed. See *Section 8: Settings* for specific settings order, ranges, and default values.

SET

The **SET** command with no options or parameters accesses the relay settings Group class and the instance corresponding to the active group. To set a different instance, specify the instance number (1–6).

Table 7.74 SET Command Overview

Command	Description	Access Level
SET	Set the Group relay settings, beginning at the first setting in the active group.	P, 2
SET *n*[a]	Set the Group *n* relay settings, beginning at the first setting in the group.	P, 2
SET *label*	Set the active group settings beginning at setting *label*.	P, 2
SET *n label*[a]	Set the Group *n* relay settings beginning at setting *label*. Note: free-form settings will not be recognized as valid labels.	P, 2

[a] Parameter n = 1–6, representing Group 1 through Group 6.

The relay validates your settings entries as you enter each setting. At the end of a settings instance session, the relay responds with a readback of all the settings in the settings instance; then prompts as follows:

```
Save settings (Y,N)?
```

If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds as follows:

```
Saving Settings, Please Wait...........
```

The relay saves the new settings, then responds as follows:

```
Settings Saved
```

If you answer **N <Enter>** to the save settings prompt, the relay responds as follows:

```
Settings aborted
```

SET A

Use the **SET A** command to set the Automation SELOGIC control equations. See *Section 2: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

Table 7.75 SET A Command

Command	Description	Access Level
SET A	Set the Automation SELOGIC control equation relay settings in Block 1.	A, 2
SET A *n*[a]	Set the Automation SELOGIC control equation relay settings in Block *n*.	A, 2

[a] Parameter n = 1–10 for Block 1 through Block 10.

The relay presents text-edit mode entry format for the free-form SELOGIC control equations you program in the Automation SELOGIC control equations settings area. See *Text-Edit Mode Line Editing on page U.4.18* for information on settings text-edit mode.

SET D

Issue the **SET D** command to remap serial port DNP3 values. To set the general DNP settings, use the Port settings for the appropriate port (see *SET P on page R.7.35*). There is only one instance of the serial port DNP3 protocol installed to access these settings. For more information, see *Section 5: DNP3 Communications*.

Table 7.76 SET D Command

Command	Description	Access Level
SET D	Set the serial port DNP3 remapping settings, beginning at the first setting in this class.	P, A, O, 2
SET D *label*	Set the serial port DNP3 remapping settings, beginning at setting *label*.	P, A, O, 2

SET F

Use the **SET F** command to set the relay front-panel settings. There is only one instance for the Front Panel settings. See *Section 5: Front-Panel Operations in the User's Guide* for information about front-panel settings.

Table 7.77 SET F Command

Command	Description	Access Level
SET F	Set the Front Panel relay settings, beginning at the first setting in this class.	P, A, O, 2
SET F *label*	Set the Front Panel relay settings, beginning at the settings *label*.	P, A, O, 2

SET G

Use the **SET G** command to the Global class settings. There is only one instance for the Global class.

Table 7.78 SET G Command

Command	Description	Access Level
SET G	Set the Global relay settings, beginning at the first setting in this class.	P, A, O, 2
SET G *label*	Set the Global relay settings, beginning at the setting *label*.	P, A, O, 2

SET L

Use the **SET L** command to set the Protection SELOGIC control equations. See *Section 2: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

Table 7.79 SET L Command

Command	Description	Access Level
SET L	Set the Protection SELOGIC control equation relay settings for the active group.	P, 2
SET L *n*[a]	Set the Protection SELOGIC relay settings for Group *n*.	P, 2

[a] Parameter n is 1–6 for Protection Groups 1 through 6.

The relay presents text-edit mode entry format for the free-form SELOGIC control equations you program in the Protection SELOGIC control equation settings area. See *Text-Edit Mode Line Editing on page U.4.18* for information on settings text-edit mode.

SET O

Use the **SET O** command to set the Output SELOGIC control equations. See *Control Outputs on page U.2.9* for more information on relay control outputs.

Table 7.80 SET O Command

Command	Description	Access Level
SET O	Set the Output SELOGIC control equation relay settings, beginning at OUT101.	O, 2
SET O *label*	Set the Output SELOGIC control equation relay settings, beginning at the output *label*.	O, 2

SET P

Use the **SET P** command to configure the relay communications ports; each port is a settings instance. The SEL-487B communications ports include serial ports at Port F, Port 1, Port 2, and Port 3. Port 5 is the communications card port in which you can install the optional Ethernet card or other communications cards.

Table 7.81 SET P Command

Command	Description	Access Level
SET P	Set the port presently in use, beginning at the first setting for this port.	P, A, O, 2
SET P *label*	Set the port presently in use, beginning at the setting *label*.	P, A, O, 2

Table 7.81 SET P Command

Command	Description	Access Level
SET P *p*[a]	Set the communications Port relay settings for Port *p*, beginning at the first setting for this port.	P, A, O, 2
SET P *p label*	Set the communications Port relay settings for Port *p*, beginning at the setting *label*.	P, A, O, 2

[a] Parameter p = 1–3, F, or 5, corresponding to Port 1–Port 3, Port F, or Port 5.

SET R

Use the **SET R** command to set Report settings and to program SER points and Reporting, Set State, and Clear State names. You can also set event report parameters and program event report digital elements. There is only one instance for the Report settings.

Table 7.82 SET R Command

Command	Description	Access Level
SET R	Set the Report relay settings, beginning at the first setting for this class.	P, A, O, 2
SET R *label*	Set the Report relay settings, beginning at the setting *label*.	P, A, O, 2

Report settings are a mix of traditional settings entry mode and text-edit entry mode. See *Making Simple Settings Changes on page U.4.12* for settings entry methods for these modes.

SET T

Use the **SET T** command to set aliases for Relay Word bits, Analog quantities, terminal names, or bus-zone names. There is only one instance for the alias settings.

Table 7.83 SET T Command

Command	Description	Access Level
SET T	Set the alias settings.	P, A, O, 2

SET Z

Use the **SET Z** command for the zone configuration settings. Included are the CT and PT ratios, Terminal-to-Bus-Zone and Bus-Zone to Bus-Zone and Terminal-to-Check-Zone connections, and zone supervision settings. There are six instances for zone configuration settings.

Table 7.84 SET Z Command

Command	Description	Access Level
SET Z	Set the active group zone configuration settings, beginning at the first setting.	P, 2
SET Z *label*	Set the active group zone configuration setting, beginning at the setting *label*.	P, 2

Table 7.84 SET Z Command

Command	Description	Access Level
SET Z *n*[a]	Set the configuration setting for Group *n*, beginning at the first setting.	
SET Z *n label*	Set the zone configuration setting for Group *n*, beginning at setting *label*.	P, 2

[a] n = 1–6 instances.

SHOW

The **SHOW** command shows the relay settings. When showing settings, the relay displays the settings label and the present value from nonvolatile memory.

The relay organizes settings in classes, instances, categories, and specific settings; see *SET on page R.7.33* for information on settings organization. The relay displays each setting in the order specified in the settings tables in *Section 8: Settings*. When you are using a terminal and you specify a setting in the middle of a settings category, the relay displays the category title, then proceeds with the class or instance settings from the setting that you specified. See *Making Simple Settings Changes on page U.4.12* for more information on entering and viewing relay settings.

SHO

The **SHO** command with no options or parameters accesses the relay settings Group class and the instance corresponding to the active group. To show a different instance, specify the instance number (1–6).

Table 7.85 SHO Command Overview

Command	Description	Access Level
SHO	Show the Group relay settings, beginning at the first setting in the active group.	1, B, P, A, O, 2
SHO *n*	Show Group *n* settings, beginning at the first setting in Group *n*.	1, B, P, A, O, 2

SHOW A

Use the **SHO A** command to show the Automation SELOGIC control equations. See *Section 2: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

Table 7.86 SHO A Command

Command	Description	Access Level
SHO A	Show the Automation SELOGIC control equation relay settings in Block 1.	1, B, P, A, O, 2
SHO A *n*[a]	Show the Automation SELOGIC control equation relay settings in Block *n*.	1, B, P, A, O, 2

[a] Parameter n = 1–10 for Block 1 through Block 10.

SHOW D

NOTE: This does not display mapping information for DNP LAN/WAN.

The **SHO D** command shows the serial port DNP3 remapping settings. To view the general serial port DNP3 settings, use the Port settings (see *SHOW P on page R.7.39*). There is only one instance of the serial port DNP3 remapping settings. The relay must have the optional serial port DNP3 protocol installed to access these settings. For more information, see *Section 5: DNP3 Communications*.

Table 7.87 SHO D Command

Command	Description	Access Level
SHO D	Show the serial DNP3 remapping settings.	1, B, P, A, O, 2
SHO D *label*	Show the serial DNP3 remapping settings, beginning at setting *label*.	1, B, P, A, O, 2

SHOW F

Use the **SHO F** command to show the relay front-panel settings. There is only one instance for the Front Panel settings. See *Section 5: Front-Panel Operations in the User's Guide* for information on front-panel settings.

Table 7.88 SHO F Command

Command	Description	Access Level
SHO F	Show the Front Panel relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2

SHOW G

Use the **SHO G** command to show the Global class settings. There is only one instance for the Global class.

Table 7.89 SHO G Command

Command	Description	Access Level
SHO G	Show the Global relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2

SHOW L

Use the **SHO L** command to show the Protection SELOGIC control equations. See *Section 2: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

Table 7.90 SHO L Command

Command	Description	Access Level
SHO L	Show the Protection SELOGIC control equation relay settings for the active group.	1, B, P, A, O, 2
SHO L *n*[a]	Show the Protection SELOGIC control equation relay settings for Group *n*.	1, B, P, A, O, 2

[a] Parameter n is 1–6 for Group 1 through Group 6.

SHOW O

Use the **SHO O** command to show the Output SELOGIC control equations. See *Control Outputs on page U.2.9* for more information on relay control outputs.

Table 7.91 SHO O Command

Command	Description	Access Level
SHO O	Show the Output SELOGIC control equation relay settings, beginning at OUT101.	1, B, P, A, O, 2

SHOW P

Use the **SHO P** command to configure the relay communications ports; each port is a settings instance. The SEL-487B communications ports include serial ports at Port F, Port 1, Port 2, and Port 3. Port 5 is the communications card port in which you can install the optional Ethernet card or other communications cards.

Table 7.92 SHO P Command

Command	Description	Access Level
SHO P	Show the relay settings for the port presently in use, beginning at the first setting.	1, B, P, A, O, 2
SHO P *p*[a]	Show the communications Port relay settings for Port *p*, beginning at the first setting for this port.	1, B, P, A, O, 2

[a] Parameter p = 1–3, F, and 5 which corresponds to Port 1–Port 3, Port F, and Port 5.

The **SHO P** command with no options and parameters shows the settings for the active serial port.

SHOW R

Use the **SHO R** command to show Report settings and to program SER Points and SER Reporting, Set State, and Clear State Names. You can also show event report parameters and program Event Report Digital Elements. There is only one instance for the Report settings.

Table 7.93 SHO R Command

Command	Description	Access Level
SHO R	Show the Report relay settings, beginning at the first setting for this class.	1, B, P, A, O, 2

SHOW T

Use the **SHO T** command to show aliases for Relay Word bits, Analog quantities, terminal names, or bus-zone names. There is only one instance for the alias settings.

Table 7.94 SHO T Command

Command	Description	Access Level
SHO T	Show the alias settings.	1, B, P, A, O, 2

SHOW Z

Use the **SHO Z** command to show the zone configuration settings. Included are the CT and PT ratios, Terminal-to-Bus-Zone and Bus-Zone to Bus-Zone and Terminal-to-Check-Zone connections, and zone supervision settings. There are six instances for zone configuration settings, with the default being the active group.

Table 7.95 SHO Z Command

Command	Description	Access Level
SHO Z	Show the zone configuration settings for the active group.	1, B, P, A, O, 2
SHO Z *n*[a]	Show the zone configuration settings for Group *n*.	1, B, P, A, O, 2

[a] n = 1–6 instances.

SNS

In response to the **SNS** command, the relay sends the name strings of the Sequential Events Recorder elements. This is a comma-delimited string used to support the SEL Fast SER report. See *Section 4: SEL Communications Protocols* for more information.

Table 7.96 SNS Command

Command	Description	Access Level
SNS	Send the name strings of SER elements.	0, 1, B, P, A, O, 2

STATUS

The **STATUS** command reports relay status information that the relay derives from internal diagnostic routines and self-tests. See *Relay Self-Tests on page U.6.34* for information on relay diagnostics.

STA

The **STA** command with no options displays a short-form relay status report. Items in the STA report are the header, failures, warnings, SELOGIC control equation programming environment errors, and relay operational status. See *Checking Relay Status on page U.4.10* for information on relay status reports.

Table 7.97 STA Command

Command	Description	Access Level
STA	Return the relay status.	1, B, P, A, O

STA A

Use the **STA A** command to view the entire relay status report. Items in the full status report include the status report items (**STA** command) plus data on A/D (analog/digital) channel offsets, power supply voltages, temperature, communications interfaces, and time-source synchronization.

Table 7.98 STA A Command

Command	Description	Access Level
STA A	Display all items of the status report.	1, B, P, A, O, 2

STA C and STA R

The **STA C** and **STA R** commands reboot the relay. Thus, these commands clear a transient failure should this unlikely event occur. Options **C** and **R** are identical. Contact your Technical Service Center or the SEL Factory before using this command.

Table 7.99 STA C and STA R Command

Command	Description	Access Level
STA C	Reset the relay.	2
STA R	Reset the relay.	2

STA S

Use the **STA S** command to view all SELOGIC control equation operating errors. See *Section 2: SELOGIC Control Equation Programming* for more information.

Table 7.100 STA S Command

Command	Description	Access Level
STA S	Display detailed SELOGIC control equation error information.	1, B, P, A, O, 2

STA SC and STA SR

The **STA SC** and **STA SR** commands clear the SELOGIC control equation operating errors from the status report if the errors are no longer present. In addition, these commands reset the Automation SELOGIC Peak and Average Execution Cycle Time statistics. See *Section 2: SELOGIC Control Equation Programming* for more information.

Table 7.101 STA SC and STA SR Command

Command	Description	Access Level
STA SC	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2
STA SR	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2

SUMMARY

The **SUMMARY** command displays a summary event report. See *Section 3: Analyzing Data in the Applications Handbook* for information on summary event reports.

SUM

Use the **SUM** command to view the event summary reports in the relay memory.

Table 7.102 SUM Command

Command	Description	Access Level
SUM	Return the most recent event summary.	1, B, P, A, O, 2
SUM *n*[a]	Return an event summary for event *n*.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see the event history report (HIS on page R.7.17).

When parameter *n* is 1 through 100, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

SUM ACK

Acknowledge the oldest summary (specify no event number). Use the **SUM NEXT** command to view the event summaries available on the present communications port. Use **SUM ACK** to acknowledge the oldest unacknowledged summary on the present communications port.

Table 7.103 SUM ACK Command

Command	Description	Access Level
SUM ACK	Acknowledge the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

If you attempt to acknowledge an event summary that you have not viewed on the present port with the **SUM NEXT** command, the relay responds as follows:

```
Event summary number n has not been viewed
```

SUM NEXT

Use the **SUM NEXT** command to view the oldest (next) unacknowledged event summary.

Table 7.104 SUM NEXT Command

Command	Description	Access Level
SUM NEXT	View the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

TARGET

The **TARGET** command displays the elements for a selected row in the Relay Word bit table. See *Appendix A: Relay Word Bits*.

TAR

Use the **TAR** command to view a row of Relay Word bits or the alias names of the Relay Word bits. When using the **TAR** command, you can specify the row number or element name.

Table 7.105 TAR Command

Command	Description	Access Level
TAR	Display Row 0 or display the most recently viewed row.	1, B, P, A, O, 2
TAR *n*	Display Row *n*.	1, B, P, A, O, 2
TAR *n k*[a]	Display Row *n* and repeat for *k* times; the repeat count *k* must follow the row number.	1, B, P, A, O, 2

Table 7.105 TAR Command

Command	Description	Access Level
TAR *name*	Display the row with the element *name*.	1, B, P, A, O, 2
TAR *name k*	Display the row with the element *name* and repeat for *k* times; the repeat count *k* can be before or after the *name* option.	1, B, P, A, O, 2

[a] Parameter k is the repeat count from 1–32767.

The relay memorizes the latest row input conditioned by your present access level. The relay displays Row 0 if you have not specified a row since power up, the access level has timed out, or you have issued the **QUIT** command.

If you specify the repeat count *k* at a number greater than eight, the relay displays the repeated rows on the terminal screen in groups of eight, with the row elements listed above each grouping.

TAR ALL

Use the **TAR ALL** command to display all of the Relay Word bits. To avoid buffer overflow because of the large number of Relay Word bits, capture this information to a file rather than display it on the screen.

Table 7.106 TAR ALL Command

Command	Description	Access Level
TAR ALL	Display all target rows.	1, B, P, A, O, 2

TAR R

The **TAR R** command has two functions. Use this command to reset any latched relay targets resulting from a tripping event. Also employ the **TAR R** command to reset to Row 0 the memorized row that the relay reports when you issue a simple **TAR** command.

Table 7.107 TAR R Command

Command	Description	Access Level
TAR R	Reset latched targets and return memorized row to Row 0.	1, B, P, A, O, 2

TAR X

Use the **TAR X** command to view a different row in the Relay Word bit table than the row in the memory. This function is useful for relay testing. See *Section 6: Testing and Troubleshooting in the User's Guide* for more information.

Table 7.108 TAR X Command

Command	Description	Access Level
TAR *n* X	Display Row *n*, but do not memorize Row *n*.	1, B, P, A, O, 2
TAR X *n k*[a]	Display Row *n* and repeat for *k* times; do not memorize Row *n*. The repeat count *k* must follow the row number.	1, B, P, A, O, 2

Table 7.108 TAR X Command

Command	Description	Access Level
TAR *name* X	Display the row with the element *name*; do not memorize the row number.	1, B, P, A, O, 2
TAR *name* X *k*	Display the row with the element *name* and repeat for *k* times; do not memorize the row number. The repeat count *k* can be at any position in the command after **TAR**.	1, B, P, A, O, 2

[a] Parameter k is the repeat count from 1–32767.

You can place the **X** option at any position in the **TAR** command.

TEST DB

Use the **TEST DB** command for testing interfaces to a virtual device database. For the SEL-487B, the interface is the communications card. The relay contains a database that describes the relay to external devices. When other devices access the relay via the communications card, the relay appears as a virtual device described by the database. The SEL-487B is Virtual Device 1.

The virtual database of any installed Ethernet card is accessible to master stations of supported Ethernet protocols (DNP3, IEC 61850) connected to the Ethernet network. You can therefore test the read functionality of all protocols in the Ethernet interface with this command.

Use the **TEST DB 1** command to override any value in the relay database. You must understand the relay database structure to effectively use the **TEST DB** command.

Values you enter in the relay database are override values. Use the **TEST DB** command to write override values in the database accessed through the communications card.

Table 7.109 TEST DB Command

Command	Description	Access Level
TEST DB	Display present override values by virtual device number and address.	1, B, P, A, O, 2
TEST DB 1 *addr value1*	Write new data *value1* to the database at an address *addr*.	B, P, A, O, 2
TEST DB 1 *addr value1 M D Y h m s*	Write new data value1 to the database at an address *addr* and include the provided date/time stamp *M D Y h m s*	B, P, A, O, 2

The database address *addr* can be any legitimate decimal or hexadecimal address. (A hexadecimal address is a numeral with an "h" suffix or a "0x" prefix.)

You can enter the override value *value1* as an integer, a floating-point number (which overrides two registers), a character (which must be in single quotes), or a string (which must be in double quotes and overrides the number of registers corresponding to the length of the string).

If a date/time stamp is also provided (*M D Y h m s*), the relay will change the static state given and, for any bits being changed by this operation, queued entries will be pushed with the provided date/time stamp. If no queue is associated with the database region (determined by *addr*), the date/time stamp will be ignored.

The order that the date should be entered on the command line depends upon the DATE_F (Global) setting. For example, if DATE_F := DMY, you would enter **TEST DB** ***vdev addr value D M Y h m s***.

While there are active test data, the relay asserts Relay Word bit TESTDB.

TEST DB OFF

Use the **TEST DB OFF** command to end the testing session and remove the override values. The relay returns the database registers to the pretest values.

Table 7.110 TEST DB OFF Command

Command	Description	Access Level
TEST DB OFF	Clear all override testing values from all virtual devices.	B, P, A, O, 2
TEST DB OFF 1	Clear all override testing values from Virtual Device 1 (the relay).	B, P, A, O, 2
TEST DB OFF 1 ***region***	Clear all override testing values from the region region in Virtual Device 1 (the relay).	B, P, A, O, 2

TEST DNP

The **TEST DNP** command is for testing the DNP interface. For more information on DNP and the SEL-487B, see *Section 5: DNP3 Communications*.

TEST DNP

The **TEST DNP** command is for testing the serial port DNP3 interface only. For more information on Serial DNP3 and the SEL-487B, see *Section 5: DNP3 Communications*.

Use the **TEST DNP** command to write override values in the DNP map with a test value.

Table 7.111 TEST DNP Command

Command	Description	Access Level
TEST DNP	Display present override values.	1, B, P, A, O, 2
TEST DNP ***type n***[a] ***value***	Write new data *value* of *type* to the DNP map at DNP point number *n*.	B, P, A, O, 2

[a] Parameter type is A for analog, B for binary, or C for counter inputs.; n is a DNP point number.

When displaying DNP test data, the relay shows the report header, then the DNP Object Type, Index, and Override Value for binary inputs, counters, and analog inputs.

To force a value, use the **TEST DNP** ***type n value*** command. The type is A for analog inputs, B for binary inputs, or C for counter inputs. The point number *n* is based on the active DNP map. The override value *value* is a value you specify. The point number and override value must be valid for the given data type; see *Section 5: DNP3 Communications*.

When you have successfully added a new DNP test value (for example, **TEST DNP A 17 -357**), the relay responds as follows:

```
Override Added
```

The relay asserts Relay Word bit TESTDNP while any DNP test data are present in the relay.

DNP Status Bytes

Whenever a DNP value is overridden and the value is read via DNP, the status byte for the overridden value indicates that the bit is locally forced to a test value.

TEST DNP OFF

Use the **TEST DNP OFF** command to remove override values. The relay returns the database registers to the pretest values.

Table 7.112 TEST DNP OFF Command

Command	Description	Access Level
TEST DNP *type n*[a] OFF	Clear the override testing value of *type* from the DNP point number *n*.	B, P, A, O, 2
TEST DNP OFF	Clear all override testing values from the DNP map.	B, P, A, O, 2

[a] Parameter n is a DNP point number; type is A for analog, B for binary, or C for counter inputs.

When you have successfully removed a DNP test value (for example, **TEST DNP A 17 OFF**), the relay responds as follows:

```
Override Removed
```

When an attempt to remove a DNP test value fails, the relay responds as follows:

```
Override Not Found
```

When removing all DNP test values (for example, **TEST DNP OFF**), the relay responds as follows:

```
All Overrides Removed
```

TEST FM

The **TEST FM** command overrides normal Fast Meter quantities for testing purposes. You can only override reported Fast Meter values. For more information on Fast Meter and the SEL-487B, see *Section 4: SEL Communications Protocols*.

TEST FM

Values you enter in Fast Meter storage are override values. Use the **TEST FM** command to display override values and write override values in the Fast Meter report.

Table 7.113 TEST FM Command

Command	Description	Access Level
TEST FM	Display present override values.	1, B, P, A, O, 2
TEST FM *label value*	Write new data *value* to the Fast Meter report at the item *label*.	B, P, A, O, 2

When displaying Fast Meter data overrides with the **TEST FM** command, the relay shows the item label and override values.

To force a value, use the **TEST FM *label value*** command.

Value can be logical 0 or logical 1 for digital and status elements, or a floating-point value for all analog quantities.

When you have successfully added a new Fast Meter test value (for example, **TEST FM AMV001 3.7**), the relay responds as follows:

```
Override Added
```

The relay asserts Relay Word bit TESTFM while any Fast Meter override data are present in the relay.

Fast Meter Status Byte

Bits labeled TEST and FMTEST reside in the Fast Meter status byte. If any item within the Fast Meter message is in test mode, the relay sets the TEST and FMTEST bits.

TEST FM OFF

Use the **TEST FM OFF** command to remove override values. The relay returns the Fast Meter registers to the pretest values.

Table 7.114 TEST FM OFF Command

Command	Description	Access Level
TEST FM *label* OFF	Clear the override values for the Fast Meter item *label*.	B, P, A, O, 2
TEST FM OFF	Clear all override testing values from Fast Meter.	B, P, A, O, 2

When you have successfully removed a Fast Meter test value (for example, **TEST FM AMV001 OFF**), the relay responds as follows:

```
Override Removed
```

When an attempt to remove an FM test value fails, the relay responds as follows:

```
Override Not Found
```

When removing all FM test values (for example, **TEST FM OFF**), the relay responds as follows:

```
All Overrides Removed
```

TIME

Use the **TIME** command to view and set the relay time clock. The ASCII interface is just one source by which you can set the internal clock. Other sources can override the ASCII **TIME** command; overriding occurs in IRIG time mode and when using DNP. See *Configuring Timekeeping on page U.4.49* for more information on configuring SEL-487B time functions.

TIME

The **TIME** command returns information about the internal relay clock. You can also set the clock if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

Table 7.115 TIME Command

Command	Description	Access Level
TIME	Display the present relay internal clock time.	1, B, P, A, O, 2
TIME *hh:mm*	Set the relay internal clock to *hh:mm*.	1, B, P, A, O, 2
TIME *hh:mm:ss*	Set the relay internal clock to *hh:mm:ss*.	1, B, P, A, O, 2

Use the **TIME *hh:mm*** and **TIME *hh:mm:ss*** commands to set the relay internal clock time. The value *hh* is for hours from 0–23; the value *mm* is for minutes from 0–59; the value *ss* is for seconds from 0–59. If you enter a valid time, the relay updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the relay responds as follows:

```
Invalid Time
```

TIME Q

The **TIME Q** command returns detailed information on the relay internal clock. Use this command to query the status of high-accuracy time source inputs and the present clock time mode.

Table 7.116 TIME Q Command

Command	Description	Access Level
TIME Q	Display detailed information about the internal relay clock; query relay time.	1, B, P, A, O, 2

When you issue the **TIME Q** command, the relay reports statistics on the relay time sources. These statistics include the present high-priority time mark source, the last time value update source, and time synchronization status among others. See *Configuring Timekeeping on page U.4.49*.

TRIGGER

The **TRIGGER** command initiates data captures for event reports. For information on event reports, see *Section 3: Analyzing Data in the Applications Handbook*. See *Reading Event Reports and SER on page U.4.34* for examples using the **TRI** command.

TRI

Use the **TRI** command to trigger the SEL-487B to record data for event reports.

Table 7.117 TRI Command

Command	Description	Access Level
TRI	Trigger relay data capture.	1, B, P, A, O, 2

When you issue the **TRI** command, the relay responds as follows:

```
Triggered
```

If the event did not trigger within one second, the relay responds as follows:

```
Did not trigger
```

VERSION

The **VERSION** command displays the relay hardware and software configuration.

VER

Use the **VER** command to list the part numbers, serial numbers, checksums, software release numbers, and other important relay configuration information.

Table 7.118 VER Command

Command	Description	Access Level
VER	Display the hardware and software configurations.	1, B, P, A, O, 2

When you issue the **VER** command, the relay displays the latest release numbers for the following items:

- FID
- Part number
- Serial number
- SELBOOT BFID
- Mainboard memory types and sizes
- Front-panel hardware
- Analog inputs ratings
- Fiber port (installed or absent)
- Interface board inputs and outputs
- Power supply ratings

- Communications card IDs and part number
- Extended relay features list (optional DNP communications capability)

A sample **VER** command response is shown in *Figure 7.3*:

```
=>>VER <Enter>
FID=SEL-487B-R102-V0-Z001001-D20030724
CID=0F73
Part Number:  0487B06512XEDXXXH
Serial Number:  20030011234
SELboot:
    BFID= SLBT-4XX-R100-V0-Z001001-D20010703
    Checksum:  4DFF
Mainboard:
    Code FLASH Size:    4 MB
    Data FLASH Size:    8 MB
    RAM Size:           2 MB
    EEPROM Size:       64 kB
Front Panel: installed
Analog Inputs:
    Currents:  5 Amp
    Voltages:  67 Volts
Fiber Port:  installed
Interface Boards: - Warning - hardware does not match part number
    Board 1:  24 inputs   8 outputs
    Board 2:  not installed
    Board 3:  not installed
    Board 4:  not installed
Communications Card:
    installed
Extended Relay Features:
    DNP

If the information above is not as expected, contact SEL for assistance.

=>
```

Figure 7.3 Sample VER Command Response

If an item is not installed, the **VER** report indicates as follows:

```
Not installed
```

at the appropriate line. If a detected hardware configuration does not match the component part number, the relay adds the following statement on the corresponding line:

```
Warning - hardware does not match part number
```

VIEW

Use the **VIEW** command to examine data within the relay database. You can view these data in three ways:

- Region
- Register item
- Bit

The **VIEW** command in the SEL-487B is very similar to the **VIEW** command in SEL Communications Processors. See *Section 4: SEL Communications Protocols* for more information on the relay database regions and data types.

SEL-487B regions are LOCAL, METER, TARGET, HISTORY, STATUS, ANALOGS, STATE and D1; view this list with the **MAP 1** command.

The SEL-487B is Virtual Device 1; all commands begin **VIEW 1**. In all database views, if a data item is in test mode, the relay displays an asterisk (*) mark following the data value.

VIEW 1 Commands—Region

Use the commands in *Table 7.119* to view the contents of the database regions.

Table 7.119 VIEW 1 Commands—Region

Command	Description	Access Level
VIEW 1 ***region***	Display the data in the relay database in the region *region*.	1, B, P, A, O, 2
VIEW 1 ***region*** **BL**	Display the data in the region *region* and include bit labels.	1, B, P, A, O, 2

VIEW 1 Commands—Register Item

Use the commands in *Table 7.120* to view register items in the relay database. Examples of register items in the METER region are IA1, I0_1, VB, and PF. Examples of register items in the LOCAL region are FID, SER_NUM, and PART_NUM.

Table 7.120 VIEW 1 Commands—Register Item

Command	Description	Access Level
VIEW 1 ***addr***	Display the data in the relay database at register address *addr*.	1, B, P, A, O, 2
VIEW 1 ***addr*** **NR** ***m***[a]	Display the data beginning at register address *addr* and continue for *m* registers.	1, B, P, A, O, 2
VIEW 1 ***region item_label***	Display the data for the addresses in the *region item_label* area of the database.	1, B, P, A, O, 2
VIEW 1 ***region item_label*** **NR** ***m***[a]	Display the data for addresses in the *region item_label* area of the database; begin at the start of *item_label* and proceed for *m* registers.	1, B, P, A, O, 2
VIEW 1 ***region offset***	Display the data for the address in the database region *region* at the offset *offset* from the beginning of the region.	1, B, P, A, O, 2
VIEW 1 ***region offset*** **NR** ***m***[a]	Display the data for the addresses in the database region *region*; begin at the offset *offset* from the beginning of the region and proceed for *m* registers.	1, B, P, A, O, 2

[a] Parameter m is an integer value representing the number of registers.

In the **VIEW 1** ***addr*** commands, option *addr* is the register address. Use the **MAP 1** ***region*** command to find the register address. You can specify register addresses as a decimal or hexadecimal number. (A hexadecimal address is a numeral with an “h” suffix or a “0x” prefix.) If you specify the data by address or by offset with the *addr* and *offset* options, the relay returns the data in hexadecimal number format. The **NR** option specifies the number of registers *m* that the relay includes in the data listing.

VIEW 1 Commands—Bit

Use commands in *Table 7.121* to inspect a specific bit in the relay database. The relay displays bit data as the bit label or number and the value logical 1 or logical 0. An example of a relay response for bit commands is `1:TARGET:ALTI = 0`, where `ALTI` is the bit label and `0` is the bit value. Other examples of bit labels are P87R1, 27P32, and ASV256.

Table 7.121 VIEW 1 Commands—Bit[a]

Command	Description	Access Level
VIEW 1 *addr bit*	Display the value at register address *addr* for the bit number *bit*.	1, B, P, A, O, 2
VIEW 1 *bit_label*	Display the value for the bit with the bit label *bit_label*.	1, B, P, A, O, 2
VIEW 1 *region bit_label*	Display the value for the particular bit with the bit label *bit_label* in the region *region*.	1, B, P, A, O, 2
VIEW 1 *region offset bit*[b]	Display the value for the bit *bit* in the region *region* that is offset from the beginning of the region by offset *offset*.	1, B, P, A, O, 2

[a] Parameter bit is a number from 0–15, with 0 as the LSB (least significant bit).
[b] Parameter offset is a decimal or hexadecimal number to indicate the offset.

The command option *bit* is the bit number. If you access bit data, the relay displays the bit label or number and the value (logical 0 or logical 1). If you reference the data by label with the **BL** and *bit_label* options, the relay returns the data according to the data type.

Use the **VIEW 1 *bit_label*** command as a shorthand method to inspect a specific data bit in the relay database. The relay searches the entire relay database structure for the bit label you specified; this process takes more time and processing than narrowing the search by using the **VIEW 1 *region*** command and the **VIEW 1 *addr*** command with the bit label option *bit_label*.

ZONE

The **ZONE** command causes the relay to display the active protection zones and the terminal and bus-zone names in each active protection zone, where active means a zone with at least one terminal in the zone.

ZON

Use the **ZON** command to display the terminal and bus-names associated with all active zones.

Table 7.122 ZON Command

Command	Description	Access Level
ZON	Display the terminal and bus-zone names associated with all active zones.	1, B, P, A, O, 2

ZON T

Use the **ZON T** command to display the terminal names in each active zone, selected for tripping by differential and breaker failure protection.

Table 7.123 ZON T Command

Command	Description	Access Level
ZON T	Display the terminals programmed for tripping in all zones	1, B, P, A, O, 2

When two zones combine, the combined zone includes the terminals from both merged zones. Not all terminals in the combined zone may be required to trip for a differential element operation. **ZON T** provides a list of all terminals assigned to trip in all the zones at the station, and **ZON T *k*** provides a list of the terminals to trip in a specific zone.

ZON k

Use the **ZON *k*** (*k* = 1 through 6) command to display the terminals in Zone *k*, if Zone *k* is active.

Table 7.124 ZON k Command

Command	Description	Access Level
ZON *k*[a]	Display the terminals in Zone *k*.	1, B, P, A, O, 2

[a] Parameter k is 1–6.

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Section 8
Settings

Overview

This section contains tables of relay settings for the SEL-487B Relay.

The relay hides some settings based upon other settings. If you set an enable setting to OFF, for example, the relay hides all settings associated with that enable setting. This section does not explain rules for hiding settings; these rules are discussed in the applications sections of the instruction manual where appropriate.

The settings prompts in this section are similar to the ASCII terminal and ACSELERATOR QuickSet® SEL-5030 software prompts. The prompts in this section are unabbreviated and show all possible setting options.

For information on using settings in protection and automation, see the examples in *Section 1: System Configuration Guideline and Application Examples in the Applications Handbook*. The section arranges settings in the following order:

- Alias settings
- Global settings
  - General global settings
  - Global enables
  - Station dc monitor
  - Control inputs (global)
  - Main Board control inputs
  - Interface Board #1 control inputs
  - Interface Board #2 control inputs
  - Interface Board #3 control inputs
  - Interface Board #4 control inputs
  - Settings group selection
  - Data reset control
  - Breaker inputs
  - Disconnects inputs and timers
- Zone configuration settings
  - Potential transformer ratios
  - Current transformer ratios
  - Terminal-to-bus-zone connections
  - Bus-zone-to-bus-zone connections
  - Zone supervision

- Zone switching supervision
- Open CT detection
- Terminal-to-check-zone connections
- Check zone supervision

- Group settings
  - Relay configuration
  - Sensitive differential elements
  - Restrained differential elements
  - Directional elements
  - Coupler security logic
  - Terminal out of service
  - Breaker failure logic
  - Definite-time overcurrent elements
  - Inverse-time overcurrent elements
  - Phase instantaneous over- and undervoltage elements
  - Sequence overvoltage elements
  - Trip logic
- Protection free-form SELOGIC® control equations
- Automation free-form SELOGIC control equations
- Output settings
  - Main board
  - Interface Board #1
  - Interface Board #2
  - Interface Board #3
  - Interface Board #4
  - Communications card outputs
  - MIRRORED BITS® communications transmit equations
- Front-panel settings
  - Pushbuttons and target LEDs
  - Selectable screens for the front panel
  - Selectable operator pushbuttons
  - Front-panel event display
  - Display points
  - Local control
- Report settings
  - SER chatter criteria
  - SER points
  - Event reporting
  - Event reporting digital elements

- Port settings
  - Protocol selection
  - Communications settings
  - SEL protocol settings
  - DNP3 protocol settings
  - MIRRORED BITS protocol settings
  - Ethernet settings
  - FTP settings
  - Telnet settings
  - Network host name
  - IEC 61850 settings
- DNP3 settings
  - DNP3 Reference Map Selection
  - DNP3 Object Default Map Enables
  - Binary Input Map
  - Binary Output Map
  - Counter Map
  - Analog Input Map
  - Analog Output Map

Alias Settings

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-zone name
- Check-zone name

Invalid alias names include the following keywords used by settings and SELOGIC control equations:

- END
- INSERT
- DELETE
- LIST
- NA
- OFF

SELOGIC control equation operators (e.g., NOT, AND, OR, COS) cannot be used as alias names.

Alias names are valid when the following are true:

- ➤ They consist of a maximum of seven characters.
- ➤ They are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

NOTE: Lowercase letters are accepted, but the relay converts them to uppercase.

For example, the default name for analog input I01 is FDR_1. You could change the default name to a more appropriate feeder name, New York, for example.

New York (including the space) consists of eight characters, one more than the allowable number of seven. Changing the name to New Yrk reduces the character count to seven, but the alias contains two elements not permitted, a space and four lowercase letters (ew rk). One possible alias for the existing name of FDR_1 could be NEW_YRK, entered using the following syntax:

primitive name, alias name,

e.g., I01, NEW_YRK

Figure 8.1 shows the steps using the **SET T** command.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"FDR_1"
?   I01,NEW_YRK <Enter>
2: I02,"FDR_2"
?   END <Enter>
Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])

1: I01,"NEW_YRK"
2: I02,"FDR_2"
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 8.1 Changing a Default Name to an Alias

Table 8.1 Default Alias Settings (Sheet 1 of 3)

Label	Default Value
I01	FDR_1
I02	FDR_2
I03	FDR_3
I04	TRFR_1
I05	TB_1
I06	TB_2
BZ1	BUS_1
BZ2	BUS_2
FBF01	F1_BF
FBF02	F2_BF
FBF03	F3_BF

Table 8.1 Default Alias Settings (Sheet 2 of 3)

Label	Default Value
FBF04	T1_BF
FBF05	TB1_BF
FBF06	TB2_BF
87Z1	Z1_TRIP
87Z2	Z2_TRIP
IN101	F1_BFI
IN102	F2_BFI
IN103	F3_BFI
IN104	T1_BFI
IN105	TB_BFI
PLT01	DIFF_EN
PLT02	BF_EN
PLT03	TNS_SW
87ST1	CTZ1_AN
87ST2	CTZ2_AN
SBFTR01	F1_BFT
SBFTR02	F2_BFT
SBFTR03	F3_BFT
SBFTR04	T1_BFT
SBFTR05	TB1_BFT
SBFTR06	TB2_BFT
87BTR01	F1_DPT
87BTR02	F2_ DPT
87BTR03	F3_ DPT
87BTR04	T1_ DPT
87BTR05	TB1_ DPT
87BTR06	TB2_ DPT
OUT101	F1_TRP
OUT102	F2_TRP
OUT103	F3_TRP
OUT104	T1_TRP
OUT105	TB_TRP
OUT107	TEST
OUT108	ALARM
TLED_1	87_DIFF
TLED_2	BK_FAIL
TLED_3	ZONE_1
TLED_4	ZONE_2
TLED_5	ZONE_3
TLED_6	ZONE_4
TLED_7	ZONE_5

Table 8.1 Default Alias Settings (Sheet 3 of 3)

Label	Default Value
TLED_8	ZONE_6
TLED_9	50_TRIP
TLED_10	51_TRIP
TLED_11	CT_ALRM
TLED_12	87_BLK
TLED_13	TOS
TLED_14	89_OIP
TLED_15	89_ALRM
TLED_16	PT_ALRM
TLED_17	27_LED
TLED_18	59_LED
TLED_19	V01_ON
TLED_20	V02_ON
TLED_21	V03_ON
TLED_22	FLT_LED
TLED_23	52_ALRM
TLED_24	IRIGLED

Global Settings

Table 8.2 Global Settings Categories

Settings	Reference
General Global Settings	*Table 8.3*
Global Enables	*Table 8.4*
Station DC Monitor	*Table 8.5*
Control Inputs (Global)	*Table 8.6*
Main Board Control Inputs	*Table 8.7*
Interface Board #1 Control Inputs	*Table 8.8*
Interface Board #2 Control Inputs	*Table 8.9*
Interface Board #3 Control Inputs	*Table 8.10*
Interface Board #4 Control Inputs	*Table 8.11*
Settings Group Selection	*Table 8.12*
Data Reset Control	*Table 8.13*
Breaker Inputs	*Table 8.14*
Disconnects Inputs and Timers	*Table 8.15*

Table 8.3 General Global Settings

Label	Prompt	Default Value
SID	Station Identifier (40 characters)	Station A
RID	Relay Identifier (40 characters)	Relay 1
NUMBK	Number of Breakers (N, 1–18)	5
NUMDS	Number of Disconnects (N, 1–48)	N
NFREQ	Nominal System Frequency (50, 60 Hz)	60
DATE_F	Date Format (MDY, YMD, DMY)	MDY

Table 8.4 Global Enables

Label	Prompt	Default Value
EDCMON	Station DC Battery Monitor (Y, N)	N
EICIS	Independent Control Input Settings (Y, N)	N
EDRSTC	Data Reset Control (Y, N)	N
EGADVS	Advanced Global Settings (Y, N)	N

Table 8.5 Station DC Monitor

Label	Prompt	Default Value
DC1LFP	Low Level Fail Pickup (OFF, 15–300 Vdc)	100
DC1LWP	Low Level Warn Pickup (OFF, 15–300 Vdc)	127
DC1HWP	High Level Warn Pickup (OFF, 15–300 Vdc)	137
DC1HFP	High Level Fail Pickup (OFF, 15–300 Vdc)	142
DC1RP	Peak-to-Peak AC Ripple Pickup (1–300 Vac)	9
DC1GF	Ground Detection Factor (1.00–2)	1.05

Table 8.6 Control Inputs (Global)

Label	Prompt	Default Value
GINPU	Input Pickup Delay (0.00–1 cyc)	0.17
GINDO	Input Dropout Delay (0.00–1 cyc)	0.17

Table 8.7 Main Board Control Inputs

Label	Prompt	Default Value
IN101PU	Input IN101 Pickup Delay (0.00–1 cyc)	0.17[a]
IN101DO	Input IN101 Dropout Delay (0.00–1 cyc)	0.17[a]
•	•	•
•	•	•
•	•	•
IN107PU	Input IN107 Pickup Delay (0.00–1 cyc)	0.17[a]
IN107DO	Input IN107 Dropout Delay (0.00–1 cyc)	0.17[a]

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.8 Interface Board #1 Control Inputs

Label	Prompt	Default Value
IN201PU	Input IN201 Pickup Delay (0.00–1 cyc)	0.17[a]
IN201DO	Input IN201 Dropout Delay (0.00–1 cyc)	0.17[a]
•	•	•
•	•	•
•	•	•
IN224PU	Input IN224 Pickup Delay (0.00–1 cyc)	0.17[a]
IN224DO	Input IN224 Dropout Delay (0.00–1 cyc)	0.17[a]

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.9 Interface Board #2 Control Inputs

Label	Prompt	Default Value
IN301PU	Input IN301 Pickup Delay (0.00–1 cyc)	0.17[a]
IN301DO	Input IN301 Dropout Delay (0.00–1 cyc)	0.17[a]
•	•	•
•	•	•
•	•	•
IN324PU	Input IN324 Pickup Delay (0.00–1 cyc)	0.17[a]
IN324DO	Input IN324 Dropout Delay (0.00–1 cyc)	0.17[a]

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.10 Interface Board #3 Control Inputs

Label	Prompt	Default Value
IN401PU	Input IN401 Pickup Delay (0.00–1 cyc)	0.17[a]
IN401DO	Input IN401 Dropout Delay (0.00–1 cyc)	0.17[a]
•	•	•
•	•	•
•	•	•
IN424PU	Input IN424 Pickup Delay (0.00–1 cyc)	0.17[a]
IN424DO	Input IN424 Dropout Delay (0.00–1 cyc)	0.17[a]

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.11 Interface Board #4 Control Inputs

Label	Prompt	Default Value
IN501PU	Input IN501 Pickup Delay (0.00–1 cyc)	0.17[a]
IN501DO	Input IN501 Dropout Delay (0.00–1 cyc)	0.17[a]
•	•	•
•	•	•
•	•	•
IN524PU	Input IN524 Pickup Delay (0.00–1 cyc)	0.17[a]
IN524DO	Input IN524 Dropout Delay (0.00–1 cyc)	0.17[a]

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.12 Settings Group Selection

Label	Prompt	Default Value
SS1	Select Setting Group 1 (SELOGIC Equation)	NA
SS2	Select Setting Group 2 (SELOGIC Equation)	NA
SS3	Select Setting Group 3 (SELOGIC Equation)	NA
SS4	Select Setting Group 4 (SELOGIC Equation)	NA
SS5	Select Setting Group 5 (SELOGIC Equation)	NA
SS6	Select Setting Group 6 (SELOGIC Equation)	NA
TGR	Group Change Delay (0–54000 cycles)	180

Table 8.13 Data Reset Control

Label	Prompt	Default Value
RST_BAT	Reset Battery Monitoring (SELOGIC Equation)	NA
RSTTRGT	Target Reset (SELOGIC Equation)	NA
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC Equation)	TRGTR

Table 8.14 Breaker Inputs

Label	Prompt	Default Value
52A01	N/O Contact Input–BK01 (SELOGIC Equation)	NA
•	•	•
•	•	•
•	•	•
52A18	N/O Contact Input–BK18 (SELOGIC Equation)	NA

Table 8.15 Disconnect Inputs and Timers

Label	Prompt	Default Value
89A01	N/O Contact Inputs–DS01 (SELOGIC Equation)	NA
89B01	N/C Contact Inputs–DS01 (SELOGIC Equation)	NA
89ALP01	DS01 Alarm Pickup Delay (0–99999 cyc)	300
•	•	•
•	•	•
•	•	•
89A48	N/O Contact Inputs–DS48 (SELOGIC Equation)	NA
89B48	N/C Contact Inputs–DS48 (SELOGIC Equation)	NA
89ALP48	DS48 Alarm Pickup Delay (0–99999 cyc)	300

Zone Configuration Settings

The following zone configuration settings are the default settings for all six setting groups. You can set each of the six zone configuration setting groups independently.

Table 8.16 Zone Configuration Settings Categories

Settings	Reference
Potential Transformer Ratios	*Table 8.17*
Current Transformer Ratios	*Table 8.18*
Terminal-to-Bus-Zone Connections	*Table 8.19*
Bus-Zone-to-Bus-Zone Connections	*Table 8.20*
Zone Supervision	*Table 8.21*
Zone Switching Supervision	*Table 8.22*
Open CT Detection	*Table 8.23*
Terminal-to-Check-Zone Connections	*Table 8.24*
Check Zone Supervision	*Table 8.25*
Current Normalization Factor	[a]

[a] This setting is included here because it appears in the read-back information as TAPnn values (nn = 01 through 18). However, the user cannot set these values; the SEL-487B calculates these internally using the nominal current and CT ratios. See Section 1: Protection Functions for more information.

Table 8.17 Potential Transformer Ratios

Label	Prompt	Default Value
PTR1	Potential Transformer Ratio–V01 (1–10000)	2000
PTR2	Potential Transformer Ratio–V02 (1–10000)	2000
PTR3	Potential Transformer Ratio–V03 (1–10000)	2000

Table 8.18 Current Transformer Ratios

Label	Prompt	Default Value
CTR01	Current Transformer Ratio–I01 (1–50000)	600
CTR02	Current Transformer Ratio–I02 (1–50000)	600
CTR03	Current Transformer Ratio–I03 (1–50000)	600
CTR04	Current Transformer Ratio–I04 (1–50000)	600
CTR05	Current Transformer Ratio–I05 (1–50000)	600
CTR06	Current Transformer Ratio–I06 (1–50000)	600
CTR07	Current Transformer Ratio–I07 (1–50000)	600
•	•	•
•	•	•
•	•	•
CTR18	Current Transformer Ratio–I18 (1–50000)	600

Table 8.19 Terminal-to-Bus-Zone Connections

Label	Prompt	Default Value
I01BZ1C	Terminal, Bus-Zone, Polarity (P, N)	FDR_1, BUS_1,P
I01BZ1V	TB_1 to BUS_1 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS01
I02BZ1C	Terminal, Bus-Zone, Polarity (P, N)	FDR_2, BUS_1,P
I02BZ1V	TB_2 to BUS_1 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS02
I03BZ2C	Terminal, Bus-Zone, Polarity (P, N)	FDR_3, BUS_2,P
I03BZ2V	FDR_1 to BUS_2 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS03
I04BZ2C	Terminal, Bus-Zone, Polarity (P, N)	TRFR_1, BUS_2,P
I04BZ2V	FDR_2 to BUS_2 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS04
I05BZ1C	Terminal, Bus-Zone, Polarity (P, N)	TB_1, BUS_1,P
I05BZ1V	FDR_3 to BUS_1 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS05
I06BZ2C	Terminal, Bus-Zone, Polarity (P, N)	TB_2, BUS_2,P
I06BZ2V	TRFR_1 to BUS_2 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS05
• • •	• • •	• • •
I*nn*BZ*p*C[a,b]	Terminal, Bus-Zone, Polarity (P, N)	None
I*nn*BZ*p*V	I*nn* to BZ*p* Connection (SELOGIC Equation)	NA

[a] nn = 1–18.
[b] p = 1–6.

Table 8.20 Bus-Zone-to-Bus-Zone Connections

Label	Prompt	Default Value
BZ*p*BZ*m*C[a,b]	Bus-Zone, Bus-Zone	None
BZ*p*BZ*m*V	BZ*p* to BZ*m* Connection (SELOGIC Equation)	NA
BZ*p*BZ*m*R	Connection to Remove Terminals when BZ*p* and BZ*m* merge (SELOGIC Equation)	NA
BZ*p*BZ*m*M	Terminals Removed when BZ*p* and BZ*m* Bus-Zones merge (Ter *k*,. . .,Ter *n*)[c]	None
BZ*p*BZ*m*T	Trip Terminals Ter *k*, . . ., Ter *n* (Y, N)	N

[a] p = 1–6.
[b] m = 1–6.
[c] Terminal k, Terminal 1, or Terminal n (maximum of four terminals from 01 through 18).

Table 8.21 Zone Supervision

Label	Prompt	Default Value
E87ZSUP	Differential Element Zone Supervision (Y, N)	N
Z1S	Zone 1 Supervision (SELOGIC Equation)	1
Z2S	Zone 2 Supervision (SELOGIC Equation)	1
Z3S	Zone 3 Supervision (SELOGIC Equation)	1
Z4S	Zone 4 Supervision (SELOGIC Equation)	1
Z5S	Zone 5 Supervision (SELOGIC Equation)	1
Z6S	Zone 6 Supervision (SELOGIC Equation)	1

Table 8.22 Zone Switching Supervision

Label	Prompt	Default Value
EZSWSUP	Zone Switching Supervision (Y, N)	N
ZSWO	Zone Switching Operation (SELOGIC control equation)	NA
RZSWOAL	Reset Zone Switching Op Alarm (SELOGIC control equation)	NA
ZSWOPU	Zone Switching Op Pickup Delay (0–99999 cyc)	1800

Table 8.23 Zone Open CT Detection

Label	Prompt	Default Value
ROCTZ1	Reset Zone 1 Open CT Detector (SELOGIC control equation)	RSTOCT1
ROCTZ2	Reset Zone 2 Open CT Detector (SELOGIC control equation)	RSTOCT2
ROCTZ3	Reset Zone 3 Open CT Detector (SELOGIC control equation)	RSTOCT3
ROCTZ4	Reset Zone 4 Open CT Detector (SELOGIC control equation)	RSTOCT4
ROCTZ5	Reset Zone 5 Open CT Detector (SELOGIC control equation)	RSTOCT5
ROCTZ6	Reset Zone 6 Open CT Detector (SELOGIC control equation)	RSTOCT6

Table 8.24 Terminal-to-Check-Zone Connections

Label	Prompt	Default Value
ECHKZN	Enable Check Zones at Station (Y, N)	N
I*nn*CZ*p*C[a,b]	Terminal, Check-Zone, Polarity (P, N)	None
I*nn*CZ*p*V[a,b]	I*nn* to CZ*p* Connection (SELOGIC control equation)	NA

[a] nn = 1–18
[b] p = 1

Table 8.25 Check Zone Supervision

Label	Prompt	Default Value
E87CZSP	Differential Element Check Zone Supervision (Y, N)	N
CZ1S	Check Zone 1 Supervision (SELOGIC control equation)	1

Group Settings

Table 8.26 Group Settings Categories

Settings	Reference
Relay Configuration	*Table 8.27*
Sensitive Differential Elements	*Table 8.28*
Check Zone Sensitive Differential Elements	*Table 8.29*
Restrained Differential Elements	*Table 8.30*
Check Zone Restrained Differential Elements	*Table 8.31*
Directional Elements	*Table 8.32*
Coupler Security Logic	*Table 8.33*
Terminal Out of Service	*Table 8.34*
Breaker Failure Logic	*Table 8.35*
Definite-Time Overcurrent Elements	*Table 8.36*
Inverse-Time Overcurrent Elements	*Table 8.37*
Phase Instantaneous Over- and Undervoltage Elements	*Table 8.38*
Sequence Overvoltage Elements	*Table 8.39*
Trip Logic	*Table 8.40*

Table 8.27 Relay Configuration

Label	Prompt	Default Value
E87SSUP	Sensitive Differential Element Supervision (Y, N)	Y
ECSL	Coupler Security Logic (N, 1–4)	N
ETOS	Terminal Out of Service (N, 1–18)	5
EBFL	Breaker Failure Logic (N, 1–18)	6
E50	Definite Time Overcurrent Elements (N, 1–18)	N
E51	Inverse Time Overcurrent Elements (N, 1–18)	N
EVOLT	Voltage Elements (Y, N)	Y
EADVS	Advanced Settings (Y, N)	N

Table 8.28 Sensitive Differential Elements

Label	Prompt	Default Value
S87P	Sensitive Differential Element Pickup (0.05–1 pu)	0.10
87STPU	87S Timer Pickup Delay (50–6000 cyc)	300

Table 8.29 Check Zone Sensitive Differential Elements[a]

Label	Prompt	Default Value
CZS87P	Check Zone Sensitive Differential Element Pickup (0.05–1 pu)	0.10
CZ87STP	Check Zone 87S Time Pickup Delay (50–6000 cyc)	300

[a] Available when ECHKZN := Y

Table 8.30 Restrained Differential Elements

Label	Prompt	Default Value
O87P	Restrained Diff Element Pickup (0.10–4 pu)	1.00
SLP1	Restrained Slope 1 Percentage (15–90%)	60
SLP2	Restrained Slope 2 Percentage (50–90%)	80
RTDI	Incr Restrained Current Threshold (0.10–10 pu)	1.20
OPDI	Incr Operating Current Threshold (0.10–10 pu)	1.20

Table 8.31 Check Zone Restrained Differential Elements[a]

Label	Prompt	Default Value
CZO87P	Check Zone Restrained Diff Element Pickup (0.10–4 pu)	1.00
CZSLP1	Check Zone Restrained Slope 1 Percentage (15–90%)	60
CZSLP2	Check Zone Restrained Slope 2 Percentage (15–90%)	80
CZRTDI	Check Zone Incr Restrained Current Threshold (0.10–10 pu)	1.20
CZOPDI	Check Zone Incr Operating Current Threshold (0.10–10 pu)	1.20

[a] Available when ECHKZN := Y

Table 8.32 Directional Elements

Label	Prompt	Default Value
50DSP	Dir Element O/C Supervision Pickup (0.05–3 pu)	0.05

Table 8.33 Coupler Security Logic (1 through 4) (Sheet 1 of 2)

Label	Prompt	Default Value
CB52A1	Coupler 1 Status (SELOGIC Equation)	NA
CB52DO1	Coupler 1 Status Dropout Delay (0.00–1000 cyc)	4
CBCLS1	Coupler 1 Close Command (SELOGIC Equation)	NA
CBCLDO1	Coupler 1 Close Command D/O Delay (0.00–1000 cyc)	5
ACTRP1	Coupler 1 Acc Trip (SELOGIC Equation)	NA
ACTPPU1	Coupler 1 Acc Trip Pickup Delay (0.00–1000 cyc)	4
•	•	•
•	•	•
•	•	•

Table 8.33 Coupler Security Logic (1 through 4) (Sheet 2 of 2)

Label	Prompt	Default Value
CB52A4	Coupler 4 Status (SELOGIC Equation)	NA
CB52DO4	Coupler 4 Status Dropout Delay (0.00–1000 cyc)	4
CBCLS4	Coupler 4 Close Command (SELOGIC Equation)	NA
CBCLDO4	Coupler 4 Close Command D/O Delay (0.00–1000 cyc)	5
ACTRP4	Coupler 4 Acc Trip (SELOGIC Equation)	NA
ACTPPU4	Coupler 4 Acc Trip Pickup Delay (0.00–1000 cyc)	4

Table 8.34 Terminal Out of Service (1 through 18)

Label	Prompt	Default Value
TOS01	Terminal 01 Out-of-Service (SELOGIC Equation)	LB01
TOS02	Terminal 02 Out-of-Service (SELOGIC Equation)	LB02
TOS03	Terminal 03 Out-of-Service (SELOGIC Equation)	LB03
TOS04	Terminal 04 Out-of-Service (SELOGIC Equation)	LB04
TOS05	Terminal 05 Out of Service (SELOGIC Equation)	LB05
TOS06	Terminal 06 Out of Service (SELOGIC Equation)	NA
•	•	•
•	•	•
•	•	•
TOS18	Terminal 18 Out-of-Service (SELOGIC Equation)	NA

Table 8.35 Breaker Failure Logic (1 through 18) (Sheet 1 of 4)

Label	Prompt	Default Value
Breaker 01 Failure Logic		
EXBF01	External Breaker Fail–BK01 (Y, N)	N
XBF01	External Brkr Fail Init–BK01 (SELOGIC Equation)	NA
50FP01	Fault Current Pickup–BK01 (0.50–50 amps, sec)	3.00
BFPU01	Brkr Fail Init Pickup Delay–BK01 (0.00–6000 cyc)	6.00
RTPU01	Retrip Delay–BK01 (0.00–6000 cyc)	3.00
BFI01	Breaker Fail Initiate–BK01 (SELOGIC Equation)	F1_BFI AND BF_EN
ATBFI01	Alt Breaker Fail Initiate–BK01 (SELOGIC Equation)	NA
EBFIS01	Breaker Fail Initiate Seal-In–BK01 (Y, N)	N
BFISP01	Breaker Fail Init Seal-In Delay–BK01 (0.00–1000 cyc)	0.50
BFIDO01	Brkr Fail Init Dropout Delay–BK01 (0.00–1000 cyc)	1.50
Breaker 02 Failure Logic		
EXBF02	External Breaker Fail–BK02 (Y, N)	N
XBF02	External Brkr Fail Init–BK02 (SELOGIC Equation)	NA
50FP02	Fault Current Pickup–BK02 (0.50–50 amps, sec)	3.00
BFPU02	Brkr Fail Init Pickup Delay–BK02 (0.00–6000 cyc)	6.00
RTPU02	Retrip Delay–BK02 (0.00–6000 cyc)	3.00

Table 8.35 Breaker Failure Logic (1 through 18) (Sheet 2 of 4)

Label	Prompt	Default Value
BFI02	Breaker Fail Initiate–BK02 (SELOGIC Equation)	F2_BFI AND BF_EN
ATBFI02	Alt Breaker Fail Initiate–BK02 (SELOGIC Equation)	NA
EBFIS02	Breaker Fail Initiate Seal-In–BK02 (Y, N)	N
BFISP02	Breaker Fail Init Seal-In Delay–BK02 (0.00–1000 cyc)	0.50
BFIDO02	Brkr Fail Init Dropout Delay–BK02 (0.00–1000 cyc)	1.50
Breaker 03 Failure Logic		
EXBF03	External Breaker Fail–BK03 (Y, N)	N
XBF03	External Brkr Fail Init–BK03 (SELOGIC Equation)	NA
50FP03	Fault Current Pickup–BK03 (0.50–50 amps, sec)	3.00
BFPU03	Brkr Fail Init Pickup Delay–BK03 (0.00–6000 cyc)	6.00
RTPU03	Retrip Delay–BK03 (0.00–6000 cyc)	3.00
BFI03	Breaker Fail Initiate–BK03 (SELOGIC Equation)	F3_BFI AND BF_EN
ATBFI03	Alt Breaker Fail Initiate–BK03 (SELOGIC Equation)	NA
EBFIS03	Breaker Fail Initiate Seal-In–BK03 (Y, N)	N
BFISP03	Breaker Fail Init Seal-In Delay–BK03 (0.00–1000 cyc)	0.50
BFIDO03	Brkr Fail Init Dropout Delay–BK03 (0.00–1000 cyc)	1.50
Breaker 04 Failure Logic		
EXBF04	External Breaker Fail–BK04 (Y, N)	N
XBF04	External Brkr Fail Init–BK04 (SELOGIC Equation)	NA
50FP04	Fault Current Pickup–BK04 (0.50–50 amps, sec)	3.00
BFPU04	Brkr Fail Init Pickup Delay–BK04 (0.00–6000 cyc)	6.00
RTPU04	Retrip Time Delay–BK04 (0.00–6000 cyc)	3.00
BFI04	Breaker Fail Initiate–BK04 (SELOGIC Equation)	T1_BFI AND BF_EN
ATBFI04	Alt Breaker Fail Initiate–BK04 (SELOGIC Equation)	NA
EBFIS04	Breaker Fail Initiate Seal-In–BK04 (Y, N)	N
BFISP04	Breaker Fail Init Seal-In Delay–BK04 (0.00–1000 cyc)	0.50
BFIDO04	Brkr Fail Init Dropout Delay–BK04 (0.00–1000 cyc)	1.50
Breaker 05 Failure Logic		
EXBF05	External Breaker Fail–BK05 (Y, N)	N
XBF05	External Brkr Fail Init–BK05 (SELOGIC Equation)	NA
50FP05	Fault Current Pickup–BK05 (0.50–50 amps, sec)	3.00
BFPU05	Brkr Fail Init Pickup Delay–BK05 (0.00–6000 cyc)	6.00
RTPU05	Retrip Delay–BK05 (0.00–6000 cyc)	3.00
BFI05	Breaker Fail Initiate–BK05 (SELOGIC Equation)	TB_BFI AND BF_EN

Table 8.35 Breaker Failure Logic (1 through 18) (Sheet 3 of 4)

Label	Prompt	Default Value
ATBFI05	Alt Breaker Fail Initiate–BK05 (SELOGIC Equation)	NA
EBFIS05	Breaker Fail Initiate Seal-In–BK05 (Y, N)	N
BFISP05	Breaker Fail Init Seal-In Delay–BK05 (0.00–1000 cyc)	0.50
BFIDO05	Brkr Fail Init Dropout Delay–BK05 (0.00–1000 cyc)	1.50
Breaker 06 Failure Logic		
EXBF06	Enable External Breaker Fail–BK06 (Y, N)	N
XBF06	External Brkr Fail Init–BK06 (SELOGIC Equation)	NA
50FP06	Fault Current Pickup–BK06 (0.50–50 amps, sec)	3.00
BFPU06	Brkr Fail Init Pickup Delay–BK06 (0.00–6000 cyc)	6.00
RTPU06	Retrip Delay–BK06 (0.00–6000 cyc)	3.00
BFI06	Breaker Fail Initiate–BK06 (SELOGIC Equation)	TB_BFI AND BF_EN
ATBFI06	Alt Breaker Fail Initiate–BK06 (SELOGIC Equation)	NA
EBFIS06	Breaker Fail Initiate Seal-In–BK06 (Y, N)	N
BFISP06	Breaker Fail Init Seal-In Delay–BK06 (0.00–1000 cyc)	0.50
BFIDO06	Brkr Fail Init Dropout Delay–BK06 (0.00–1000 cyc)	1.50
Breaker 07 Failure Logic		
EXBF07	External Breaker Fail–BK07 (Y, N)	N
XBF07	External Brkr Fail Init–BK07 (SELOGIC Equation)	NA
50FP07	Fault Current Pickup–BK07 (0.50–50 amps, sec)	3.00
BFPU07	Brkr Fail Init Pickup Delay–BK07 (0.00–6000 cyc)	6.00
RTPU07	Retrip Delay–BK07 (0.00–6000 cyc)	3.00
BFI07	Breaker Fail Initiate–BK07 (SELOGIC Equation)	NA
ATBFI07	Alt Breaker Fail Initiate–BK07 (SELOGIC Equation)	NA
EBFIS07	Breaker Fail Initiate Seal-In–BK07 (Y, N)	N
BFISP07	Breaker Fail Init Seal-In Delay–BK07 (0.00–1000 cyc)	0.50
BFIDO07	Brkr Fail Init Dropout Delay–BK07 (0.00–1000 cyc)	1.50
Breaker 08 Failure Logic		
EXBF08	External Breaker Fail–BK08 (Y, N)	Y
XBF08	External Brkr Fail Init–BK08 (SELOGIC Equation)	NA
50FP08	Fault Current Pickup–BK08 (0.50–50 amps, sec)	3.00
BFPU08	Brkr Fail Init Pickup Delay–BK08 (0.00–6000 cyc)	6.00
RTPU08	Retrip Delay–BK08 (0.00–6000 cyc)	3.00
BFI08	Breaker Fail Initiate–BK08 (SELOGIC Equation)	NA
ATBFI08	Alt Breaker Fail Initiate–BK08 (SELOGIC Equation)	NA
EBFIS08	Breaker Fail Initiate Seal-In–BK08 (Y, N)	N

Table 8.35 **Breaker Failure Logic (1 through 18)** (Sheet 4 of 4)

Label	Prompt	Default Value
BFISP08	Breaker Fail Init Seal-In Delay–BK08 (0.00–1000 cyc)	0.50
BFIDO08	Brkr Fail Init Dropout Delay–BK08 (0.00–1000 cyc)	1.50
•	•	•
•	•	•
•	•	•
Breaker 18 Failure Logic		
EXBF18	External Breaker Fail–BK18 (Y, N)	Y
XBF18	External Brkr Fail Init–BK18 (SELOGIC Equation)	NA
50FP18	Fault Current Pickup–BK18 (0.50–50 amps, sec)	3.00
BFPU18	Brkr Fail Init Pickup Delay–BK18 (0.00–6000 cyc)	6.00
RTPU18	Retrip Delay–BK18 (0.00–6000 cyc)	3.00
BFI18	Breaker Fail Initiate–BK18 (SELOGIC Equation)	NA
ATBFI18	Alt Breaker Fail Initiate–BK18 (SELOGIC Equation)	NA
EBFIS18	Breaker Fail Initiate Seal-In–BK18 (Y, N)	N
BFISP18	Breaker Fail Init Seal-In Delay–BK18 (0.00–1000 cyc)	0.50
BFIDO18	Brkr Fail Init Dropout Delay–BK18 (0.00–1000 cyc)	1.50

Table 8.36 **Definite-Time Overcurrent Elements**

Label	Prompt	Default Value
50P01P	Terminal 01 Pickup (OFF, 0.25–100 amps, sec)	OFF
50P01D	Terminal 01 Pickup Delay (0.00–99999 cyc)	10.00
•	•	•
•	•	•
•	•	•
50P18P	Terminal 18 Pickup (OFF, 0.25–100 amps, sec)	OFF
50P18D	Terminal 18 Pickup Delay (0.00–99999 cyc)	10.00

Table 8.37 **Inverse-Time Overcurrent Elements (1 through 18)** (Sheet 1 of 2)

Label	Prompt	Default Value
51P01P	51P01 O/C Pickup (0.50–16 amps, sec)	0.50
51P01C	51P01 Inv-Time O/C Curve (U1–U5, C1–C5)	U1
51P01TD	51P01 Inv-Time O/C Time Dial (0.50–15) [U1–U5] or 51P01 Inv-Time O/C Time Dial (0.05–1) [C1–C5]	0.50
51P01RS	51P01 Inv-Time O/C EM Reset (Y, N)	Y
51P01TC	51P01 Inv-Time O/C Torque Cont (SELOGIC Equation)	1
•	•	•
•	•	•
•	•	•

Table 8.37 Inverse-Time Overcurrent Elements (1 through 18) (Sheet 2 of 2)

Label	Prompt	Default Value
51P18P	51P18 O/C Pickup (0.50–16 amps, sec)	0.50
51P18C	51P18 Inv-Time O/C Curve (U1–U5, C1–C5)	U1
51P18TD	51P18 Inv-Time O/C Time Dial (0.50–15) [U1–U5] or 51P18 Inv-Time O/C Time Dial (0.05–1) [C1–C5]	0.50
51P18RS	51P18 Inv-Time O/C EM Reset (Y, N)	Y
51P18TC	51P18 Inv-Time O/C Torque Cont (SELOGIC Equation)	1

Table 8.38 Phase Instantaneous Over- and Undervoltage Elements

Label	Prompt	Default Value
27P11P	Voltage 1 Level 1 U/V Pickup (OFF, 1.0–200 volts)	OFF
27P12P	Voltage 1 Level 2 U/V Pickup (OFF, 1.0–200 volts)	OFF
59P11P	Voltage 1 Level 1 O/V Pickup (OFF, 1.0–200 volts)	OFF
59P12P	Voltage 1 Level 2 O/V Pickup (OFF, 1.0–200 volts)	OFF
• • •	• • •	• • •
27P31P	Voltage 3 Level 1 U/V Pickup (OFF, 1.0–200 volts)	OFF
27P32P	Voltage 3 Level 2 U/V Pickup (OFF, 1.0–200 volts)	OFF
59P31P	Voltage 3 Level 1 O/V Pickup (OFF, 1.0–200 volts)	OFF
59P32P	Voltage 3 Level 2 O/V Pickup (OFF, 1.0–200 volts)	OFF

Table 8.39 Sequence Overvoltage Elements

Label	Prompt	Default Value
59Q1P	Neg.-Seq. Level 1 O/V Pickup (OFF, 1.0–200 volts)	20.0
59Q2P	Neg.-Seq. Level 2 O/V Pickup (OFF, 1.0–200 volts)	40.0
59N1P	Zero-Seq. Level 1 O/V Pickup (OFF, 1.0–200 volts)	20.0
59N2P	Zero-Seq. Level 2 O/V Pickup (OFF, 1.0–200 volts)	40.0

Table 8.40 Trip Logic (Sheet 1 of 2)

Label	Prompt	Default Value
TR01	Trip 01 (SELOGIC Equation)	F1_BFT OR F1_DPT
ULTR01	Unlatch Trip 01 (SELOGIC Equation)	NA
TR02	Trip 02 (SELOGIC Equation)	F2_BFT OR F2_DPT
ULTR02	Unlatch Trip 02 (SELOGIC Equation)	NA
TR03	Trip 03 (SELOGIC Equation)	F3_BFT OR F3_DPT
ULTR03	Unlatch Trip 03 (SELOGIC Equation)	NA
TR04	Trip 04 (SELOGIC Equation)	T1_BFT OR T1_DPT
ULTR04	Unlatch Trip 04 (SELOGIC Equation)	NA
TR05	Trip 05 (SELOGIC Equation)	TB1_BFT OR TB1_DPT OR TB2_BFT OR TB2_DPT
ULTR05	Unlatch Trip 05 (SELOGIC Equation)	NA

Table 8.40 Trip Logic (Sheet 2 of 2)

Label	Prompt	Default Value
TR06	Trip 06 (SELOGIC Equation)	NA
ULTR06	Unlatch Trip 06 (SELOGIC Equation)	NA
•	•	•
•	•	•
•	•	•
TR18	Trip 18 (SELOGIC Equation)	NA
ULTR18	Unlatch Trip 18 (SELOGIC Equation)	NA
TDURD	Minimum Trip Duration Time Delay (2.000–8000 cyc)	12.000
ER	Event Report Trigger Equation (SELOGIC Equation)	R_TRIG 87ST

Protection Free-Form SELOGIC Control Equations

The following protection free-form SELOGIC control equation settings are the default settings for all six settings groups. You can set each of the six protection free-form SELOGIC control equation setting groups independently. See *Section 2: SELOGIC Control Equation Programming*.

Table 8.41 Protection Free-Form SELOGIC Control Equations

Label	Default Value
PLT01S :=	NOT DIFF_EN AND PLT04 # DIFFERENTIAL ENABLED
PLT01R :=	PCT02Q AND DIFF_EN AND NOT PLT04
PLT02S :=	NOT BF_EN AND PLT05 # BREAKER FAILURE ENABLED
PLT02R :=	PCT03Q AND BF_EN AND NOT PLT05
PLT03S :=	NOT TNS_SW AND PLT06 # RELAY TEST MODE
PLT03R :=	PCT04Q AND TNS_SW AND NOT PLT06
PLT04S :=	PB1_PUL AND NOT DIFF_EN # ONLY ONE OP PER PB1 PRESS
PLT04R :=	PB1_PUL AND DIFF_EN
PLT05S :=	PB2_PUL AND NOT BF_EN # ONLY ONE OP PER PB2 PRESS
PLT05R :=	PB2_PUL AND BF_EN
PLT06S :=	PB4_PUL AND NOT TNS_SW # ONLY ONE OP PER PB4 PRESS
PLT06R :=	PB4_PUL AND TNS_SW
PCT01PU :=	240
PCT01IN :=	59Q1 OR 59N1
PCT02PU :=	60 # 1 SEC DELAY DISABLE ON PB1
PCT02IN :=	PB1
PCT03PU :=	60 # 1 SEC DELAY DISABLE ON PB2
PCT03IN :=	PB2
PCT04PU :=	60 # 1 SEC DELAY DISABLE ON PB4
PCT04IN :=	PB4

Automation Free-Form SELOGIC Control Equations

Automation free-form SELOGIC control equations are in blocks 1 through 10. See *Section 2: SELOGIC Control Equation Programming in the Reference Manual*.

Output Settings

Table 8.42 Output Settings Categories

Settings	Reference
Main Board	*Table 8.43*
Interface Board #1	*Table 8.44*
Interface Board #2	*Table 8.45*
Interface Board #3	*Table 8.46*
Interface Board #4	*Table 8.47*
Communications Card Outputs	*Table 8.48*
MIRRORED BITS Transmit Equations	*Table 8.49*

Table 8.43 Main Board

Label	Prompt	Default Value
OUT101	NA	TRIP01 AND NOT TNS_SW
OUT102	NA	TRIP02 AND NOT TNS_SW
OUT103	NA	TRIP03 AND NOT TNS_SW
OUT104	NA	TRIP04 AND NOT TNS_SW
OUT105	NA	TRIP05 AND NOT TNS_SW
OUT106	NA	NA
OUT107	NA	TNS_SW #RELAY TEST MODE
OUT108	NA	NOT (SALARM OR HALARM)

Table 8.44 Interface Board #1

Label	Prompt	Default Value
OUT201	NA	NA
•	•	•
•	•	•
•	•	•
OUT208	NA	NA

Table 8.45 Interface Board #2

Label	Prompt	Default Value
OUT301	NA	NA
•	•	•
•	•	•
•	•	•
OUT308	NA	NA

Table 8.46 Interface Board #3

Label	Prompt	Default Value
OUT401	NA	NA
•	•	•
•	•	•
•	•	•
OUT408	NA	NA

Table 8.47 Interface Board #4

Label	Prompt	Default Value
OUT501	NA	NA
•	•	•
•	•	•
•	•	•
OUT508	NA	NA

Table 8.48 Communications Card Outputs

Label	Prompt	Default Value
CCOUT01	NA	NA
•	•	•
•	•	•
•	•	•
CCOUT32	NA	NA

Table 8.49 MIRRORED BITS Transmit Equations

Label	Prompt	Default Value
TMB1A	NA	NA
•	•	•
•	•	•
•	•	•
TMB8A	NA	NA
TMB1B	NA	NA
•	•	•
•	•	•
•	•	•
TMB8B	NA	NA

Front-Panel Settings

Table 8.50 Front-Panel Settings Categories

Settings	Reference
Front-Panel Settings	*Table 8.51*
Selectable Screens for the Front Panel	*Table 8.52*
Selectable Operator Pushbuttons	*Table 8.53*
Front-Panel Event Display	*Table 8.54*
Display Points	
Boolean Display Points	*Table 8.55*
Analog Display Points	*Table 8.56*
Local Control	*Table 8.57*
Local Bits SELOGIC	*Table 8.58*

Table 8.51 Front-Panel Settings (Sheet 1 of 4)

Label	Prompt	Default Value
FP_TO	Front Panel Display Time-Out (OFF, 1–60 minutes)	15
EN_LEDC[a]	Enable LED Asserted Color (R, G, A)	G
TR_LEDC[a]	Trip LED Asserted Color (R, G, A)	R
PB1_LED	Pushbutton LED 1 (SELOGIC Equation)	DIFF_EN # Differential Protection Enabled
PB1_COL[a]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB2_LED	Pushbutton LED 2 (SELOGIC Equation)	BF_EN # Breaker Failure Enabled
PB2_COL[a]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB3_LED	Pushbutton LED 3 (SELOGIC Equation)	NA
PB3_COL[a]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB4_LED	Pushbutton LED 4 (SELOGIC Equation)	TNS_SW # Test Normal Switch Enabled
PB4_COL[a]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB5_LED	Pushbutton LED 5 (SELOGIC Equation)	NA
PB5_COL[a]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB6_LED	Pushbutton LED 6 (SELOGIC Equation)	NA
PB6_COL[a]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB7_LED	Pushbutton LED 7 (SELOGIC Equation)	NA

Table 8.51 **Front-Panel Settings** (Sheet 2 of 4)

Label	Prompt	Default Value
PB7_COL[a]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB8_LED	Pushbutton LED 8 (SELOGIC Equation)	NA
PB8_COL[a,b]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB9_LED[b]	Pushbutton LED 9 (SELOGIC Equation)	NA
PB9_COL[a,b]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB10LED[b]	Pushbutton LED 10 (SELOGIC Equation)	NA
PB10COL[a,b]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB11LED[b]	Pushbutton LED 11 (SELOGIC Equation)	NA
PB11COL[a,b]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
PB12LED[b]	Pushbutton LED 12 (SELOGIC Equation)	NA
PB12COL[a,b]	PB_LED Assert & Deassert Color (Enter 2: R, G, A, O)	AO
T1_LED	Target LED 1 (SELOGIC Equation)	87BTR
T1LEDL	Target LED 1 Latch (Y, N)	Y
T1LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T2_LED	Target LED 2 (SELOGIC Equation)	SBFTR
T2LEDL	Target LED 2 Latch (Y, N)	Y
T2LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T3_LED	Target LED 3 (SELOGIC Equation)	Z1_TRIP
T3LEDL	Target LED 3 Latch (Y, N)	Y
T3LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T4_LED	Target LED 4 (SELOGIC Equation)	Z2_TRIP
T4LEDL	Target LED 4 Latch (Y, N)	Y
T4LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T5_LED	Target LED 5 (SELOGIC Equation)	87Z3
T5LEDL	Target LED 5 Latch (Y, N)	Y
T5LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T6_LED	Target LED 6 (SELOGIC Equation)	87Z4

Table 8.51 Front-Panel Settings (Sheet 3 of 4)

Label	Prompt	Default Value
T6LEDL	Target LED 6 Latch (Y, N)	Y
T6LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T7_LED	Target LED 7 (SELOGIC Equation)	87Z5
T7LEDL	Target LED 7 Latch (Y, N)	Y
T7LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T8_LED	Target LED 8 (SELOGIC Equation)	87Z6
T8LEDL	Target LED 8 Latch (Y, N)	Y
T8LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T9_LED	Target LED 9 (SELOGIC Equation)	50P01T OR 50P02T OR. . .50P18T
T9LEDL	Target LED 9 Latch (Y, N)	Y
T91LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T10_LED	Target LED 10 (SELOGIC Equation)	51P01T OR 51P02T OR. . .51P18T
T10LEDL	Target LED 10 Latch (Y, N)	Y
T10LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T11_LED	Target LED 11 (SELOGIC Equation	87ST
T11LEDL	Target LED 11 Latch (Y, N)	N
T11LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T12_LED	Target LED 12 (SELOGIC Equation	NOT (Z1S AND Z2S AND. . .Z6S)
T12LEDL	Target LED 12 Latch (Y, N)	Y
T12LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T13_LED	Target LED 13 (SELOGIC Equation)	TOS01 OR TOS02 OR. . .TOS18
T13LEDL	Target LED 13 Latch (Y, N)	N
T13LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T14_LED	Target LED 14 (SELOGIC Equation)	89IOP
T14LEDL	Target LED 14 Latch (Y, N)	N
T14LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T15_LED	Target LED 15 (SELOGIC Equation)	89AL
T15LEDL	Target LED 15 Latch (Y, N)	N
T15LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO

Table 8.51 Front-Panel Settings (Sheet 4 of 4)

Label	Prompt	Default Value
T16_LED	Target LED 16 (SELOGIC Equation)	PCT01Q
T16LEDL	Target LED 16 Latch (Y, N)	Y
T16LEDC[a]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T17_LED[c]	Target LED 17 (SELOGIC Equation)	27P11 OR 27P12 OR ... 27P32
T17LEDL[c]	Target LED 17 Latch (Y, N)	N
T17LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T18_LED[c]	Target LED 18 (SELOGIC Equation)	59P11 OR 59P12 OR ... 59P32
T18LEDL[c]	Target LED 18 Latch (Y, N)	N
T18LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T19_LED[c]	Target LED 19 (SELOGIC Equation)	V01FIM>55
T19LEDL[c]	Target LED 19 Latch (Y, N)	N
T19LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T20_LED[c]	Target LED 20 (SELOGIC Equation)	V02FIM>55
T20LEDL[c]	Target LED 20 Latch (Y, N)	N
T20LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T21_LED[c]	Target LED 21 (SELOGIC Equation)	V03FIM>55
T21LEDL[c]	Target LED 21 Latch (Y, N)	N
T21LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T22_LED[c]	Target LED 22 (SELOGIC Equation)	FAULT
T22LEDL[c]	Target LED 22 Latch (Y, N)	N
T22LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T23_LED[c]	Target LED 23 (SELOGIC Equation)	52AL
T23LEDL[c]	Target LED 23 Latch (Y, N)	N
T23LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO
T24_LED[c]	Target LED 24 (SELOGIC Equation)	TIRIG
T24LEDL[c]	Target LED 24 Latch (Y, N)	N
T24LEDC[a,c]	TLED Assert & Deassert Color (Enter 2: R, G, A, O)	RO

[a] LED color settings are only available on HMI2 models.
[b] PB9–PB12 settings are only available on 12-pushbutton models.
[c] T17LED–T24LED settings are only available on 12-pushbutton models.

Table 8.52 Selectable Screens for the Front Panel

Label	Prompt	Default Value
SCROLD	Front Panel Display Update Rate (OFF, 1–15 secs)[a]	5
STA_BAT	Station Battery Screen (Y, N)	N
FUND_VI	Fundamental Voltage and Current Screen (Y, N)	Y
DIFF	Differential Metering (Y, N)	Y
ZONECFG	Terminals Associated with Zones (Y, N)	Y

[a] Screens will not rotate when SCROLD := OFF; the first screen in the rotation order remains on the screen.

Table 8.53 Selectable Operator Pushbuttons

Label	Prompt	Default Value
PB1_HMI	Pushbutton 1 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB2_HMI	Pushbutton 2 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB3_HMI	Pushbutton 3 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB4_HMI	Pushbutton 4 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB5_HMI	Pushbutton 5 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB6_HMI	Pushbutton 6 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB7_HMI	Pushbutton 7 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB8_HMI	Pushbutton 8 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB9_HMI[c]	Pushbutton 9 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB10HMI[c]	Pushbutton 10 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB11HMI[c]	Pushbutton 11 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF
PB12HMI[c]	Pushbutton 12 HMI Screen (OFF, AP, DP, EVE, SER)[a,b]	OFF

[a] PBn_HMI can only be set to DP if a valid display point has been set.
[b] Each instance (AP, DP, EVE, SER) can only be set to a single operator pushbutton.
OFF = No HMI Pushbutton Operation
AP = Alarm Points
DP = Display Points
EVE = Event Summaries
SER = SER HMI Display
[c] PB9–PB12 settings are only available on 12-pushbutton models.

Table 8.54 Front-Panel Event Display

Label	Prompt	Default Value
DISP_ER	Enable HMI Auto Display of Events Summaries (Y, N)	Y
TYPE_ER	Types of Events for HMI Auto Display (ALL, TRIP)[a]	ALL
NUM_ER	Number of Events for HMI Display (1–100)[b]	10

[a] Setting is only available if DISP_ER := Y.
[b] Setting is only available if an operator pushbutton has been set to EVE.

Table 8.55 Boolean Display Points and Aliases[a]

Label	Prompt	Default Value[b]
[Relay Word Bit Name]	Name of any element in element store.	None
[Label]	String of ASCII characters except double quotation marks[c]	None
[Set String]	String of ASCII characters except double quotation marks[c]	None
[Clear String]	String of ASCII characters except double quotation marks[c]	None
[Text Size]	S for Single, D for Double	S

[a] Relay Word Bit Name, "Label","String Set","Clear String","Text Size".
[b] The SEL-487B has no default values programmed for these settings.
[c] Total length of Boolean Display Point is 20 characters; 19 characters of ASCII string with one (1) character reserved for an "=".

Table 8.56 Analog Display Points and User Text and Formatting[a]

Label	Prompt	Default Value[b]
[Analog Quantity Name]	Name of any element in element store	None
[User Text]	String of ASCII characters except double quotation marks and { }[c]	None
[Formatting]	{total width.characters to right of decimal place, scaling factor}[d]	None
[User Text]	String of ASCII characters except double quotation marks and { }[c]	None
[Text Size]	S for Single, D for Double	S

[a] Analog Quantity Name, "User Text and Formatting","Text Size".
[b] The SEL-487B has no default values programmed for these settings.
[c] Total length of Analog Display Point is 20 characters.
[d] See Display Points on page U.5.9 in the User's Guide for examples of setting Analog Display Points.

Table 8.57 Local Control[a]

Label	Prompt	Default Value[b]
[Local Bit number]	Valid Local Bit number (LB01, for example)	None
[Local Label]	String of up to 20 printable ASCII characters except double quotation marks	None
[Local Set State]	String of up to 20 printable ASCII characters except double quotation marks	None
[Local State]	String of up to 20 printable ASCII characters except double quotation marks	
[Pulse Enable]	Pulse Local Bit (Y, N)	N

[a] Local Bit, Local Label, Local Set State, Local Clear State, Pulse Enable.
[b] The SEL-487B has no default values programmed for these settings.

Table 8.58 Local Bit SELogic[a]

Label	Prompt	Default Value
LB_SP*mm*	Local Bit Supervision (SELogic Equation, NA)	1
LB_DP*mm*	Local Bit Status Display (SELogic Equation, NA)	LB*mm*

[a] Settings in Table 8.58 appear if the associated local bit is defined. If no local bits are defined, the whole category is hidden.

Report Settings

Table 8.59 Report Settings Categories

Settings	Reference
SER Chatter Criteria	*Table 8.60*
SER Points	*SER Points*
Event Reporting	*Table 8.61*
Event Reporting Digital Elements	*Table 8.62*

Table 8.60 SER Chatter Criteria

Label	Prompt	Default Value
ESERDEL	Automatic Removal of Chattering SER Points (Y, N)	N
SRDLCNT	Number of Counts Before Auto-Removal (2–20)	5
SRDLTIM	Time for Auto-Removal (0.1–30 seconds)	1.0

SER Points

Enter SER Points in the free-form style with the following syntax:

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

For example, Reporting Name TARGET RESET PB has two display states, one when Relay Word bit TRGTR asserts (Set State Name) and one when Relay Word bit TRGTR deasserts (Clear State Name). For each item, assign a suitable label:

NOTE: Reporting Name, Set State Name, and Clear State Name are strings of up to 20 printable ASCII characters except double quotation marks.

Relay Word Bit = TRGTR

Local Name = TARGET RESET PB

Local Set State = TEST

Local Clear State = OFF

HMI Alarm = Y

Use the **SET R** command and enter the settings for the example as shown in *Figure 8.2*.

```
=>>SET R <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N      ?<Enter>

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1:
?   TRGTR,"TARGET RESET PB","TEST","OFF","Y" <Enter>
2:
?   END <Enter>
Report

.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 8.2 Setting an SER Point to Report TRGTR Relay Word Bit Status

Table 8.61 Event Reporting

Label	Prompt	Default Value
LER	Length of Event Report (15, 30, 60, 120 cycles)	15
PRE	Length of Pre-Fault (1–13 cycles) for LER = 15	5
PRE	Length of Pre-Fault (1–28 cycles) for LER = 30	5
PRE	Length of Pre-Fault (1–58 cycles) for LER = 60	5
PRE	Length of Pre-Fault (1–118 cycles) for LER = 120	5

Because substations differ in layout, digital points in the event report also differ from substation to substation. *Table 8.62* shows the relay default settings. The table shows the position in the report (left-to-right), the primitive name, and the alias name.

You can change any or all of these settings to suit a particular application. You can enter up to 800 Relay Word bits from 100 different Relay Word bit rows in the event report. You can enter a # sign for formatting of the event report, but it counts against the 800 bit limit. The rows containing the following Relay Word bits count against the 100 row limit even if they are not selected by the user: ZONE1–ZONE6, 87BTR, 87BTR01–87BTR18, SBFTR, SBFTR01–SBFTR18, TRIP, TRIP01–TRIP18, 87Z1–6, BFZ1–6, ER, RMB*n*A, TMB*n*A, RMB*n*B, TMB*n*B, ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, TLED_1, TLED_2, TLED_3, TLED_4, TLED_5, TLED_6, TLED_7, ,TLED_8, TLED_9, TLED_10, TLED_11, TLED_12, TLED_13, TLED_14, TLED_15, TLED_16, TLED_17, TLED_18, TLED_19, TLED_20, TLED_21, TLED_22, TLED_23, TLED_24, Z1BZ1, Z1BZ2, Z1BZ3, Z1BZ4, Z1BZ5, Z1BZ6, Z2BZ2, Z2BZ3, Z2BZ4, Z2BZ5, Z2BZ6, Z3BZ3, Z3BZ4, Z3BZ5, Z3BZ6, Z4BZ4, Z4BZ5, Z4BZ6, Z5BZ5, Z5BZ6, Z6BZ6, CZONE1, 87CZ1 (*n* = 1–8; see *Appendix A: Relay Word Bits* for a list of Relay Word bits available in the SEL-487B).

Table 8.62 Default Event Report Settings

Position	Primitive Name	Alias Name
1	87Z1	Z1_TRIP
2	87Z2	Z2_TRIP
3	#	
4	FBF01	F1_BF
5	FBF02	F2_BF
6	FBF03	F3_BF
7	FBF04	T1_BF
8	FBF05	TB1_BF
9	FBF06	TB2_BF
10	#	
11	PLT01	DIFF_EN
12	PLT02	BF_EN
13	PLT03	TNS_SW
14	#	
15	IN101	F1_BFI
16	IN102	F2_BFI
17	IN103	F3_BFI
18	IN104	T1_BFI
19	IN105	TB_BFI
20	#	
21	OUT101	F1_TRIP
22	OUT102	F2_TRIP
23	OUT103	F3_TRIP
24	OUT104	T1_TRIP
25	OUT105	TB_TRIP
26	#	
27	OUT107	TEST
28	OUT108	ALARM

Use the **SET R** command to change the default event report settings. *Figure 8.3* shows the steps to add the output from Coupler Security Logic 1 to the event report.

```
=>>SET R <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N      ?> <Enter>

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1: TRGTR,"TARGET RESET PB","TEST","OFF","Y"
?  <Enter>
2:
? <Enter>

EVENT REPORTING

Length of Event Report (15, 30, 60, 120 cycles)      LER     := 15     ?> <Enter>

Event Reporting Digital Elements
(800 Relay Word Bits Maximum from 100 Rows Maximum)

1: Z1_TRIP
?  >
29:
?  CSL1 <Enter>
30:
?  END <Enter>
Report

.
.
.

29: CSL1

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 8.3 Steps to Add the Output From Coupler Security Logic 1 to the Event Report

Figure 8.4 shows the event report after adding the output from Coupler Security Logic 1. Relay Word bit CSL1 appears in the right-most column of the event report.

```
ZZ FFFTTT DBT FFFTT FFFTT TA
12 1231BB IFN 1231B 1231B EL
__ ____12 F_S _____ _____ SA
TT BBBB__ FE_ BBBBB TTTTT TRC
RR FFFFBB _NS FFFFF RRRRR  MS
II     FF E W IIIII IIIII   L
PP        N         PPPPP   1

=>>
```

Figure 8.4 Example Event Report After Adding Output From Coupler Security Logic 1

Port Settings

Table 8.63 Port Settings Categories

Settings	Reference
Protocol Selection	*Table 8.64*
Communications Settings	*Table 8.65*
SEL Protocol Settings	*Table 8.66*
DNP3 Protocol (Serial) Settings	*Table 8.67*
MIRRORED BITS Protocol Settings	*Table 8.68*
Ethernet Settings	*Table 8.69*
FTP Settings	*Table 8.70*
Telnet Settings	*Table 8.71*
Network Host Name	*Table 8.72*
IEC 61850 Settings	*Table 8.73*
DNP3 Protocol (Ethernet) Settings	*Table 8.74*

Table 8.64 Protocol Selection

Label	Prompt	Default Value
EPORT	Enable Port (Y, N)	Y
MAXACC	Maximum Access Level (1, B, P, A, 0, 2, C)	C
PROTO	Protocol (SEL, DNP, MBA, MBB)	SEL

Table 8.65 Communications Settings

Label	Prompt	Default Value
MBT	Using Pulsar 9600 modem? (Y, N)	N
SPEED[a]	Data Speed (300 to 57600)	9600
DATABIT	Data Bits (7, 8 bits)	8
PARITY	Parity (Odd, Even, None)	N
STOPBIT	Stop Bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

[a] Maximum speed for MIRRORED BITS communications is 38400 bps.

NOTE: Enter nonprinting characters in the format \0xx where xx is a hexadecimal code for the desired character.

Table 8.66 SEL Protocol Settings

Label	Prompt	Default Value
TIMEOUT	Port Time-Out (OFF, 1–60 minutes)	5
AUTO	Send Auto-Messages to Port (Y, N)	Y
FASTOP	Enable Fast Operate Messages (Y, N)	N
TERTIM1	Initial Delay-Disconnect Sequence (0–600 seconds)	1
TERSTRN	Termination String-Disconn. Sequence (0–600 seconds)[a]	\005
TERTIM2	Final Delay-Disconnect Sequence (0–600 seconds)	0

[a] TERSTRN set at \005 is <Ctrl+E>.

Table 8.67 DNP3 Protocol Serial Port Settings

Label	Prompt	Default Value
DNPADR	DNP Address (0–65519)	0
ECLASSB	Class for Binary Event Data (OFF, 1–3)	1
ECLASSC	Class for Counter Event Data (OFF, 1–3)	OFF
ECLASSA	Class for Analog Event Data (OFF, 1–3)	2
TIMERQ[a]	Time-Set Request Interval (I, M, 1–32767 minutes)	I
DECPLA	Currents Scaling (0–3 decimal places)	1
DECPLV	Voltages Scaling (0–3 decimal places)	1
DECPLM	Miscellaneous Data Scaling (0–3 decimal places)	1
STIMEO	Select/Operate Time-Out (0.0–60.0 seconds)	1.0
DRETRY	Data Link Retries (OFF, 1–15)	OFF
DTIMEO	Data Link Time-Out (0.0–30.0 seconds)	1.0
MINDLY	Minimum Delay from DCD to TX (0.00–1.00 seconds)	0.05
MAXDLY	Maximum Delay from DCD to TX (0.00–1.00 seconds)	0.10
PREDLY	Settle Time-RTS On to TX (OFF, 0.00–30.00 seconds)	0.00
PSTDLY	Settle Time-TX to RTS Off (0.00–30.00 seconds)	0.00
ANADBA	Analog Reporting Deadband for Currents (0–32767)	100
ANADBV	Analog Reporting Deadband for Voltages (0–32767)	100
ANADBM	Analog Reporting Deadband (0–32767)	100
EVELOCK	Event Summary Lock Period (0–1000 seconds)	0
ETIMEO	Event Data Confirmation Time-Out (0.1–100.0 seconds)	10.0
UNSOL	Enable Unsolicited Reporting (Y, N)	N
PUNSOL	Enable Unsolicited Reporting at Power Up (Y, N)	N
REPADR	DNP Address to Report to (0–65519)	1
NUMEVE	Number of Events to Transmit On (1–200)	10
AGEEVE	Age of Oldest Event to Transmit On (0.0–60.0 seconds)	2.0
MODEM	Modem Connected to Port (Y, N)	N
MSTR	Modem Startup String (30 characters maximum)	E0X0&D0S0=4
PH_NUM	Phone Number for Dial-Out (30 characters maximum)	“”
MDTIME	Time to Attempt Dial (5–300 seconds)	60
MDRET	Time Between Dial-Out Attempts (5–3600 seconds)	120

[a] This setting sets the frequency with which the relay requests a DNP time synchronization. Setting M disables the time synchronization request, but the relay still accepts and applies time synchronization from the master. When set to I, the relay ignores (does not apply) time synchronization from the master.

Table 8.68 MIRRORED BITS Protocol Settings

Label	Prompt	Default Value
TX_ID	MIRRORED BITS ID of This Device (1–4)	2
RX_ID	MIRRORED BITS ID of Device Receiving From (1–4)	1
RBADPU	Outage Duration to Set RBAD (1–10000 seconds)	10
CBADPU	Channel Unavailability to Set CBAD (1–100000 ppm)	20000
TXMODE	Transmission Mode (N-Normal, P-Paced)	N
MBNUM	Number of MIRRORED BITS Channels (0–8)	8
RMB1FL	RMB1 Channel Fail State (0, 1, P)	P
RMB1PU	RMB1 Pickup Time (1–8 messages)	1
RMB1DO	RMB1 Dropout Time (1–8 messages)	1
RMB2FL	RMB2 Channel Fail State (0, 1, P)	P
RMB2PU	RMB2 Pickup Time (1–8 messages)	1
RMB2DO	RMB2 Dropout Time (1–8 messages)	1
RMB3FL	RMB3 Channel Fail State (0, 1, P)	P
RMB3PU	RMB3 Pickup Time (1–8 messages)	1
RMB3DO	RMB3 Dropout Time (1–8 messages)	1
RMB4FL	RMB4 Channel Fail State (0, 1, P)	P
RMB4PU	RMB4 Pickup Time (1–8 messages)	1
RMB4DO	RMB4 Dropout Time (1–8 messages)	1
RMB5FL	RMB5 Channel Fail State (0, 1, P)	P
RMB5PU	RMB5 Pickup Time (1–8 messages)	1
RMB5DO	RMB5 Dropout Time (1–8 messages)	1
RMB6FL	RMB6 Channel Fail State (0, 1, P)	P
RMB6PU	RMB6 Pickup Time (1–8 messages)	1
RMB6DO	RMB6 Dropout Time (1–8 messages)	1
RMB7FL	RMB7 Channel Fail State (0, 1, P)	P
RMB7PU	RMB7 Pickup Time (1–8 messages)	1
RMB7DO	RMB7 Dropout Time (1–8 messages)	1
RMB8FL	RMB8 Channel Fail State (0, 1, P)	P
RMB8PU	RMB8 Pickup Time (1–8 messages)	1
RMB8DO	RMB8 Dropout Time (1–8 messages)	1
MBTIME	Accept MIRRORED BITS Time Synchronization (Y, N)	N
MBNUMAN	Number of Analog Channels (0–7)	0
MBANA1	Selection for Analog Channel 1 (analog label)	PMV58
MBANA2	Selection for Analog Channel 2 (analog label)	PMV59
MBANA3	Selection for Analog Channel 3 (analog label)	PMV60
MBANA4	Selection for Analog Channel 4 (analog label)	PMV61
MBANA5	Selection for Analog Channel 5 (analog label)	PMV62
MBANA6	Selection for Analog Channel 6 (analog label)	PMV63
MBANA7	Selection for Analog Channel 7 (analog label)	PMV64
MBNUMVT	Number of Virtual Terminal Channels (OFF, 0–7)	OFF

NOTE: Settings in Table 8.69 through Table 8.73 apply to Port 5 of the SEL-487B. These settings are available only when the SEL-487B includes the Ethernet card.

NOTE: Fast SER over Ethernet is not supported on the SEL-2702 card on the SEL-487B.

Table 8.69 Ethernet Settings

Label	Prompt	Default Value
IPADDR	IP Address (www[h].xxx[h].yyy[h].zzz[h])	192.92.92.92
SUBNETM	Subnet Mask (www[h].xxx[h].yyy[h].zzz[h])	255.255.255.0
DEFRTR	Default Router (www[h].xxx[h].yyy[h].zzz[h])	
ETCPKA	Enable TCP Keep-Alive (Y, N)	Y
KAIDLE	TCP Keep-Alive Idle Range (1-20 s)	10
KAINTV	TCP Keep-Alive Interval Range (1-20 s)	1
KACNT	TCP Keep-Alive Count Range (1-20)	6
NETPORT	Primary Network Port (A=Port A, B=Port B, D=Disabled)	A
FAILOVR	Enable Fail-Over Mode (Y, N)	Y
FTIME	Network Port Fail-Over Time (5–65535 msec)	5
NETASPD	Network Speed, Port A (A=Auto, 10=10 Mbps, 100=100 Mbps)	A
NETBSPD	Network Speed, Port B (A=Auto, 10=10 Mbps, 100=100 Mbps)	A

Table 8.70 FTP Settings

Label	Prompt	Default Value
FTPSERV	Enable FTP Server (Y, N)	N
FTPCBAN	FTP Connect Banner	SEL-2702 FTP SERVER:
FTPIDLE	FTP Idle Time-Out (5–255 minutes)	5
FTPANMS	Enable Anonymous FTP Login (Y, N)	N
FTPAUSR	Associate Anonymous User Access Rights With User	""

Table 8.71 Telnet Settings

Label	Prompt	Default Value
T1CBAN	Telnet Connect Banner For Host	HOST TERMINAL SERVER:
T1INIT	Allow Telnet Sessions To Be Initiated By The Host (Y, N)	Y
T1RECV	Allow Telnet Sessions To Be Received By The Host (Y, N)	N
T1PNUM	Telnet Port Number For Host (1–65519)	23
T2CBAN	Telnet Connect Banner For Card	SEL-2702 TERMINAL SERVER:
T2RECV	Allow Telnet Sessions To Be Received By The Card (Y, N)	N
T2PNUM	Telnet Port Number For Card (1–65519)	1024
TIDLE	Telnet Idle Time-Out (0–255 minutes)	5

Table 8.72 Network Host Name

Label	Prompt	Default Value
HOST1	Alias for Host 1 (www[h].xxx[h].yyy[h].zzz[h])	NA
IPADR1	IP Address for Host 1 (www[h].xxx[h].yyy[h].zzz[h])	NA
• • •	• • •	• • •
HOST20	Alias for Host 20 (www[h].xxx[h].yyy[h].zzz[h])	
IPADR20	IP Address for Host 20 (www[h].xxx[h].yyy[h].zzz[h])	

Table 8.73 IEC 61850 Settings

Label	Prompt	Default Value
E61850	Enable IEC 61850 Protocol (Y, N)	N
EGSE	Enable IEC 61850 GSE (Y, N)	N

Table 8.74 DNP LAN/WAN Settings (Sheet 1 of 3)

Label	Prompt	Default
ENDNP	Enable DNP3 (Y, N)	N
DNPADR	DNP3 Address (0–65519)	0
DNPPNUM	DNP3 Port Number for TCP and UDP (1–65534)	20000
DNPMAP	DNP3 map Mode (AUTO, CUSTOM)	AUTO
RPADR01	DNP3 Address for Master 1 (0–65519)	1
DNPIP01	IP Address for Master 1 (www.xxx.yyy.zzz)	""
DNPTR01	Transport Protocol for Master 1 (UDP, TCP)	TCP
DNPUP01	UDP Response Port Number for Master 1 (1–65534, REQ)	20000
UNSL01	Enable Unsolicited Reporting for Master 1 (Y, N)	N
PUNSL01	Enable Unsolicited Reporting at Powerup for Master 1 (Y, N)	N
DNPMP01	CUSTOM Mode: DNP3 map associated with Master 1 (1–5)	"1"
DNPCL01	Enable Controls for Master 1 (Y, N)	N
RPADR02	DNP3 Address for Master 2 (0–65519)	1
DNPIP02	IP Address for Master 2 (www.xxx.yyy.zzz)	""
• • •		
DNPCL02	Enable Controls for Master 2 (Y, N)	N
RPADR03	DNP3 Address for Master 3 (0–65519)	1
DNPIP03	IP Address for Master 3 (www.xxx.yyy.zzz)	""
• • •		
DNPCL03	Enable Controls for Master 3 (Y, N)	N

Table 8.74 DNP LAN/WAN Settings (Sheet 2 of 3)

Label	Prompt	Default
RPADR04	DNP3 Address for Master 4 (0–65519)	1
DNPIP04	IP Address for Master 4 (www.xxx.yyy.zzz)	""
• • •		
DNPCL04	Enable Controls for Master 4 (Y, N)	N
RPADR05	DNP3 Address for Master 5 (0–65519)	1
DNPIP05	IP Address for Master 5 (www.xxx.yyy.zzz)	""
• • •		
DNPCL05	Enable Controls for Master 5 (Y, N)	N
RPADR06	DNP3 Address for Master 6 (0–65519)	1
DNPIP06	IP Address for Master 6 (www.xxx.yyy.zzz)	""
• • •		
DNPCL06	Enable Controls for Master 4 (Y, N)	N
RPADR07	DNP3 Address for Master 7 (0–65519)	1
DNPIP07	IP Address for Master 7 (www.xxx.yyy.zzz)	""
• • •		
DNPCL07	Enable Controls for Master 7 (Y, N)	N
RPADR08	DNP3 Address for Master 8 (0–65519)	1
DNPIP08	IP Address for Master 8 (www.xxx.yyy.zzz)	""
• • •		
DNPCL08	Enable Controls for Master 8 (Y, N)	N
RPADR09	DNP3 Address for Master 9 (0–65519)	1
DNPIP09	IP Address for Master 9 (www.xxx.yyy.zzz)	""
• • •		
DNPCL09	Enable Controls for Master 9 (Y, N)	N
RPADR10	DNP3 Address for Master 10 (0–65519)	1
DNPIP10	IP Address for Master 10 (www.xxx.yyy.zzz)	""
• • •		
DNPCL10	Enable Controls for Master 10 (Y, N)	N
ECLASSA	Class for Analog Event Data (0–3)	2
ECLASSB	Class for Binary Event Data (0–3)	1

Table 8.74 DNP LAN/WAN Settings (Sheet 3 of 3)

Label	Prompt	Default
ECLASSC	Class for Counter Event Data (0–3)	0
DECPL	Data Scaling Decimal Places (0–3)	0
ANADB	Data Reporting Deadband Counts (0–32767)	100
16BIT	DNP analog input objects default variation size (16/32)	16
STIMEO	Seconds to Select/Operate Time-out (0.0–30.0)	1.0
DNPPAIR	AUTO Mode: Enable Use of DNP3 Trip Close Pairs (Y, N)	N
DNPINA	Seconds to send Inactive Heartbeat (0=Off, 1–7200)	120
NUMEVE	Number of Events to Transmit On (1–200)	10
AGEEVE	Age of Oldest Event to Transmit On (0–100000 sec)	2
ETIMEO	Event Message Confirm Timeout (1–50 sec)	2
URETRY	Unsolicited Message Max Retry Attempts (2–10)	3
UTIMEO	Unsolicited Message Offline Timeout (1–5000 sec)	60

Table 8.75 HTTP Settings

Label	Prompt	Default
EHTTP	Enable HTTP Server (Y, N)	"N"
HPNUM	HTTP Port Number (1–65534)	80
HIDLE	HTTP Session Idle Timeout in minutes (1–30)	10

DNP3 Settings—Serial Port

When entering new data in the user-defined maps, the SEL-487B prompts for the following three kinds of information:

- Index Number

  Select the appropriate index number from the DNP map; see *Section 5: DNP3 Communications* for more information.
- Scale Factor

  Divide the original number by the scale factor to create a number suitable for presentation to the DNP protocol.
- Deadband

  State the number of counts by which the value of a specific point must vary before DNP generates a change event.

Table 8.76 DNP3 Reference Map Selection

Label	Prompt	Default Value
MAPSEL	Reference Map Selection (B, E)	B

Table 8.77 DNP3 Object Default Map Enables

Label	Prompt	Default Value
DNPBID	Use Default DNP map for Binary Inputs (Y, N)	Y
DNPBOD	Use Default DNP map for Binary Outputs (Y, N)	Y
DNPCOD	Use Default DNP map for Counters (Y, N)	Y
DNPAID	Use Default DNP map for Analog Inputs (Y, N)	Y
DNPAOD	Use Default DNP map for Analog Outputs (Y, N)	Y

Use the free-style format to modify the data in the user-defined maps with the syntax shown in *Table 8.78*.

Table 8.78 DNP3 User-Defined Map Entries Using Free-Form Style

Map	Syntax
Binary Input	Index Number
Binary Output	Index Number
Counter	Index Number, Deadband
Analog Input	Index Number, Scale Factor, Deadband
Analog Output	Index Number

Appendix A

Relay Word Bits

Overview

This section contains a table of the Relay Word bits available in the SEL-487B Relay. For information on using analog quantities in protection and automation, see the SEL-487B *Applications Handbook*.

Relay Word Bits

Use this appendix as a reference for Relay Word bit labels. *Table A.1* lists the Relay Word bits in alphabetic order.

Table A.1 Alphabetic List of Relay Word Bits (Sheet 1 of 14)

Name	Definition
27P11	V01, Level 1 undervoltage element picked up
27P12	V01, Level 2 undervoltage element picked up
27P21	V02, Level 1 undervoltage element picked up
27P22	V02, Level 2 undervoltage element picked up
27P31	V03, Level 1 undervoltage element picked up
27P32	V03, Level 2 undervoltage element picked up
50DS01–50DS18	Terminal 01–Terminal 18 directional element current threshold exceeded
50F01–50F18	Circuit Breaker 01–Circuit Breaker 18 breaker failure current threshold exceeded
50P01–50P18	Terminal 01–Terminal 18 instantaneous overcurrent element
50P01T–50P18T	Terminal 01–Terminal 18 definite-time overcurrent element timed out
51P01–51P18	Terminal 01–Terminal 18 inverse-time overcurrent element picked up
51P01R–51P18R	Terminal 01–Terminal 18 inverse-time overcurrent element is reset
51P01T–51P18T	Terminal 01–Terminal 18 inverse-time overcurrent element timed out
52A01–52A18	Circuit Breaker 01–Circuit Breaker 18 status
52AL	Any circuit breaker alarm
52AL01–52AL18	Circuit Breaker 01–Circuit Breaker 18 alarm
52CL01–52CL18	Circuit Breaker 01–Circuit Breaker 18 closed
59N1	Level 1 zero-sequence overvoltage element picked up

Table A.1 Alphabetic List of Relay Word Bits (Sheet 2 of 14)

Name	Definition
59N2	Level 2 zero-sequence overvoltage element picked up
59P11	V01, Level 1 overvoltage element picked up
59P12	V01, Level 2 overvoltage element picked up
59P21	V02, Level 1 overvoltage element picked up
59P22	V02, Level 2 overvoltage element picked up
59P31	V03, Level 1 overvoltage element picked up
59P32	V03, Level 2 overvoltage element picked up
59Q1	Level 1 negative-sequence instantaneous overvoltage element picked up
59Q2	Level 2 negative-sequence instantaneous overvoltage element picked up
87BTR	Any terminal bus-zone differential trip asserted
87BTR01–87BTR18	Terminal 01–Terminal 18 bus-zone differential trip asserted
87CZ1	Check Zone 1 differential element trip
87O1	Zone 1 restraint differential operating current above O87P
87O2	Zone 2 restraint differential operating current above O87P
87O3	Zone 3 restraint differential operating current above O87P
87O4	Zone 4 restraint differential operating current above O87P
87O5	Zone 5 restraint differential operating current above O87P
87O6	Zone 6 restraint differential operating current above O87P
87OCZ1	Check Zone 1 restraint differential operating current above CZO87P
87R1	Zone 1 restraint differential element picked up
87R2	Zone 2 restraint differential element picked up
87R3	Zone 3 restraint differential element picked up
87R4	Zone 4 restraint differential element picked up
87R5	Zone 5 restraint differential element picked up
87R6	Zone 6 restraint differential element picked up
87RCZ1	Check Zone 1 restraint differential element picked up
87S1	Zone 1 sensitive differential element picked up
87S2	Zone 2 sensitive differential element picked up
87S3	Zone 3 sensitive differential element picked up
87S4	Zone 4 sensitive differential element picked up
87S5	Zone 5 sensitive differential element picked up
87S6	Zone 6 sensitive differential element picked up
87SCZ1	Check Zone 1 sensitive differential element picked up
87ST	Any sensitive differential element timer timed out
87ST1	Zone 1 sensitive differential element timed out
87ST2	Zone 2 sensitive differential element timed out
87ST3	Zone 3 sensitive differential element timed out
87ST4	Zone 4 sensitive differential element timed out
87ST5	Zone 5 sensitive differential element timed out

Table A.1 Alphabetic List of Relay Word Bits (Sheet 3 of 14)

Name	Definition
87ST6	Zone 6 sensitive differential element timed out
87STCZ1	Check Zone 1 sensitive differential element timed out
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip
87Z3	Zone 3 differential element trip
87Z4	Zone 4 differential element trip
87Z5	Zone 5 differential element trip
87Z6	Zone 6 differential element trip
89A01–89A48	Disconnect 01–Disconnect 48 a auxiliary contact closed
89AL	Any disconnect auxiliary contact discrepancy alarm
89AL01–89AL48	Disconnect 01–Disconnect 48 auxiliary contact discrepancy alarm
89B01–89B48	Disconnect 01–Disconnect 48 b auxiliary contact closed
89CL01–89CL48	Disconnect 01–Disconnect 48 closed
89OIP	Any disconnect operation in progress
89OIP01–89OIP48	Disconnect 01–Disconnect 48 operation in progress
ABFIT01–ABFIT18	Circuit Breaker 01–Circuit Breaker 18 alternate circuit breaker failure initiate
ACN01Q–ACN32Q	Automation counter outputs
ACN01R–ACN32R	Automation counter resets
ACTRP1	Coupler 1 accelerated trip SELOGIC® control equation
ACTRP2	Coupler 2 accelerated trip SELOGIC control equation
ACTRP3	Coupler 3 accelerated trip SELOGIC control equation
ACTRP4	Coupler 4 accelerated trip SELOGIC control equation
ACTRPT1	Coupler 1 accelerated trip timed out
ACTRPT2	Coupler 2 accelerated trip timed out
ACTRPT3	Coupler 3 accelerated trip timed out
ACTRPT4	Coupler 4 accelerated trip timed out
AFRTEXA	Automation SELOGIC control equation first execution automation
AFRTEXP	Automation SELOGIC control equation first execution protection
ALT01–ALT32	Automation latches
ANOKA	Analog transfer OK on MIRRORED BITS® communications Channel A
ANOKB	Analog transfer OK on MIRRORED BITS communications Channel B
AST01Q–AST32Q	Automation sequencing timer outputs
AST01R–AST32R	Automation sequencing timer resets
ASV001–ASV256	Automation SELOGIC control equation variables
ATBFI01–ATBFI18	Circuit Breaker 01–Circuit Breaker 18 alternate breaker failure initiate SELOGIC control equation
AUNRLBL	Automation SELOGIC control equation unresolved label

Table A.1 Alphabetic List of Relay Word Bits (Sheet 4 of 14)

Name	Definition
BADPASS	Bad password
BFI01–BFI18	Circuit Breaker 01–Circuit Breaker 18 breaker failure initiate SELOGIC control equation
BFIT01–BFIT18	Circuit Breaker 01–Circuit Breaker 18 breaker failure timed out
BFZ1	Zone 1 breaker failure
BFZ2	Zone 2 breaker failure
BFZ3	Zone 3 breaker failure
BFZ4	Zone 4 breaker failure
BFZ5	Zone 5 breaker failure
BFZ6	Zone 6 breaker failure
BZ1BZ2R	A connection exists between BZ1 and BZ2, and the coupler is removed
BZ1BZ3R	A connection exists between BZ1 and BZ3, and the coupler is removed
BZ1BZ4R	A connection exists between BZ1 and BZ4, and the coupler is removed
BZ1BZ5R	A connection exists between BZ1 and BZ5, and the coupler is removed
BZ1BZ6R	A connection exists between BZ1 and BZ6, and the coupler is removed
BZ2BZ3R	A connection exists between BZ2 and BZ3, and the coupler is removed
BZ2BZ4R	A connection exists between BZ2 and BZ4, and the coupler is removed
BZ2BZ5R	A connection exists between BZ2 and BZ5, and the coupler is removed
BZ2BZ6R	A connection exists between BZ2 and BZ6, and the coupler is removed
BZ3BZ4R	A connection exists between BZ3 and BZ4, and the coupler is removed
BZ3BZ5R	A connection exists between BZ3 and BZ5, and the coupler is removed
BZ3BZ6R	A connection exists between BZ3 and BZ6, and the coupler is removed
BZ4BZ5R	A connection exists between BZ4 and BZ5, and the coupler is removed
BZ4BZ6R	A connection exists between BZ4 and BZ6, and the coupler is removed
BZ5BZ6R	A connection exists between BZ5 and BZ6, and the coupler is removed
BZ1BZ2V	A connection exists between BZ1 and BZ2
BZ1BZ3V	A connection exists between BZ1 and BZ3
BZ1BZ4V	A connection exists between BZ1 and BZ4
BZ1BZ5V	A connection exists between BZ1 and BZ5
BZ1BZ6V	A connection exists between BZ1 and BZ6
BZ2BZ3V	A connection exists between BZ2 and BZ3
BZ2BZ4V	A connection exists between BZ2 and BZ4

Table A.1 Alphabetic List of Relay Word Bits (Sheet 5 of 14)

Name	Definition
BZ2BZ5V	A connection exists between BZ2 and BZ5
BZ2BZ6V	A connection exists between BZ2 and BZ6
BZ3BZ4V	A connection exists between BZ3 and BZ4
BZ3BZ5V	A connection exists between BZ3 and BZ5
BZ3BZ6V	A connection exists between BZ3 and BZ6
BZ4BZ5V	A connection exists between BZ4 and BZ5
BZ4BZ6V	A connection exists between BZ4 and BZ6
BZ5BZ6V	A connection exists between BZ5 and BZ6
CB52A1–CB52A4	Coupler 1–Coupler 4 status SELOGIC control equation
CB52T1–CB52T4	Coupler 1–Coupler 4 status timed out
CBADA	Unavailability threshold exceeded for MIRRORED BITS communications Channel A
CBADB	Unavailability threshold exceeded for MIRRORED BITS communications Channel B
CBCLS1–CBCLS4	Coupler 1–Coupler 4 close command SELOGIC control equation
CBCLST1–CBCLST4	Coupler 1–Coupler 4 close command timed out
CCALARM	Communications card alarm
CCOK	Ethernet communications card status OK
CCIN001–CCIN128	Communications card input points
CCOUT01–CCOUT32	Communications card output points
CCSTA01	Card Status Register Bit 15 - Spare
CCSTA02	Card Status Register Bit 14 - Spare
CCSTA03	Card Status Register Bit 13 - Spare
CCSTA04	Card Status Register Bit 12 - Spare
CCSTA05	Card Status Register Bit 11 - Spare
CCSTA06	Card Status Register Bit 10 - Spare
CCSTA07	Card Status Register Bit 9 - Spare
CCSTA08	Card Status Register Bit 8 - Spare
CCSTA09	Card Status Register Bit 7 - Low Resource bit
CCSTA10	Card Status Register Bit 6 - Alarm bit
CCSTA11	Card Status Register Bit 5 - Settings selection
CCSTA12	Card Status Register Bit 4 - Running in SELBoot
CCSTA13	Card Status Register Bit 3 - Settings error
CCSTA14	Card Status Register Bit 2 - Network port active
CCSTA15	Card Status Register Bit 1 - Self-test failure
CCSTA16	Card Status Register Bit 0 - Alive and initialized
CCSTA17	Self Test Failure Bit 15 - Spare
CCSTA18	Self Test Failure Bit 14 - Spare
CCSTA19	Self Test Failure Bit 13 - SLBT Incompatible
CCSTA20	Self Test Failure Bit 12 - No Host Response to Interrupt
CCSTA21	Self Test Failure Bit 11 - Active Ethernet Port

Table A.1 Alphabetic List of Relay Word Bits (Sheet 6 of 14)

Name	Definition
CCSTA22	Self Test Failure Bit 10 - Host Access Counter Error
CCSTA23	Self Test Failure Bit 9 - Host Access Counter Warning
CCSTA24	Self Test Failure Bit 8 - Host Incompatible
CCSTA25	Self Test Failure Bit 7 - Host Commanded Read/Write Test Results
CCSTA26	Self Test Failure Bit 6 - Shared Memory Interface Failure
CCSTA27	Self Test Failure Bit 5 - Configuration
CCSTA28	Self Test Failure Bit 4 - Executable Storage Block
CCSTA29	Self Test Failure Bit 3 - Settings Check
CCSTA30	Self Test Failure Bit 2 - SLBT Code Flash Check
CCSTA31	Self Test Failure Bit 1 - EXE Code Flash Check
CCSTA32	Self Test Failure Bit 0 - RAM Check
CHSG	Asserted during settings group change
CON1	Zone 1 in high-security mode
CON2	Zone 2 in high-security mode
CON3	Zone 3 in high-security mode
CON4	Zone 4 in high-security mode
CON5	Zone 5 in high-security mode
CON6	Zone 6 in high-security mode
CONCZ1	Check Zone 1 in high-security mode
CSL1	Coupler 1 security logic picked up
CSL2	Coupler 2 security logic picked up
CSL3	Coupler 3 security logic picked up
CSL4	Coupler 4 security logic picked up
CZ1S	Check Zone 1 supervision asserted
CZONE1	Check Zone 1 is active
DC1F	DC Monitor fail alarm
DC1G	DC Monitor ground fault alarm
DC1R	DC Monitor alarm for ac ripple
DC1W	DC Monitor warning alarm
DE1F	Zone 1 forward directional element picked up
DE2F	Zone 2 forward directional element picked up
DE3F	Zone 3 forward directional element picked up
DE4F	Zone 4 forward directional element picked up
DE5F	Zone 5 forward directional element picked up
DE6F	Zone 6 forward directional element picked up
DECZ1F	Check Zone 1 forward directional element picked up
DOKA	Normal MIRRORED BITS communications Channel A status
DOKB	Normal MIRRORED BITS communications Channel B status
DOP1	Zone 1 incremental operating current picked up
DOP2	Zone 2 incremental operating current picked up

Table A.1 Alphabetic List of Relay Word Bits (Sheet 7 of 14)

Name	Definition
DOP3	Zone 3 incremental operating current picked up
DOP4	Zone 4 incremental operating current picked up
DOP5	Zone 5 incremental operating current picked up
DOP6	Zone 6 incremental operating current picked up
DOPCZ1	Check Zone 1 incremental operating current picked up
DRT1	Zone 1 incremental restraint current picked up
DRT2	Zone 2 incremental restraint current picked up
DRT3	Zone 3 incremental restraint current picked up
DRT4	Zone 4 incremental restraint current picked up
DRT5	Zone 5 incremental restraint current picked up
DRT6	Zone 6 incremental restraint current picked up
DRTCZ1	Check Zone 1 incremental restraint current picked up
EN	Relay enabled
ER	Event report trigger equation (SELOGIC control equation)
EVELOCK	Lock DNP Events
EXT1	Zone 1 external fault declaration
EXT2	Zone 2 external fault declaration
EXT3	Zone 3 external fault declaration
EXT4	Zone 4 external fault declaration
EXT5	Zone 5 external fault declaration
EXT6	Zone 6 external fault declaration
EXTCZ1	Check Zone 1 external fault declaration
FAULT	Busbar fault in any zone
FAULT1	Zone 1 fault detector picked up
FAULT2	Zone 2 fault detector picked up
FAULT3	Zone 3 fault detector picked up
FAULT4	Zone 4 fault detector picked up
FAULT5	Zone 5 fault detector picked up
FAULT6	Zone 6 fault detector picked up
FLTCZ1	Check Zone 1 fault detector picked up
FBF01–FBF18	Circuit Breaker 01–Circuit Breaker 18 failure
FDIF1	Zone 1 filtered restrained differential element picked up
FDIF2	Zone 2 filtered restrained differential element picked up
FDIF3	Zone 3 filtered restrained differential element picked up
FDIF4	Zone 4 filtered restrained differential element picked up
FDIF5	Zone 5 filtered restrained differential element picked up
FDIF6	Zone 6 filtered restrained differential element picked up
FDIFCZ1	Check Zone 1 filtered restrained differential element picked up
FSERP1	Fast SER enabled for Serial Port 1
FSERP2	Fast SER enabled for Serial Port 2
FSERP3	Fast SER enabled for Serial Port 3

Table A.1 Alphabetic List of Relay Word Bits (Sheet 8 of 14)

Name	Definition
FSERPF	Fast SER enabled for Serial Port F
GFAULT1	Zone 1 fast fault detection
GFAULT2	Zone 2 fast fault detection
GFAULT3	Zone 3 fast fault detection
GFAULT4	Zone 4 fast fault detection
GFAULT5	Zone 5 fast fault detection
GFAULT6	Zone 6 fast fault detection
GFLTCZ1	Check Zone 1 fast fault detection
HALARM	Hardware alarm
I01BZ1V–I01BZ6V	Terminal I01 connected to BZ1–BZ6
I02BZ1V–I02BZ6V	Terminal I02 connected to BZ1–BZ6
I03BZ1V–I03BZ6V	Terminal I03 connected to BZ1–BZ6
I04BZ1V–I04BZ6V	Terminal I04 connected to BZ1–BZ6
I05BZ1V–I05BZ6V	Terminal I05 connected to BZ1–BZ6
I06BZ1V–I06BZ6V	Terminal I06 connected to BZ1–BZ6
I07BZ1V–I07BZ6V	Terminal I07 connected to BZ1–BZ6
I08BZ1V–I08BZ6V	Terminal I08 connected to BZ1–BZ6
I09BZ1V–I09BZ6V	Terminal I09 connected to BZ1–BZ6
I10BZ1V–I10BZ6V	Terminal I10 connected to BZ1–BZ6
I11BZ1V–I11BZ6V	Terminal I11 connected to BZ1–BZ6
I12BZ1V–I12BZ6V	Terminal I12 connected to BZ1–BZ6
I13BZ1V–I13BZ6V	Terminal I13 connected to BZ1–BZ6
I14BZ1V–I14BZ6V	Terminal I14 connected to BZ1–BZ6
I15BZ1V–I15BZ6V	Terminal I15 connected to BZ1–BZ6
I16BZ1V–I16BZ6V	Terminal I16 connected to BZ1–BZ6
I17BZ1V–I17BZ6V	Terminal I17 connected to BZ1–BZ6
I18BZ1V–I18BZ6V	Terminal I18 connected to BZ1–BZ6
I01CZ1V	Terminal I01 connected to CZ1
I02CZ1V	Terminal I02 connected to CZ1
I03CZ1V	Terminal I03 connected to CZ1
I04CZ1V	Terminal I04 connected to CZ1
I05CZ1V	Terminal I05 connected to CZ1
I06CZ1V	Terminal I06 connected to CZ1
I07CZ1V	Terminal I07 connected to CZ1
I08CZ1V	Terminal I08 connected to CZ1
I09CZ1V	Terminal I09 connected to CZ1
I10CZ1V	Terminal I10 connected to CZ1
I11CZ1V	Terminal I11 connected to CZ1
I12CZ1V	Terminal I12 connected to CZ1
I13CZ1V	Terminal I13 connected to CZ1
I14CZ1V	Terminal I14 connected to CZ1

Table A.1 Alphabetic List of Relay Word Bits (Sheet 9 of 14)

Name	Definition
I15CZ1V	Terminal I15 connected to CZ1
I16CZ1V	Terminal I16 connected to CZ1
I17CZ1V	Terminal I17 connected to CZ1
I18CZ1V	Terminal I18 connected to CZ1
IFAULT1	Zone 1 fault detection
IFAULT2	Zone 2 fault detection
IFAULT3	Zone 3 fault detection
IFAULT4	Zone 4 fault detection
IFAULT5	Zone 5 fault detection
IFAULT6	Zone 6 fault detection
IFLTCZ1	Check Zone 1 fault detection
IN101–IN107	Main board inputs
IN201–IN224	Optional I/O Board 1 inputs
IN301–IN323	Optional I/O Board 2 inputs
IN401–IN424	Optional I/O Board 3 inputs
IN501–IN524	Optional I/O Board 4 inputs
LB01–LB32	Local bits
LB_DP01–LB_DP32	Local bit status display (SELOGIC control equation)
LB_SP01–LB_SP32	Local bit supervision (SELOGIC control equation)
LBOKA	MIRRORED BITS communications Channel A normal status while in loopback mode
LBOKB	MIRRORED BITS communications Channel B normal status while in loopback mode
MATHERR	SELOGIC control equation math error
OC01–OC18	Circuit Breaker 01–Circuit Breaker 18 open command
OCTZ1	Zone 1 Open CT detection
OCTZ2	Zone 2 Open CT detection
OCTZ3	Zone 3 Open CT detection
OCTZ4	Zone 4 Open CT detection
OCTZ5	Zone 5 Open CT detection
OCTZ6	Zone 6 Open CT detection
OPH01–OPH18	Terminal 01–Terminal 18 open phase detected
OUT101–OUT108	Main board outputs
OUT201–OUT208	Optional I/O Board 1 outputs
OUT301–OUT308	Optional I/O Board 2 outputs
OUT401–OUT408	Optional I/O Board 3 outputs
OUT501–OUT508	Optional I/O Board 4 outputs
P87R1	Zone 1 instantaneous differential element picked up
P87R2	Zone 2 instantaneous differential element picked up
P87R3	Zone 3 instantaneous differential element picked up
P87R4	Zone 4 instantaneous differential element picked up
P87R5	Zone 5 instantaneous differential element picked up

Table A.1 Alphabetic List of Relay Word Bits (Sheet 10 of 14)

Name	Definition
P87R6	Zone 6 instantaneous differential element picked up
P87RCZ1	Check Zone 1 instantaneous differential element picked up
PB1–PB12	Pushbuttons
PB1_LED–PB12LED	Pushbutton LEDs
PB1_PUL–PB12PUL	Pushbutton pulse inputs (on for one processing interval when button is pushed)
PCN01Q–PCN32Q	Protection counter outputs
PCN01R–PCN32R	Protection counter resets
PCT01Q–PCT16Q	Protection conditioning timer outputs
PFRTEX	Protection SELOGIC control equation first execution
PLT01–PLT32	Protection latches
PST01Q–PST32Q	Protection sequencing timer outputs
PST01R–PST32R	Protection sequencing timer resets
PSV01–PSV64	Protection SELOGIC control equation variables
PUNRLBL	Protection SELOGIC control equation unresolved label
RB01–RB96	Remote bits
RBADA	Outage too long on MIRRORED BITS communications Channel A
RBADB	Outage too long on MIRRORED BITS communications Channel B
RDIF1	Zone 1 unfiltered restrained differential element picked up
RDIF2	Zone 2 unfiltered restrained differential element picked up
RDIF3	Zone 3 unfiltered restrained differential element picked up
RDIF4	Zone 4 unfiltered restrained differential element picked up
RDIF5	Zone 5 unfiltered restrained differential element picked up
RDIF6	Zone 6 unfiltered restrained differential element picked up
RDIFCZ1	Check Zone 1 unfiltered restrained differential element picked up
RMB1A–RMB8A	Channel A receive MIRRORED BITS communications
RMB1B–RMB8B	Channel B receive MIRRORED BITS communications
ROCTZ1	Reset Zone 1 Open CT Detector (SELOGIC control equation)
ROCTZ2	Reset Zone 2 Open CT Detector (SELOGIC control equation)
ROCTZ3	Reset Zone 3 Open CT Detector (SELOGIC control equation)
ROCTZ4	Reset Zone 4 Open CT Detector (SELOGIC control equation)
ROCTZ5	Reset Zone 5 Open CT Detector (SELOGIC control equation)
ROCTZ6	Reset Zone 6 Open CT Detector (SELOGIC control equation)
ROKA	Normal MIRRORED BITS communications Channel A status while not in loopback mode
ROKB	Normal MIRRORED BITS communications Channel B status while not in loopback mode
RST_BAT	Reset battery monitoring (SELOGIC control equation)
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC control equation)
RSTOCT1	Zone 1 Open CT detection reset

Table A.1 Alphabetic List of Relay Word Bits (Sheet 11 of 14)

Name	Definition
RSTOCT2	Zone 2 Open CT detection reset
RSTOCT3	Zone 3 Open CT detection reset
RSTOCT4	Zone 4 Open CT detection reset
RSTOCT5	Zone 5 Open CT detection reset
RSTOCT6	Zone 6 Open CT detection reset
RSTTRGT	Target reset (SELOGIC control equation)
RT01–RT18	Circuit Breaker 01–Circuit Breaker 18 retrip
RZSWOAL	Reset zone switching operation alarm
SALARM	Software alarm
SBFTR	Any circuit breaker failure trip
SBFTR01–SBFTR18	Circuit Breaker 01–Circuit Breaker 18 breaker failure trip
SG1	Settings Group 1 active
SG2	Settings Group 2 active
SG3	Settings Group 3 active
SG4	Settings Group 4 active
SG5	Settings Group 5 active
SG6	Settings Group 6 active
TESTDB	Communications card database test bit
TESTDNP	DNP test bit
TESTFM	Fast meter test bit
TESTPUL	Pulse test bit
TIRIG	Assert while time is based on IRIG for both mark and value
TLED_1	Trip LED 1
TLED_10	Trip LED 10
TLED_11	Trip LED 11
TLED_12	Trip LED 12
TLED_13	Trip LED 13
TLED_14	Trip LED 14
TLED_15	Trip LED 15
TLED_16	Trip LED 16
TLED_17	Trip LED 17
TLED_18	Trip LED 18
TLED_19	Trip LED 19
TLED_2	Trip LED 2
TLED_20	Trip LED 20
TLED_21	Trip LED 21
TLED_22	Trip LED 22
TLED_23	Trip LED 23
TLED_24	Trip LED 24
TLED_3	Trip LED 3
TLED_4	Trip LED 4

Table A.1 Alphabetic List of Relay Word Bits (Sheet 12 of 14)

Name	Definition
TLED_5	Trip LED 5
TLED_6	Trip LED 6
TLED_7	Trip LED 7
TLED_8	Trip LED 8
TLED_9	Trip LED 9
TMB1A	Channel A Transmit MIRRORED BIT 1
TMB1B	Channel B Transmit MIRRORED BIT 1
TMB2A	Channel A Transmit MIRRORED BIT 2
TMB2B	Channel B Transmit MIRRORED BIT 2
TMB3A	Channel A Transmit MIRRORED BIT 3
TMB3B	Channel B Transmit MIRRORED BIT 3
TMB4A	Channel A Transmit MIRRORED BIT 4
TMB4B	Channel B Transmit MIRRORED BIT 4
TMB5A	Channel A Transmit MIRRORED BIT 5
TMB5B	Channel B Transmit MIRRORED BIT 5
TMB6A	Channel A Transmit MIRRORED BIT 6
TMB6B	Channel B Transmit MIRRORED BIT 6
TMB7A	Channel A Transmit MIRRORED BIT 7
TMB7B	Channel B Transmit MIRRORED BIT 7
TMB8A	Channel A Transmit MIRRORED BIT 8
TMB8B	Channel B Transmit MIRRORED BIT 8
TOS01–TOS18	Terminal 01–Terminal 18 out of service
TRGTR	Reset all active target relay words
TRIP	Any terminal trip output
TRIP01–TRIP18	Terminal 01–Terminal 18 trip output
TRIPLED	Trip LED
TUPDH	Assert if update source is high-accuracy time source
ULTR01–ULTR18	Terminal 01–Terminal 18 unlatch trip
XBF01–XBF18	Circuit Breaker 01–Circuit Breaker 18 external breaker failure input (SELOGIC control equation)
Z1BZ1	Bus-Zone 1 is part of Protective Zone 1
Z1BZ2	Bus-Zone 2 is part of Protective Zone 1
Z1BZ3	Bus-Zone 3 is part of Protective Zone 1
Z1BZ4	Bus-Zone 4 is part of Protective Zone 1
Z1BZ5	Bus-Zone 5 is part of Protective Zone 1
Z1BZ6	Bus-Zone 6 is part of Protective Zone 1
Z1S	Zone 1 supervision asserted
Z2BZ2	Bus-Zone 2 is part of Protective Zone 2
Z2BZ3	Bus-Zone 3 is part of Protective Zone 2
Z2BZ4	Bus-Zone 4 is part of Protective Zone 2
Z2BZ5	Bus-Zone 5 is part of Protective Zone 2

Table A.1 Alphabetic List of Relay Word Bits (Sheet 13 of 14)

Name	Definition
Z2BZ6	Bus-Zone 6 is part of Protective Zone 2
Z2S	Zone 2 supervision asserted
Z3BZ3	Bus-Zone 3 is part of Protective Zone 3
Z3BZ4	Bus-Zone 4 is part of Protective Zone 3
Z3BZ5	Bus-Zone 5 is part of Protective Zone 3
Z3BZ6	Bus-Zone 6 is part of Protective Zone 3
Z3S	Zone 3 supervision asserted
Z4BZ4	Bus-Zone 4 is part of Protective Zone 4
Z4BZ5	Bus-Zone 5 is part of Protective Zone 4
Z4BZ6	Bus-Zone 6 is part of Protective Zone 4
Z4S	Zone 4 supervision asserted
Z5BZ5	Bus-Zone 5 is part of Protective Zone 5
Z5BZ6	Bus-Zone 6 is part of Protective Zone 5
Z5S	Zone 5 supervision asserted
Z6BZ6	Bus-Zone 6 is part of Protective Zone 6
Z6S	Zone 6 supervision asserted
ZN1I01–ZN1I18	Terminal 01–Terminal 18 connected to Zone 1
ZN1I01T–ZN1I18T	Terminal 01–Terminal 18 connected to Zone 1 and will be tripped
ZN2I01–ZN2I18	Terminal 01–Terminal 18 connected to Zone 2
ZN2I01T–ZN2I18T	Terminal 01–Terminal 18 connected to Zone 2 and will be tripped
ZN3I01–ZN3I18	Terminal 01–Terminal 18 connected to Zone 3
ZN3I01T–ZN3I18T	Terminal 01–Terminal 18 connected to Zone 3 and will be tripped
ZN4I01–ZN4I18	Terminal 01–Terminal 18 connected to Zone 4
ZN4I01T–ZN4I18T	Terminal 01–Terminal 18 connected to Zone 4 and will be tripped
ZN5I01–ZN5I18	Terminal 01–Terminal 18 connected to Zone 5
ZN5I01T–ZN5I18T	Terminal 01–Terminal 18 connected to Zone 5 and will be tripped
ZN6I01–ZN6I18	Terminal 01–Terminal 18 connected to Zone 6
ZN6I01T–ZN6I18T	Terminal 01–Terminal 18 connected to Zone 6 and will be tripped
ZONE1	Differential Zone 1 is active
ZONE2	Differential Zone 2 is active
ZONE3	Differential Zone 3 is active
ZONE4	Differential Zone 4 is active
ZONE5	Differential Zone 5 is active
ZONE6	Differential Zone 6 is active
ZSWO	Zone switching operation
ZSWOAL	Zone switching operation alarm
ZSWOIP	Zone switching operation in progress

Table A.1 Alphabetic List of Relay Word Bits (Sheet 14 of 14)

Name	Definition
ZSWOP	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in any zone
ZSWOP1	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 1
ZSWOP2	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 2
ZSWOP3	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 3
ZSWOP4	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 4
ZSWOP5	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 5
ZSWOP6	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 6

Table A.2 Row List of Relay Word Bits (Sheet 1 of 11)

Row	7	6	5	4	3	2	1	0
0	EN	TRIPLED	*	*	*	*	*	*
1	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
2	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
3	OPH08	OPH07	OPH06	OPH05	OPH04	OPH03	OPH02	OPH01
4	OPH16	OPH15	OPH14	OPH13	OPH12	OPH11	OPH10	OPH09
5	*	*	*	*	*	*	OPH18	OPH17
6	52AL03	52A03	52CL02	52AL02	52A02	52CL01	52AL01	52A01
7	52A06	52CL05	52AL05	52A05	52CL04	52AL04	52A04	52CL03
8	52CL08	52AL08	52A08	52CL07	52AL07	52A07	52CL06	52AL06
9	52AL11	52A11	52CL10	52AL10	52A10	52CL09	52AL09	52A09
10	52A14	52CL13	52AL13	52A13	52CL12	52AL12	52A12	52CL11
11	52CL16	52AL16	52A16	52CL15	52AL15	52A15	52CL14	52AL14
12	*	52AL	52CL18	52AL18	52A18	52CL17	52AL17	52A17
13	89CL02	89B02	89A02	89AL01	89OIP01	89CL01	89B01	89A01
14	89A04	89AL03	89OIP03	89CL03	89B03	89A03	89AL02	89OIP02
15	89OIP05	89CL05	89B05	89A05	89AL04	89OIP04	89CL04	89B04
16	89B07	89A07	89AL06	89OIP06	89CL06	89B06	89A06	89AL05
17	89AL08	89OIP08	89CL08	89B08	89A08	89AL07	89OIP07	89CL07
18	89CL10	89B10	89A10	89AL09	89OIP09	89CL09	89B09	89A09
19	89A12	89AL11	89OIP11	89CL11	89B11	89A11	89AL10	89OIP10
20	89OIP13	89CL13	89B13	89A13	89AL12	89OIP12	89CL12	89B12
21	89B15	89A15	89AL14	89OIP14	89CL14	89B14	89A14	89AL13
22	89AL16	89OIP16	89CL16	89B16	89A16	89AL15	89OIP15	89CL15
23	89CL18	89B18	89A18	89AL17	89OIP17	89CL17	89B17	89A17
24	89A20	89AL19	89OIP19	89CL19	89B19	89A19	89AL18	89OIP18
25	89OIP21	89CL21	89B21	89A21	89AL20	89OIP20	89CL20	89B20

Table A.2 **Row List of Relay Word Bits** (Sheet 2 of 11)

Row	7	6	5	4	3	2	1	0
26	89B23	89A23	89AL22	89OIP22	89CL22	89B22	89A22	89AL21
27	89AL24	89OIP24	89CL24	89B24	89A24	89AL23	89OIP23	89CL23
28	89CL26	89B26	89A26	89AL25	89OIP25	89CL25	89B25	89A25
29	89A28	89AL27	89OIP27	89CL27	89B27	89A27	89AL26	89OIP26
30	89OIP29	89CL29	89B29	89A29	89AL28	89OIP28	89CL28	89B28
31	89B31	89A31	89AL30	89OIP30	89CL30	89B30	89A30	89AL29
32	89AL32	89OIP32	89CL32	89B32	89A32	89AL31	89OIP31	89CL31
33	89CL34	89B34	89A34	89AL33	89OIP33	89CL33	89B33	89A33
34	89A36	89AL35	89OIP35	89CL35	89B35	89A35	89AL34	89OIP34
35	89OIP37	89CL37	89B37	89A37	89AL36	89OIP36	89CL36	89B36
36	89B39	89A39	89AL38	89OIP38	89CL38	89B38	89A38	89AL37
37	89AL40	89OIP40	89CL40	89B40	89A40	89AL39	89OIP39	89CL39
38	89CL42	89B42	89A42	89AL41	89OIP41	89CL41	89B41	89A41
39	89A44	89AL43	89OIP43	89CL43	89B43	89A43	89AL42	89OIP42
40	89OIP45	89CL45	89B45	89A45	89AL44	89OIP44	89CL44	89B44
41	89B47	89A47	89AL46	89OIP46	89CL46	89B46	89A46	89AL45
42	89AL48	89OIP48	89CL48	89B48	89A48	89AL47	89OIP47	89CL47
43	*	*	*	*	*	*	89OIP	89AL
44	I08BZ1V	I07BZ1V	I06BZ1V	I05BZ1V	I04BZ1V	I03BZ1V	I02BZ1V	I01BZ1V
45	I16BZ1V	I15BZ1V	I14BZ1V	I13BZ1V	I12BZ1V	I11BZ1V	I10BZ1V	I09BZ1V
46	*	*	*	*	*	*	I18BZ1V	I17BZ1V
47	*	*	*	*	*	*	*	*
48	I08BZ2V	I07BZ2V	I06BZ2V	I05BZ2V	I04BZ2V	I03BZ2V	I02BZ2V	I01BZ2V
49	I16BZ2V	I15BZ2V	I14BZ2V	I13BZ2V	I12BZ2V	I11BZ2V	I10BZ2V	I09BZ2V
50	*	*	*	*	*	*	I18BZ2V	I17BZ2V
51	*	*	*	*	*	*	*	*
52	I08BZ3V	I07BZ3V	I06BZ3V	I05BZ3V	I04BZ3V	I03BZ3V	I02BZ3V	I01BZ3V
53	I16BZ3V	I15BZ3V	I14BZ3V	I13BZ3V	I12BZ3V	I11BZ3V	I10BZ3V	I09BZ3V
54	*	*	*	*	*	*	I18BZ3V	I17BZ3V
55	*	*	*	*	*	*	*	*
56	I08BZ4V	I07BZ4V	I06BZ4V	I05BZ4V	I04BZ4V	I03BZ4V	I02BZ4V	I01BZ4V
57	I16BZ4V	I15BZ4V	I14BZ4V	I13BZ4V	I12BZ4V	I11BZ4V	I10BZ4V	I09BZ4V
58	*	*	*	*	*	*	I18BZ4V	I17BZ4V
59	*	*	*	*	*	*	*	*
60	I08BZ5V	I07BZ5V	I06BZ5V	I05BZ5V	I04BZ5V	I03BZ5V	I02BZ5V	I01BZ5V
61	I16BZ5V	I15BZ5V	I14BZ5V	I13BZ5V	I12BZ5V	I11BZ5V	I10BZ5V	I09BZ5V
62	*	*	*	*	*	*	I18BZ5V	I17BZ5V
63	*	*	*	*	*	*	*	*
64	I08BZ6V	I07BZ6V	I06BZ6V	I05BZ6V	I04BZ6V	I03BZ6V	I02BZ6V	I01BZ6V
65	I16BZ6V	I15BZ6V	I14BZ6V	I13BZ6V	I12BZ6V	I11BZ6V	I10BZ6V	I09BZ6V
66	*	*	*	*	*	*	I18BZ6V	I17BZ6V

Table A.2 Row List of Relay Word Bits (Sheet 3 of 11)

Row	7	6	5	4	3	2	1	0
67	*	*	*	*	*	*	*	*
68	ZN1I08	ZN1I07	ZN1I06	ZN1I05	ZN1I04	ZN1I03	ZN1I02	ZN1I01
69	ZN1I16	ZN1I15	ZN1I14	ZN1I13	ZN1I12	ZN1I11	ZN1I10	ZN1I09
70	*	*	*	*	*	*	ZN1I18	ZN1I17
71	*	*	*	*	*	*	*	*
72	ZN2I08	ZN2I07	ZN2I06	ZN2I05	ZN2I04	ZN2I03	ZN2I02	ZN2I01
73	ZN2I16	ZN2I15	ZN2I14	ZN2I13	ZN2I12	ZN2I11	ZN2I10	ZN2I09
74	*	*	*	*	*	*	ZN2I18	ZN2I17
75	*	*	*	*	*	*	*	*
76	ZN3I08	ZN3I07	ZN3I06	ZN3I05	ZN3I04	ZN3I03	ZN3I02	ZN3I01
77	ZN3I16	ZN3I15	ZN3I14	ZN3I13	ZN3I12	ZN3I11	ZN3I10	ZN3I09
78	*	*	*	*	*	*	ZN3I18	ZN3I17
79	*	*	*	*	*	*	*	*
80	ZN4I08	ZN4I07	ZN4I06	ZN4I05	ZN4I04	ZN4I03	ZN4I02	ZN4I01
81	ZN4I16	ZN4I15	ZN4I14	ZN4I13	ZN4I12	ZN4I11	ZN4I10	ZN4I09
82	*	*	*	*	*	*	ZN4I18	ZN4I17
83	*	*	*	*	*	*	*	*
84	ZN5I08	ZN5I07	ZN5I06	ZN5I05	ZN5I04	ZN5I03	ZN5I02	ZN5I01
85	ZN5I16	ZN5I15	ZN5I14	ZN5I13	ZN5I12	ZN5I11	ZN5I10	ZN5I09
86	*	*	*	*	*	*	ZN5I18	ZN5I17
87	*	*	*	*	*	*	*	*
88	ZN6I08	ZN6I07	ZN6I06	ZN6I05	ZN6I04	ZN6I03	ZN6I02	ZN6I01
89	ZN6I16	ZN6I15	ZN6I14	ZN6I13	ZN6I12	ZN6I11	ZN6I10	ZN6I09
90	*	*	*	*	*	*	ZN6I18	ZN6I17
91	*	*	*	*	*	*	*	*
92	ZN1I08T	ZN1I07T	ZN1I06T	ZN1I05T	ZN1I04T	ZN1I03T	ZN1I02T	ZN1I01T
93	ZN1I16T	ZN1I15T	ZN1I14T	ZN1I13T	ZN1I12T	ZN1I11T	ZN1I10T	ZN1I09T
94	*	*	*	*	*	*	ZN1I18T	ZN1I17T
95	*	*	*	*	*	*	*	*
96	ZN2I08T	ZN2I07T	ZN2I06T	ZN2I05T	ZN2I04T	ZN2I03T	ZN2I02T	ZN2I01T
97	ZN2I16T	ZN2I15T	ZN2I14T	ZN2I13T	ZN2I12T	ZN2I11T	ZN2I10T	ZN2I09T
98	*	*	*	*	*	*	ZN2I18T	ZN2I17T
99	*	*	*	*	*	*	*	*
100	ZN3I08T	ZN3I07T	ZN3I06T	ZN3I05T	ZN3I04T	ZN3I03T	ZN3I02T	ZN3I01T
101	ZN3I16T	ZN3I15T	ZN3I14T	ZN3I13T	ZN3I12T	ZN3I11T	ZN3I10T	ZN3I09T
102	*	*	*	*	*	*	ZN3I18T	ZN3I17T
103	*	*	*	*	*	*	*	*
104	ZN4I08T	ZN4I07T	ZN4I06T	ZN4I05T	ZN4I04T	ZN4I03T	ZN4I02T	ZN4I01T
105	ZN4I16T	ZN4I15T	ZN4I14T	ZN4I13T	ZN4I12T	ZN4I11T	ZN4I10T	ZN4I09T
106	*	*	*	*	*	*	ZN4I18T	ZN4I17T
107	*	*	*	*	*	*	*	*

Table A.2 Row List of Relay Word Bits (Sheet 4 of 11)

Row	7	6	5	4	3	2	1	0
108	ZN5I08T	ZN5I07T	ZN5I06T	ZN5I05T	ZN5I04T	ZN5I03T	ZN5I02T	ZN5I01T
109	ZN5I16T	ZN5I15T	ZN5I14T	ZN5I13T	ZN5I12T	ZN5I11T	ZN5I10T	ZN5I09T
110	*	*	*	*	*	*	ZN5I18T	ZN5I17T
111	*	*	*	*	*	*	*	*
112	ZN6I08T	ZN6I07T	ZN6I06T	ZN6I05T	ZN6I04T	ZN6I03T	ZN6I02T	ZN6I01T
113	ZN6I16T	ZN6I15T	ZN6I14T	ZN6I13T	ZN6I12T	ZN6I11T	ZN6I10T	ZN6I09T
114	*	*	*	*	*	*	ZN6I18T	ZN6I17T
115	*	*	*	*	*	*	*	*
116	*	*	BZ1BZ6V	BZ1BZ5V	BZ1BZ4V	BZ1BZ3V	BZ1BZ2V	*
117	*	*	BZ2BZ6V	BZ2BZ5V	BZ2BZ4V	BZ2BZ3V	*	*
118	*	*	BZ3BZ6V	BZ3BZ5V	BZ3BZ4V	*	*	*
119	*	*	BZ4BZ6V	BZ4BZ5V	*	*	*	*
120	*	*	BZ5BZ6V	*	*	*	*	*
121	*	*	*	*	*	*	*	*
122	*	*	*	*	*	*	*	*
123	*	*	*	*	*	*	*	*
124	*	*	BZ1BZ6R	BZ1BZ5R	BZ1BZ4R	BZ1BZ3R	BZ1BZ2R	*
125	*	*	BZ2BZ6R	BZ2BZ5R	BZ2BZ4R	BZ2BZ3R	*	*
126	*	*	BZ3BZ6R	BZ3BZ5R	BZ3BZ4R	*	*	*
127	*	*	BZ4BZ6R	BZ4BZ5R	*	*	*	*
128	*	*	BZ5BZ6R	*	*	*	*	*
129	*	*	*	*	*	*	*	*
130	*	*	*	*	*	*	*	*
131	*	*	*	*	*	*	*	*
132	*	*	Z1BZ6	Z1BZ5	Z1BZ4	Z1BZ3	Z1BZ2	Z1BZ1
133	*	*	Z2BZ6	Z2BZ5	Z2BZ4	Z2BZ3	Z2BZ2	*
134	*	*	Z3BZ6	Z3BZ5	Z3BZ4	Z3BZ3	*	*
135	*	*	Z4BZ6	Z4BZ5	Z4BZ4	*	*	*
136	*	*	Z5BZ6	Z5BZ5	*	*	*	*
137	*	*	Z6BZ6	*	*	*	*	*
138	*	*	ZONE6	ZONE5	ZONE4	ZONE3	ZONE2	ZONE1
139	*	ZSWOP	ZSWOP6	ZSWOP5	ZSWOP4	ZSWOP3	ZSWOP2	ZSWOP1
140	*	*	*	*	ZSWOAL	ZSWOIP	ZSWO	RZSWOAL
141	*	*	Z6S	Z5S	Z4S	Z3S	Z2S	Z1S
142	*	*	ROCTZ6	ROCTZ5	ROCTZ4	ROCTZ3	ROCTZ2	ROCTZ1
143	*	*	OCTZ6	OCTZ5	OCTZ4	OCTZ3	OCTZ2	OCTZ1
144	*	*	RSTOCT6	RSTOCT5	RSTOCT4	RSTOCT3	RSTOCT2	RSTOCT1
145	*	*	87S6	87S5	87S4	87S3	87S2	87S1
146	*	87ST	87ST6	87ST5	87ST4	87ST3	87ST2	87ST1
147	87R1	P87R1	87O1	FAULT1	CON1	EXT1	DOP1	DRT1
148	*	*	*	*	FDIF1	RDIF1	IFAULT1	GFAULT1

Table A.2 Row List of Relay Word Bits (Sheet 5 of 11)

Row	7	6	5	4	3	2	1	0
149	87R2	P87R2	87O2	FAULT2	CON2	EXT2	DOP2	DRT2
150	*	*	*	*	FDIF2	RDIF2	IFAULT2	GFAULT2
151	87R3	P87R3	87O3	FAULT3	CON3	EXT3	DOP3	DRT3
152	*	*	*	*	FDIF3	RDIF3	IFAULT3	GFAULT3
153	87R4	P87R4	87O4	FAULT4	CON4	EXT4	DOP4	DRT4
154	*	*	*	*	FDIF4	RDIF4	IFAULT4	GFAULT4
155	87R5	P87R5	87O5	FAULT5	CON5	EXT5	DOP5	DRT5
156	*	*	*	*	FDIF5	RDIF5	IFAULT5	GFAULT5
157	87R6	P87R6	87O6	FAULT6	CON6	EXT6	DOP6	DRT6
158	*	*	*	*	FDIF6	RDIF6	IFAULT6	GFAULT6
159	*	*	*	*	*	*	*	FAULT
160	*	*	DE6F	DE5F	DE4F	DE3F	DE2F	DE1F
161	50DS08	50DS07	50DS06	50DS05	50DS04	50DS03	50DS02	50DS01
162	50DS16	50DS15	50DS14	50DS13	50DS12	50DS11	50DS10	50DS09
163	*	*	*	*	*	*	50DS18	50DS17
164	*	CSL1	ACTRPT1	ACTRP1	CBCLST1	CBCLS1	CB52T1	CB52A1
165	*	CSL2	ACTRPT2	ACTRP2	CBCLST2	CBCLS2	CB52T2	CB52A2
166	*	CSL3	ACTRPT3	ACTRP3	CBCLST3	CBCLS3	CB52T3	CB52A3
167	*	CSL4	ACTRPT4	ACTRP4	CBCLST4	CBCLS4	CB52T4	CB52A4
168	TOS08	TOS07	TOS06	TOS05	TOS04	TOS03	TOS02	TOS01
169	TOS16	TOS15	TOS14	TOS13	TOS12	TOS11	TOS10	TOS09
170	*	*	*	*	*	*	TOS18	TOS17
171	FBF01	XBF01	RT01	ABFIT01	ATBFI01	BFIT01	BFI01	50F01
172	FBF02	XBF02	RT02	ABFIT02	ATBFI02	BFIT02	BFI02	50F02
173	FBF03	XBF03	RT03	ABFIT03	ATBFI03	BFIT03	BFI03	50F03
174	FBF04	XBF04	RT04	ABFIT04	ATBFI04	BFIT04	BFI04	50F04
175	FBF05	XBF05	RT05	ABFIT05	ATBFI05	BFIT05	BFI05	50F05
176	FBF06	XBF06	RT06	ABFIT06	ATBFI06	BFIT06	BFI06	50F06
177	FBF07	XBF07	RT07	ABFIT07	ATBFI07	BFIT07	BFI07	50F07
178	FBF08	XBF08	RT08	ABFIT08	ATBFI08	BFIT08	BFI08	50F08
179	FBF09	XBF09	RT09	ABFIT09	ATBFI09	BFIT09	BFI09	50F09
180	FBF10	XBF10	RT10	ABFIT10	ATBFI10	BFIT10	BFI10	50F10
181	FBF11	XBF11	RT11	ABFIT11	ATBFI11	BFIT11	BFI11	50F11
182	FBF12	XBF12	RT12	ABFIT12	ATBFI12	BFIT12	BFI12	50F12
183	FBF13	XBF13	RT13	ABFIT13	ATBFI13	BFIT13	BFI13	50F13
184	FBF14	XBF14	RT14	ABFIT14	ATBFI14	BFIT14	BFI14	50F14
185	FBF15	XBF15	RT15	ABFIT15	ATBFI15	BFIT15	BFI15	50F15
186	FBF16	XBF16	RT16	ABFIT16	ATBFI16	BFIT16	BFI16	50F16
187	FBF17	XBF17	RT17	ABFIT17	ATBFI17	BFIT17	BFI17	50F17
188	FBF18	XBF18	RT18	ABFIT18	ATBFI18	BFIT18	BFI18	50F18
189	50P04T	50P04	50P03T	50P03	50P02T	50P02	50P01T	50P01

Table A.2 Row List of Relay Word Bits (Sheet 6 of 11)

Row	7	6	5	4	3	2	1	0
190	50P08T	50P08	50P07T	50P07	50P06T	50P06	50P05T	50P05
191	50P12T	50P12	50P11T	50P11	50P10T	50P10	50P09T	50P09
192	50P16T	50P16	50P15T	50P15	50P14T	50P14	50P13T	50P13
193	*	*	*	*	50P18T	50P18	50P17T	50P17
194	51P03T	51P03	51P02R	51P02T	51P02	51P01R	51P01T	51P01
195	51P06	51P05R	51P05T	51P05	51P04R	51P04T	51P04	51P03R
196	51P08R	51P08T	51P08	51P07R	51P07T	51P07	51P06R	51P06T
197	51P11T	51P11	51P10R	51P10T	51P10	51P09R	51P09T	51P09
198	51P14	51P13R	51P13T	51P13	51P12R	51P12T	51P12	51P11R
199	51P16R	51P16T	51P16	51P15R	51P15T	51P15	51P14R	51P14T
200	*	*	51P18R	51P18T	51P18	51P17R	51P17T	51P17
201	*	*	27P32	27P31	27P22	27P21	27P12	27P11
202	*	*	59P32	59P31	59P22	59P21	59P12	59P11
203	*	*	*	*	59N2	59N1	59Q2	59Q1
204	87BTR08	87BTR07	87BTR06	87BTR05	87BTR04	87BTR03	87BTR02	87BTR01
205	87BTR16	87BTR15	87BTR14	87BTR13	87BTR12	87BTR11	87BTR10	87BTR09
206	*	*	*	*	*	87BTR	87BTR18	87BTR17
207	*	*	87Z6	87Z5	87Z4	87Z3	87Z2	87Z1
208	SBFTR08	SBFTR07	SBFTR06	SBFTR05	SBFTR04	SBFTR03	SBFTR02	SBFTR01
209	SBFTR16	SBFTR15	SBFTR14	SBFTR13	SBFTR12	SBFTR11	SBFTR10	SBFTR09
210	*	*	*	*	*	SBFTR	SBFTR18	SBFTR17
211	*	*	BFZ6	BFZ5	BFZ4	BFZ3	BFZ2	BFZ1
212	ER	EVELOCK	*	*	*	*	*	*
213	TRIP08	TRIP07	TRIP06	TRIP05	TRIP04	TRIP03	TRIP02	TRIP01
214	TRIP16	TRIP15	TRIP14	TRIP13	TRIP12	TRIP11	TRIP10	TRIP09
215	*	*	*	*	*	TRIP	TRIP18	TRIP17
216	ULTR08	ULTR07	ULTR06	ULTR05	ULTR04	ULTR03	ULTR02	ULTR01
217	ULTR16	ULTR15	ULTR14	ULTR13	ULTR12	ULTR11	ULTR10	ULTR09
218	*	*	*	*	*	*	ULTR18	ULTR17
219	DC1F	DC1W	DC1G	DC1R	*	*	*	*
220	*	OC04	*	OC03	*	OC02	*	OC01
221	*	OC08	*	OC07	*	OC06	*	OC05
222	*	OC12	*	OC11	*	OC10	*	OC09
223	*	OC16	*	OC15	*	OC14	*	OC13
224	*	*	*	*	*	OC18	*	OC17
225	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
226	*	*	*	*	*	*	*	*
227	*	*	*	*	*	*	*	*
228	LB08	LB07	LB06	LB05	LB04	LB03	LB02	LB01
229	LB16	LB15	LB14	LB13	LB12	LB11	LB10	LB09
230	LB24	LB23	LB22	LB21	LB20	LB19	LB18	LB17

Table A.2 Row List of Relay Word Bits (Sheet 7 of 11)

Row	7	6	5	4	3	2	1	0
231	LB32	LB31	LB30	LB29	LB28	LB27	LB26	LB25
232	RB89	RB90	RB91	RB92	RB93	RB94	RB95	RB96
233	RB81	RB82	RB83	RB84	RB85	RB86	RB87	RB88
234	RB73	RB74	RB75	RB76	RB77	RB78	RB79	RB80
235	RB65	RB66	RB67	RB68	RB69	RB70	RB71	RB72
236	RB57	RB58	RB59	RB60	RB61	RB62	RB63	RB64
237	RB49	RB50	RB51	RB52	RB53	RB54	RB55	RB56
238	RB41	RB42	RB43	RB44	RB45	RB46	RB47	RB48
239	RB33	RB34	RB35	RB36	RB37	RB38	RB39	RB40
240	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
241	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
242	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
243	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
244	*	IN107	IN106	IN105	IN104	IN103	IN102	IN101
245	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
246	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
247	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
248	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
249	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
250	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
251	IN408	IN407	IN406	IN405	IN404	IN403	IN402	IN401
252	IN416	IN415	IN414	IN413	IN412	IN411	IN410	IN409
253	IN424	IN423	IN422	IN421	IN420	IN419	IN418	IN417
254	IN508	IN507	IN506	IN505	IN504	IN503	IN502	IN501
255	IN516	IN515	IN514	IN513	IN512	IN511	IN510	IN509
256	IN524	IN523	IN522	IN521	IN520	IN519	IN518	IN517
257	*	*	*	*	*	*	*	*
258	*	*	*	*	*	*	*	*
259	*	*	*	*	*	*	*	*
260	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
261	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
262	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
263	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
264	PSV40	PSV39	PSV38	PSV37	PSV36	PSV35	PSV34	PSV33
265	PSV48	PSV47	PSV46	PSV45	PSV44	PSV43	PSV42	PSV41
266	PSV56	PSV55	PSV54	PSV53	PSV52	PSV51	PSV50	PSV49
267	PSV64	PSV63	PSV62	PSV61	PSV60	PSV59	PSV58	PSV57
268	PLT08	PLT07	PLT06	PLT05	PLT04	PLT03	PLT02	PLT01
269	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
270	PLT24	PLT23	PLT22	PLT21	PLT20	PLT19	PLT18	PLT17
271	PLT32	PLT31	PLT30	PLT29	PLT28	PLT27	PLT26	PLT25

Table A.2 Row List of Relay Word Bits (Sheet 8 of 11)

Row	7	6	5	4	3	2	1	0
272	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
273	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
274	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
275	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
276	PST24Q	PST23Q	PST22Q	PST21Q	PST20Q	PST19Q	PST18Q	PST17Q
277	PST32Q	PST31Q	PST30Q	PST29Q	PST28Q	PST27Q	PST26Q	PST25Q
278	PST08R	PST07R	PST06R	PST05R	PST04R	PST03R	PST02R	PST01R
279	PST16R	PST15R	PST14R	PST13R	PST12R	PST11R	PST10R	PST09R
280	PST24R	PST23R	PST22R	PST21R	PST20R	PST19R	PST18R	PST17R
281	PST32R	PST31R	PST30R	PST29R	PST28R	PST27R	PST26R	PST25R
282	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
283	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
284	PCN24Q	PCN23Q	PCN22Q	PCN21Q	PCN20Q	PCN19Q	PCN18Q	PCN17Q
285	PCN32Q	PCN31Q	PCN30Q	PCN29Q	PCN28Q	PCN27Q	PCN26Q	PCN25Q
286	PCN08R	PCN07R	PCN06R	PCN05R	PCN04R	PCN03R	PCN02R	PCN01R
287	PCN16R	PCN15R	PCN14R	PCN13R	PCN12R	PCN11R	PCN10R	PCN09R
288	PCN24R	PCN23R	PCN22R	PCN21R	PCN20R	PCN19R	PCN18R	PCN17R
289	PCN32R	PCN31R	PCN30R	PCN29R	PCN28R	PCN27R	PCN26R	PCN25R
290	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV001
291	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
292	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
293	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
294	ASV040	ASV039	ASV038	ASV037	ASV036	ASV035	ASV034	ASV033
295	ASV048	ASV047	ASV046	ASV045	ASV044	ASV043	ASV042	ASV041
296	ASV056	ASV055	ASV054	ASV053	ASV052	ASV051	ASV050	ASV049
297	ASV064	ASV063	ASV062	ASV061	ASV060	ASV059	ASV058	ASV057
298	ASV072	ASV071	ASV070	ASV069	ASV068	ASV067	ASV066	ASV065
299	ASV080	ASV079	ASV078	ASV077	ASV076	ASV075	ASV074	ASV073
300	ASV088	ASV087	ASV086	ASV085	ASV084	ASV083	ASV082	ASV081
301	ASV096	ASV095	ASV094	ASV093	ASV092	ASV091	ASV090	ASV089
302	ASV104	ASV103	ASV102	ASV101	ASV100	ASV099	ASV098	ASV097
303	ASV112	ASV111	ASV110	ASV109	ASV108	ASV107	ASV106	ASV105
304	ASV120	ASV119	ASV118	ASV117	ASV116	ASV115	ASV114	ASV113
305	ASV128	ASV127	ASV126	ASV125	ASV124	ASV123	ASV122	ASV121
306	ASV136	ASV135	ASV134	ASV133	ASV132	ASV131	ASV130	ASV129
307	ASV144	ASV143	ASV142	ASV141	ASV140	ASV139	ASV138	ASV137
308	ASV152	ASV151	ASV150	ASV149	ASV148	ASV147	ASV146	ASV145
309	ASV160	ASV159	ASV158	ASV157	ASV156	ASV155	ASV154	ASV153
310	ASV168	ASV167	ASV166	ASV165	ASV164	ASV163	ASV162	ASV161
311	ASV176	ASV175	ASV174	ASV173	ASV172	ASV171	ASV170	ASV169
312	ASV184	ASV183	ASV182	ASV181	ASV180	ASV179	ASV178	ASV177

Table A.2 Row List of Relay Word Bits (Sheet 9 of 11)

Row	7	6	5	4	3	2	1	0
313	ASV192	ASV191	ASV190	ASV189	ASV188	ASV187	ASV186	ASV185
314	ASV200	ASV199	ASV198	ASV197	ASV196	ASV195	ASV194	ASV193
315	ASV208	ASV207	ASV206	ASV205	ASV204	ASV203	ASV202	ASV201
316	ASV216	ASV215	ASV214	ASV213	ASV212	ASV211	ASV210	ASV209
317	ASV224	ASV223	ASV222	ASV221	ASV220	ASV219	ASV218	ASV217
318	ASV232	ASV231	ASV230	ASV229	ASV228	ASV227	ASV226	ASV225
319	ASV240	ASV239	ASV238	ASV237	ASV236	ASV235	ASV234	ASV233
320	ASV248	ASV247	ASV246	ASV245	ASV244	ASV243	ASV242	ASV241
321	ASV256	ASV255	ASV254	ASV253	ASV252	ASV251	ASV250	ASV249
322	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
323	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
324	ALT24	ALT23	ALT22	ALT21	ALT20	ALT19	ALT18	ALT17
325	ALT32	ALT31	ALT30	ALT29	ALT28	ALT27	ALT26	ALT25
326	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
327	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
328	AST24Q	AST23Q	AST22Q	AST21Q	AST20Q	AST19Q	AST18Q	AST17Q
329	AST32Q	AST31Q	AST30Q	AST29Q	AST28Q	AST27Q	AST26Q	AST25Q
330	AST08R	AST07R	AST06R	AST05R	AST04R	AST03R	AST02R	AST01R
331	AST16R	AST15R	AST14R	AST13R	AST12R	AST11R	AST10R	AST09R
332	AST24R	AST23R	AST22R	AST21R	AST20R	AST19R	AST18R	AST17R
333	AST32R	AST31R	AST30R	AST29R	AST28R	AST27R	AST26R	AST25R
334	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
335	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
336	ACN24Q	ACN23Q	ACN22Q	ACN21Q	ACN20Q	ACN19Q	ACN18Q	ACN17Q
337	ACN32Q	ACN31Q	ACN30Q	ACN29Q	ACN28Q	ACN27Q	ACN26Q	ACN25Q
338	ACN08R	ACN07R	ACN06R	ACN05R	ACN04R	ACN03R	ACN02R	ACN01R
339	ACN16R	ACN15R	ACN14R	ACN13R	ACN12R	ACN11R	ACN10R	ACN09R
340	ACN24R	ACN23R	ACN22R	ACN21R	ACN20R	ACN19R	ACN18R	ACN17R
341	ACN32R	ACN31R	ACN30R	ACN29R	ACN28R	ACN27R	ACN26R	ACN25R
342	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
343	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
344	SALARM	HALARM	BADPASS	CCALARM	CCOK	*	*	*
345	*	*	TIRIG	TUPDH	*	*	*	*
346	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
347	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
348	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
349	OUT408	OUT407	OUT406	OUT405	OUT404	OUT403	OUT402	OUT401
350	OUT508	OUT507	OUT506	OUT505	OUT504	OUT503	OUT502	OUT501
351	PB1	PB2	PB3	PB4	PB5	PB6	PB7	PB8
352	PB1_PUL	PB2_PUL	PB3_PUL	PB4_PUL	PB5_PUL	PB6_PUL	PB7_PUL	PB8_PUL
353	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED

Table A.2 Row List of Relay Word Bits (Sheet 10 of 11)

Row	7	6	5	4	3	2	1	0
354	RST_BAT	RSTDNPE	*	*	*	*	*	*
355	TRGTR	RSTTRGT	*	*	*	*	*	*
356	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
357	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
358	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
359	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
360	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*
361	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
362	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
363	*	*	*	*	*	*	*	*
364	CCIN121	CCIN122	CCIN123	CCIN124	CCIN125	CCIN126	CCIN127	CCIN128
365	CCIN113	CCIN114	CCIN115	CCIN116	CCIN117	CCIN118	CCIN119	CCIN120
366	CCIN105	CCIN106	CCIN107	CCIN108	CCIN109	CCIN110	CCIN111	CCIN112
367	CCIN097	CCIN098	CCIN099	CCIN100	CCIN101	CCIN102	CCIN103	CCIN104
368	CCIN089	CCIN090	CCIN091	CCIN092	CCIN093	CCIN094	CCIN095	CCIN096
369	CCIN081	CCIN082	CCIN083	CCIN084	CCIN085	CCIN086	CCIN087	CCIN088
370	CCIN073	CCIN074	CCIN075	CCIN076	CCIN077	CCIN078	CCIN079	CCIN080
371	CCIN065	CCIN066	CCIN067	CCIN068	CCIN069	CCIN070	CCIN071	CCIN072
372	CCIN057	CCIN058	CCIN059	CCIN060	CCIN061	CCIN062	CCIN063	CCIN064
373	CCIN049	CCIN050	CCIN051	CCIN052	CCIN053	CCIN054	CCIN055	CCIN056
374	CCIN041	CCIN042	CCIN043	CCIN044	CCIN045	CCIN046	CCIN047	CCIN048
375	CCIN033	CCIN034	CCIN035	CCIN036	CCIN037	CCIN038	CCIN039	CCIN040
376	CCIN025	CCIN026	CCIN027	CCIN028	CCIN029	CCIN030	CCIN031	CCIN032
377	CCIN017	CCIN018	CCIN019	CCIN020	CCIN021	CCIN022	CCIN023	CCIN024
378	CCIN009	CCIN010	CCIN011	CCIN012	CCIN013	CCIN014	CCIN015	CCIN016
379	CCIN001	CCIN002	CCIN003	CCIN004	CCIN005	CCIN006	CCIN007	CCIN008
380	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
381	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
382	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
383	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
384	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
385	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
386	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
387	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
388	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*
389	*	*	*	*	*	*	*	CZONE1
390	*	*	*	*	*	*	*	CZ1S
391	*	*	*	*	*	*	*	87CZ1
392	I08CZ1V	I07CZ1V	I06CZ1V	I05CZ1V	I04CZ1V	I03CZ1V	I02CZ1V	I01CZ1V
393	I16CZ1V	I15CZ1V	I14CZ1V	I13CZ1V	I12CZ1V	I11CZ1V	I10CZ1V	I09CZ1V
394	*	*	*	*	*	*	I18CZ1V	I17CZ1V

Table A.2 Row List of Relay Word Bits (Sheet 11 of 11)

Row	7	6	5	4	3	2	1	0
395	*	*	*	*	*	*	*	*
396	*	*	*	*	*	*	*	*
397	*	*	*	*	*	*	*	*
398	*	*	*	*	*	*	*	*
399	*	*	*	*	*	*	*	*
400	*	*	*	*	*	*	*	*
401	*	*	*	*	*	*	*	*
402	*	*	*	*	*	*	*	*
403	*	*	*	*	*	*	*	*
404	*	*	*	*	*	*	*	87SCZ1
405	*	*	*	*	*	*	*	87STCZ1
406	87RCZ1	P87RCZ1	87OCZ1	FLTCZ1	CONCZ1	EXTCZ1	DOPCZ1	DRTCZ1
407	*	*	*	*	FDIFCZ1	RDIFCZ1	IFLTCZ1	GFLTCZ1
408	*	*	*	*	*	*	*	*
409	*	*	*	*	*	*	*	*
410	*	*	*	*	*	*	*	*
411	*	*	*	*	*	*	*	*
412	*	*	*	*	*	*	*	DECZ1F
413	LB_SP08	LB_SP07	LB_SP06	LB_SP05	LB_SP04	LB_SP03	LB_SP02	LB_SP01
414	LB_SP16	LB_SP15	LB_SP14	LB_SP13	LB_SP12	LB_SP11	LB_SP10	LB_SP09
415	LB_SP24	LB_SP23	LB_SP22	LB_SP21	LB_SP20	LB_SP19	LB_SP18	LB_SP17
416	LB_SP32	LB_SP31	LB_SP30	LB_SP29	LB_SP28	LB_SP27	LB_SP26	LB_SP25
417	LB_DP08	LB_DP07	LB_DP06	LB_DP05	LB_DP04	LB_DP03	LB_DP02	LB_DP01
418	LB_DP16	LB_DP15	LB_DP14	LB_DP13	LB_DP12	LB_DP11	LB_DP10	LB_DP09
419	LB_DP24	LB_DP23	LB_DP22	LB_DP21	LB_DP20	LB_DP19	LB_DP18	LB_DP17
420	LB_DP32	LB_DP31	LB_DP30	LB_DP29	LB_DP28	LB_DP27	LB_DP26	LB_DP25
421	TLED_17	TLED_18	TLED_19	TLED_20	TLED_21	TLED_22	TLED_23	TLED_24
422	PB9	PB10	PB11	PB12	*	*	*	*
423	PB9_LED	PB10LED	PB11LED	PB12LED	*	*	*	*
424	PB9_PUL	PB10PUL	PB11PUL	PB12PUL	*	*	*	*

Appendix B
Analog Quantities

Overview

This section contains a table of the analog quantities available within the SEL-487B Relay. For information on using analog quantities in protection and automation, see the SEL-487B *Applications Handbook*.

Analog Quantities

Use this section as a reference for analog quantities. *Table B.1* groups the analog quantities by function; *Table B.2* groups the analog quantities alphabetically.

Table B.1 Analog Quantities Sorted by Function (Sheet 1 of 3)

Label	Description	Units
Current		
I*nn*FIM[a]	Phase filtered instantaneous current magnitude	A (sec)
I*nn*FIA[a]	Phase filtered instantaneous current angle	degrees
I*nn*FM[a]	Phase one-cycle average current magnitude	A (pri)
I*nn*FA[a]	Phase one-cycle average current angle	degrees
IOP*k*[b]	Zone *k* operating current	pu
IOPCZ1	Check Zone 1 operating current	pu
IRT*k*[b]	Zone *k* restraint current	pu
IRTCZ1	Check Zone 1 operating current	pu
IOP*k*F[b]	Zone *k* one-cycle average operating current	pu
IOPCZ1F	Check Zone 1 one-cycle average operating current	pu
IRT*k*F[b]	Zone *k* one-cycle average restraint current	pu
IRTCZ1F	Check Zone 1 one-cycle average restraint current	pu
Voltage		
V*mm*FIM[c]	Phase filtered instantaneous voltage magnitude	V (sec)
V*mm*FIA[c]	Phase filtered instantaneous voltage angle	degrees
V*mm*FM[c]	Phase one-cycle average voltage magnitude	kV (pri)
V*mm*FA[c]	Phase one-cycle average voltage angle	degrees
V1FIM	Positive-sequence filtered instantaneous voltage magnitude, V1	V (sec)
3V2FIM	Negative-sequence filtered instantaneous voltage magnitude, 3V2	V (sec)

Table B.1 Analog Quantities Sorted by Function (Sheet 2 of 3)

Label	Description	Units
3V0FIM	Zero-sequence filtered instantaneous voltage magnitude, 3V0	V (sec)
DC1	Filtered dc monitor voltage	V
DC1PO	Average positive-to-ground dc voltage	V
DC1NE	Average negative-to-ground dc voltage	V
DC1RI	AC ripple of dc voltage (peak-to-peak)	V
DC1MIN	Minimum dc voltage	V
DC1MAX	Maximum dc voltage	V
Database Structure		
RA001–RA256	Remote analogs from Ethernet card	N/A
Date and Time		
TODMS	Time of day in milliseconds (0–86399999)	ms
THR	Hour (0–23)	hours
TMIN	Minute (0–59)	minutes
TSEC	Seconds (0–59)	seconds
TMSEC	Milliseconds (0–999)	ms
DDOW	Day of the week (Encoded value: 1=Sun, 2=Mon, 3=Tue, 4=Wed, 5=Thu, 6=Fri, 7=Sat)	n/a
DDOM	Day of the month (1–31)	n/a
DDOY	Day of the year (1–366)	n/a
DMON	Month (1–12)	n/a
DYEAR	Year (2000–2200)	n/a
MIRRORED BITS®		
MB1A–MB7A	MIRRORED BITS® communications Channel A received analog values	n/a
MB1B–MB7B	MIRRORED BITS® communications Channel B received analog values	n/a
SELOGIC® and Automation Elements		
PMV01–PMV64	Protection SELOGIC® control equation math variable	n/a
PCT01PU–PCT16PU	Protection conditioning timer pickup time	cycles
PCT01DO–PCT16DO	Protection conditioning timer dropout time	cycles
PST01ET–PST32ET	Protection sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection sequencing timer preset time	cycles
PCN01CV–PCN32CV	Protection counter current value	n/a
PCN01PV–PCN32PV	Protection counter preset value	n/a
AMV001–AMV256	Automation SELOGIC® control equation math variable	n/a
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds

Table B.1 Analog Quantities Sorted by Function (Sheet 3 of 3)

Label	Description	Units
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
ACN01CV–ACN32CV	Automation counter current value	n/a
ACN01PV–ACN32PV	Automation counter preset value	n/a
Setting Group		
ACTGRP	Active group setting	n/a

[a] nn = 01-18
[b] k = 1-6
[c] mm = 01-03

Table B.2 Analog Quantities Sorted Alphabetically (Sheet 1 of 2)

Label	Description	Units
3V0FIM	Zero-sequence filtered instantaneous voltage magnitude, 3V0	V (sec)
3V2FIM	Negative-sequence filtered instantaneous voltage magnitude, 3V2	V (sec)
ACN01CV–ACN32CV	Automation counter current value	n/a
ACN01PV–ACN32PV	Automation counter preset value	n/a
ACTGRP	Active group setting	n/a
AMV001–AMV256	Automation SELOGIC® control equation math variable	n/a
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
DC1	Filtered dc monitor voltage	V
DC1MAX	Maximum dc voltage	V
DC1MIN	Minimum dc voltage	V
DC1NE	Average negative-to-ground dc voltage	V
DC1PO	Average positive-to-ground dc voltage	V
DC1RI	AC ripple of dc voltage (peak-to-peak)	V
DDOM	Day of the month (1–31)	n/a
DDOW	Day of the week (encoded value: 1=Sun, 2=Mon, 3=Tue, 4=Wed, 5=Thu, 6=Fri, 7=Sat)	n/a
DDOY	Day of the year (1–366)	n/a
DMON	Month (1–12)	n/a
DYEAR	Year (2000–2200)	n/a
I*nn*FA[a]	Phase one-cycle average current angle	degrees
I*nn*FIA[a]	Phase filtered instantaneous current angle	degrees
I*nn*FIM[a]	Phase filtered instantaneous current magnitude	A (sec)
I*nn*FM[a]	Phase one-cycle average current magnitude	A (pri)
IOP*k*[b]	Zone *k* operating current	pu

Table B.2 Analog Quantities Sorted Alphabetically (Sheet 2 of 2)

Label	Description	Units
IOPCZ1	Check Zone 1 operating current	pu
IOP*k*F[b]	Zone *k* one-cycle average operating current	pu
IOPCZ1F	Check Zone 1 one-cycle average operating current	pu
IRT*k*[b]	Zone *k* restraint current	pu
IRTCZ1	Check Zone 1 restraint current	pu
IRT*k*F[b]	Zone *k* one-cycle average restraint current	pu
IRTCZ1F	Check Zone 1 one-cycle average restraint current	pu
MB1A–MB7A	MIRRORED BITS communications Channel A received analog values	n/a
MB1B–MB7B	MIRRORED BITS communications Channel B received analog values	n/a
PCN01CV–PCN32CV	Protection counter current value	n/a
PCN01PV–PCN32PV	Protection counter preset value	n/a
PCT01DO–PCT16DO	Protection conditioning timer dropout time	cycles
PCT01PU–PCT16PU	Protection conditioning timer pickup time	cycles
PMV01–PMV64	Protection SELOGIC control equation math variable	n/a
PST01ET–PST32ET	Protection sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection sequencing timer preset time	cycles
RA001–RA256	Remote analogs from Ethernet card	n/a
THR	Hour (0–23)	hours
TMIN	Minute (0–59)	minutes
TMSEC	Milliseconds (0–999)	ms
TODMS	Time of day in milliseconds (0–86399999)	ms
TSEC	Seconds (0–59)	seconds
V1FIM	Positive-sequence filtered instantaneous voltage magnitude, V1	V (sec)
V*mm*FA[c]	Phase one-cycle average voltage angle	degrees
V*mm*FIA[c]	Phase filtered instantaneous voltage angle	degrees
V*mm*FIM[c]	Phase filtered instantaneous voltage magnitude	V (sec)
V*mm*FM[c]	Phase one-cycle average voltage magnitude	kV (pri)

[a] nn = 01–18.
[b] k = 1–6.
[c] mm = 01–03.

Glossary

9U	The designation of the vertical height of a device in rack units. Nine rack units, 9U, total approximately 400 mm (15.75 inches).
7U	The designation of the vertical height of a device in rack units. Seven rack units, 7U, total approximately 311 mm (12.25 inches).
A	Abbreviation for amps or amperes; unit of electrical current flow.
a contact	A normally open auxiliary contact that closes when the device is closed and opens when the device is open.
ABS Operator	An operator in math SELOGIC® control equations that provides absolute value.
AC Ripple	The peak-to-peak ac component of a signal or waveform. In the station dc battery system, monitoring ac ripple provides an indication of whether the substation battery charger has failed.
Acceptance Testing	Testing that confirms that the relay meets published critical performance specifications and requirements of the intended application. This involves testing protection elements and logic functions when qualifying a relay model for use on the utility system.
Access Level	A relay command level with a specified set of relay information and commands. All access levels, except for Access Level 0, require the correct password.
Access Level 0	The least secure and most limited access level; not password protected. You must enter a password from this level to go to a higher level.
Access Level 1	The default access level for the relay front panel, used to monitor (view) relay information.
Access Level 2	The most secure access level, from which you have total relay functionality and control of all settings types.
Access Level A	A relay command level used to access all Access Level 1 and Access Level B (Breaker) functions, plus Alias, Automation, Global, Front Panel, Report, Port, and DNP settings.
Access Level B	A relay command level used for Access Level 1 functions, plus circuit breaker control and data.
Access Level O	A relay command level used to access all Access Level 1 and Access Level B (Breaker) functions, plus Alias, Output, Global, Front Panel, Report, Port, and DNP settings.
Access Level P	A relay command level used to access all Access Level 1 and Access Level B (Breaker) functions, plus Protection, Global, Group, Front Panel, Report, Port, Alias, Zone configuration, and DNP settings.

ACSELERATOR Architect® SEL-5032 Software
ACSELERATOR Architect is an add-on to the ACSELERATOR Suite that utilizes the IEC 61850 Substation Configuration Language to configure SEL IEDs.

ACSELERATOR QuickSet® SEL-5030 Software
A Windows®-based program that simplifies settings and provides analysis support.

ACSI
Abstract Communications Service Interface for the IEC 61850 protocol. Defines a set of objects, a set of services to manipulate and access those objects, and a base set of data types for describing objects.

Active Settings Group
The settings group that the SEL-487B is presently using from among six settings groups available in the relay.

Active Zone
A zone is active when any I*qq*BZ*p*V (*qq* = 01–18, *p* = 1–6) Relay Word bit asserts. For example, Zone 1 becomes active when Relay Word bit I01BZ1V asserts.

Advanced Settings
Settings for customizing protection functions; these settings are hidden unless you set EADVS := Y.

Alias
An alternative name assigned to Relay Word bits, analog quantities, default terminals, and bus-zone names.

Analog Quantities
Variables represented by such fluctuating measurable quantities as temperature, frequency, current, and voltage.

AND Operator
Logical AND. An operator in Boolean SELOGIC control equations that requires fulfillment of conditions on both sides of the operator before the equation is true.

ANSI Standard Device Numbers
A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include the following:

27	Undervoltage Element
50	Overcurrent Element
51	Inverse Time-Overcurrent Element
52	AC Circuit Breaker
59	Overvoltage Element
86	Breaker Failure Lockout
89	Disconnect

These numbers are frequently used within a suffix letter to further designate their application. The suffix letters used in this instruction manual include the following:

P	Phase Element
N	Neutral/Ground Element
Q	Negative-Sequence Element

Anti-Aliasing Filter
A low pass filter that blocks frequencies too high for the given sampling rate.

ASCII
Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The SEL-487B uses ASCII text characters to communicate, through front- and rear-panel EIA-232 serial ports and virtual serial ports.

ASCII Terminal A terminal without built-in logic or local processing capability that can only send and receive information.

Assert To activate. To fulfill the logic or electrical requirements needed to operate a device. To set a logic condition to the true state (logical 1) of that condition. To apply a closed contact to an SEL-487B input. To close a normally open output contact. To open a normally closed output contact.

AT Modem Command Set Dialing String Standard The command language standard that Hayes Microcomputer Products, Inc. developed to control auto-dial modems from an ASCII terminal (usually EIA-232 connected) or a PC (personal computer) containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, baud rate, passwords, relay elements, and other information that an IED (e.g., SEL-2020/2030/2032 Communications Processor) needs to automatically communicate with relays.

Automatic Messages Messages including status failure and status warning messages that the relay generates at the serial ports and displays automatically on the front-panel LCD.

Automation Variables Variables that are included in automation SELOGIC control equations.

AX-S4 MMS “Access for MMS” is an IEC 61850, UCA2, and MMS client application produced by SISCO, Inc., for real-time data integration in Microsoft Windows-based systems supporting OPC and DDE. Included with AX-S4 MMS is the interactive MMS Object Explorer for browser-like access to IEC 61850 / UCA2 and MMS device objects.

b contact A normally closed auxiliary contact that opens when the device is closed and closes when the device is open.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Bit Label The identifier for a particular bit.

Bit Value Logical 0 or logical 1.

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators, such as AND, NOT, and OR.

Breaker Auxiliary Contact An electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A Form A breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed and opens when the breaker is open. A Form B breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Breaker-and-a-Half Configuration A switching station arrangement of three circuit breakers per two circuits; the two circuits share one of the circuit breakers.

Breaker Differential Differential zone of protection configured exclusively across the tie breaker; the breaker differential protects only the area between the two tie-breaker CTs.

Buffered Report IEC 61850 IEDs can issue buffered reports of internal events (caused by trigger options data-change, quality-change, and data-update). These event reports can be sent immediately or buffered (to some practical limit) for transmission, such that values of data are not lost due to transport flow control constraints or loss of connection. Buffered reporting provides sequence-of-events (SOE) functionality.

Busbar Electrical junction of two or more primary circuits. For a single busbar, there could be multiple bus-zones; there can be more bus-zones than busbars, but not more busbars than bus-zones.

Buscoupler (see also Tie Breaker) Equipment with at least a current transformer and circuit breaker, connecting two busbars when the circuit breaker is closed. Disconnects of other terminals at the station (feeders, lines, etc.) are normally arranged in parallel with the buscoupler. Closing two or more disconnects of the other terminals bypasses the buscoupler, forming a connection without a circuit breaker between two or more busbars.

Busbar Protection Element Each of the six busbar protection elements comprise a differential element, a directional element, and a fault detection logic.

Bus Sectionalizer (see also Buscoupler) Equipment with at least a current transformer and circuit breaker, connecting two busbars when the circuit breaker is closed.

Bus-Zone-to-Bus-Zone Connection Variable SELOGIC variable stating the conditions when the relay merges two zones to form a single protection zone.

Bus-Zone (see also Protection Zone) Area of protection formed by a minimum of two terminals.

Category A collection of similar relay settings.

Checksum A method for checking the accuracy of data transmission, involving summation of a group of digits and comparison of this sum to a previously calculated value.

Check Zone Protection zone formed by two or more terminals where the differential calculation is independent of the status of the disconnect auxiliary contacts.

CID Checksum identification of the firmware.

CID File IEC 61850 Configured IED Description file. XML file that contains the configuration for a specific IED.

Circuit Breaker Failure Logic This logic within the SEL-487B detects and warns of failure or incomplete operation of a circuit breaker in clearing a fault or in performing a trip or close sequence.

Class The first level of the relay settings structure, including Global, Group, Breaker Monitor, Port, Report, Front Panel, DNP settings, Protection SELOGIC control equations, Automation SELOGIC control equations, and Output SELOGIC control equations.

Commissioning Testing Testing that serves to validate all system ac and dc connections and confirm that the relay, auxiliary equipment, and SCADA interface all function as intended with your settings. Perform such testing when installing a new protection system.

Common Data Class IEC 61850 grouping of data objects that model substation functions. Common Data Classes include Status information, Measured information, Controllable status, Controllable analog, Status settings, Analog settings, and Description information.

Common Inputs Relay control inputs that share a common terminal.

Communications Protocol A language for communication between devices.

Comparison Boolean SELOGIC control equation operation that compares two numerical values. Compares floating-point values, such as currents, total counts, and other measured and calculated quantities.

Computer Terminal Emulation Software Software such as Microsoft® HyperTerminal® or ProComm Plus® that can be used to send and receive ASCII text messages and files via a computer serial port.

COMTRADE Abbreviation for Common Format for Transient Data Exchange.

Conditioning Timers Timers for conditioning Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state.

Contact Input See Control Input.

Contact Output See Control Output.

Control Input Relay input for monitoring the state of external circuits. Connects auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay output that affects the state of other equipment. Connects control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

COS Operator Operator in math SELOGIC control equations that provides the cosine function.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

CT Current transformer.

CT Subsidence Current Subsidence current appears as a small exponentially decaying dc current with a long time constant. This current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load.

CTR Current transformer ratio.

Current Transformer Saturation CT condition when the CT does not reproduce the primary current with the specified accuracy.

Data Attribute In the IEC 61850 protocol, the name, format, range of possible values, and representation of values being communicated.

Data Bit A single unit of information that can assume a value of either logical 0 or logical 1 and can convey control, address, information, or frame check sequence data.

Data Class In the IEC 61850 protocol, an aggregation of classes or data attributes.

Data Label The identifier for a particular data item.

Data Object In the IEC 61850 protocol, part of a logical node representing specific information (status or measurement, for example). From an object-oriented point of view, a data object is an instance of a data class.

DC Offset A dc component of fault current that results from the physical phenomenon preventing an instantaneous change of current in an inductive circuit.

DCE Devices Data communication equipment devices (modems).

Deadband The range of variation an analog quantity can traverse before causing a response.

Deassert To deactivate. To remove the logic or electrical requirements needed to operate a device. To clear a logic condition to its false state (logical 0). To open the circuit or open the contacts across an SEL-487B input. To open a normally open output contact. To close a normally closed output contact.

Debounce Time The time that masks the period when relay contacts continue to move after closing; debounce time covers this indeterminate state.

Default Data Map The default map of objects and indices that the SEL-487B uses in DNP protocol.

Differential Element Using the busbar as reference, the differential element calculates the difference between current towards the busbars and away from the busbars.

Directional Element The directional element compares the direction of current at the reference terminal to the direction of current at all other terminals in each protection zone.

Disconnect (Isolator) Mechanical switch that isolates primary equipment such as circuit breakers from the electrical system.

DNP (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol primarily intended for SCADA applications; owned and controlled by the DNP User's Group (www.dnp.org).

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. You can set the time, in the case of a logic variable timer, or the dropout time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

DTE Devices Data terminal equipment (computers, terminals, printers, relays, etc.).

DTT (Direct Transfer Trip) A communications-assisted tripping scheme. A relay at one end of a line sends a tripping signal to the relay at the opposite end of the line.

Dumb Terminal See ASCII terminal.

Dynamic Zone Selection The process by which the currents from the CTs are assigned to or removed from the differential calculations as a function of the boolean value (logical 0 or logical 1) of a particular SELOGIC equation.

EEPROM Electrically Erasable Programmable Read-Only Memory. Nonvolatile memory where relay settings, event reports, SER records, and other nonvolatile data are stored.

EHV Extra high voltage. Voltages greater than 230 kV.

EIA-232 Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

EIA-485 Electrical standard for multidrop serial data communications interfaces, based on the standard EIA/TIA-485. Formerly known as RS-485.

Electrical Operating Time Time between trip or close initiation and an open phase status change.

Electromechanical Reset Setting of the relay to match the reset characteristics of an electromechanical overcurrent relay.

End-Zone Fault A fault between the circuit breaker and the CT of a terminal.

ESD (Electrostatic Discharge) The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

Ethernet A network physical and data link layer defined by IEEE® 802.2 and IEEE 802.3.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; fault location; maximum fault phase current; active group at the trigger instant; and targets.

Event Report A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or ASCII **TRI** command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, time source, etc. The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

EXP Operator Math SELOGIC control equation operator that provides exponentiation.

F_TRIG Falling-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a falling edge.

Fail-Safe Refers to an output that is open during normal relay operation and closed when relay power is removed or if the relay fails. Configure alarm outputs for fail-safe operation.

Falling Edge Transition from logical 1 to logical 0.

Fast Meter SEL binary serial port command used to collect metering data with SEL relays.

Fast Operate SEL binary serial port command used to perform control with SEL relays.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Fault Detection Logic Logic that distinguishes between internal and external faults.

Float High The highest charging voltage supplied by a battery charger.

Float Low The lowest charging voltage supplied by a battery charger.

Form C Output An output with both an a output and b output sharing a common post.

Free-Form Logic Custom logic creation and execution order.

Free-Form SELOGIC Control Equations Free-form relay programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

FTP File transfer protocol.

Function In IEC 61850, task(s) performed by the substation automation system, i.e., by application functions. Generally, functions exchange data with other functions. Details are dependent on the functions involved.

Functions are performed by IEDs (physical devices). A function may be split into parts residing in different IEDs but communicating with each other (distributed function) and with parts of other functions. These communicating parts are called logical nodes.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

Functional Component Portion of an IEC 61850 Logical Node dedicated to a particular function including status, control, and descriptive tags.

Fundamental Frequency The component of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Global Settings General settings including those for relay and station identifiers, number of breakers, number of disconnects, date format, nominal system frequency, enables, station dc monitoring, control inputs, settings group selection, and data reset controls.

GOMSFE Generic Object Model for Substation and Feeder Equipment; a system for presenting and exchanging IED data.

GOOSE IEC 61850 Generic Object Oriented Substation Event. GOOSE objects can quickly and conveniently transfer status, controls, and measured values among peers on an IEC 61850 network.

GPS Global Positioning System. Source of position and high-accuracy time information.

GUI Graphical user interface.

Hexadecimal Address An address reference represented as a base-16 value. Hexadecimal number representation is typically indicated by a 0x prefix or an h suffix.

HMI Human machine interface.

Local HMI: the LCD display on each of the SEL-487B relays.

System HMI: the display connected to the SEL-2030 that dynamically shows the station linking arrangement.

Station HMI: the equipment from which station-wide data acquisition and control are performed.

HV High voltage. System voltage greater than or equal to 100 kV and less than 230 kV.

I01–I18 Input phase currents.

ICD File IEC 61850 IED Capability Description file. XML file that describes IED capabilities, including information on logical node and GOOSE support.

IEC 61850 Internationally standardized method of communications and integration conceived with the goal of supporting systems of multivendor IEDs networked together to perform protection, monitoring, automation, metering, and control.

IED Intelligent electronic device.

IGBT Insulated gate bipolar junction transistor.

Inboard CT (bushing CT) Current transformer physically positioned in such a way that the CT is bypassed when the feeder is on transfer.

Input Conditioning The establishment of debounce time and assertion level.

Instance A subdivision of a relay settings class. Group settings have several subdivisions (Group 1–Group 6), while the Global settings class has one instance.

IP Address An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the IP address of the destination. The format of an IP address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

IRIG-B A time code input that the relay can use to set the internal relay clock.

Jitter Time, amplitude, frequency, or phase-related abrupt, spurious variations in duration, magnitude, or frequency.

L/R Circuit inductive/resistive ratio.

Latch Bits Nonvolatile storage locations for binary information.

LED Light-emitting diode. Used as indicators on the relay front panel.

Left-Side Value LVALUE. Result storage location of a SELOGIC control equation.

Line Impedance The phasor sum of resistance and reactance in the form of positive-sequence, negative-sequence, and zero-sequence impedances of the protected line.

LMD SEL distributed port switch protocol.

LN Operator Math SELOGIC control equation operator that provides natural logarithm.

Local Bits The Relay Word bit outputs of local control switches that you access through the SEL-487B front panel. Local control switches replace traditional panel mounted control switches.

Lockout Relay An auxiliary relay that prevents operation of associated devices until it is reset either electrically or manually.

Logical 0 A false logic condition, dropped out element, or deasserted control input or control output.

Logical 1 A true logic condition, picked up element, or asserted control input or control output.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function.

Low-Level Test Interface An interface that provides a means for interrupting the connection between the relay input transformers and the input processing module and allows inserting reduced-scale test quantities for relay testing.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

Maintenance Testing Testing that confirms that the relay is measuring ac quantities accurately and verifies correct functioning of auxiliary equipment, scheme logic, and protection elements.

Math Operations Calculations for automation or extended protection functions.

Math Operators Operators that you use in the construction of math SELOGIC control equations to manipulate numerical values.

Maximum Dropout Time The maximum time interval following a change of input conditions between the deassertion of the input and the deassertion of the output.

Mechanical Operating Time Time between trip initiation or close initiation and the change in status of an associated circuit breaker auxiliary 52A normally open contacts.

MIRRORED BITS® Communications Patented relay-to-relay communications protocol that sends internal logic status, encoded in a digital message, from one relay to the other. Eliminates the need for some communications hardware.

MMS Manufacturing Messaging Specification, a data exchange protocol used by IEC 61850 and UCA.

MOD Motor-operated disconnect.

MOV Metal-oxide varistor.

Negation Operator A SELOGIC control equation math operator that changes the sign of the argument. The argument of the negation operation is multiplied by –1.

Negative Sequence Use the following expression to calculate the negative-sequence voltage:

$$3V_2 = V_A + a^2V_B + aV_C$$

where a = 1 ∠ 120°

NEMA National Electrical Manufacturers' Association.

Nonvolatile Memory Relay memory that persists over time to maintain the contained data even when the relay is de-energized.

NOT Operator A logical operator that produces the inverse value.

OR Operator Logical OR. A Boolean SELOGIC control equation operator that compares two Boolean values and yields either a logical 1 if either compared Boolean value is logical 1 or a logical 0 if both compared Boolean values are logical 0.

OSI Open Systems Interconnect. A model for describing communications protocols. Also an ISO suite of protocols designed to this model.

Outboard CT Current transformer physically positioned in such a way that the CT remains in circuit when the feeder is on transfer.

Overlap Configuration Configuration of the tie-breaker protection whereby the area between the tie-breaker CTs are part of two bus-zones, i.e., a fault between the tie-breaker CTs is common to two bus-zones.

Override Values Test values you enter in Fast Meter and DNP storage.

Parentheses Operator Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Phase Overcurrent Element Elements that operate by comparing the phase current applied to the secondary current inputs with the phase overcurrent setting. The relay asserts these elements when any combination of the phase currents exceeds phase current setting thresholds.

Pickup Time The time measured from the application of an input signal until the output signal asserts. You can set the time, as in the case of a logic variable timer, or the pickup time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

Port Settings Communications port settings such as Data Bits, Speed, and Stop Bits.

Positive-Sequence Use the following expression to calculate the positive-sequence voltage:

$$3V_1 = V_A + aV_B + a^2V_C$$

Where a = 1 ∠ 120°

Primitive Name The mnemonic current labels (I01, I02 through I18), voltage labels (V01, V02 and V03) and bus-zone labels (BZ1, BZ2 through BZ6).

Protection and Automation Separation Segregation of protection and automation processing and settings.

Protection Settings Group	Individual scheme settings for as many as six different schemes (or instances).
Protection-Disabled State	Suspension of relay protection element and trip/close logic processing and de-energization of all control outputs.
Protection Zone (also see Bus-Zone)	Area of protection formed by a minimum of one bus-zone. A protection zone can include more than one bus-zone. For example, merging two bus-zones results in a single protection zone. When no bus-zones are merged, a protection zone and a bus-zone have the same meanings.
PT	Potential transformer. Also referred to as a voltage transformer or VT.
PTR	Potential transformer ratio.
Qualifier Code	Specifies type of range for DNP3 objects. With the help of qualifier codes, DNP master devices can compose the shortest, most concise messages.
R_TRIG	Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.
RAM	Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data.
Relay Word Bit	A single relay element or logic result. A Relay Word bit can equal either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted control input or control output. Logical 0 represents a false logic condition, dropped out element, or deasserted control input or control output. Use Relay Word bits in SELOGIC control equations.
Remapping	The process of selecting data from the default map and configuring new indices to form a smaller data set optimized to your application.
Remote Bit	A Relay Word bit with a state that is controlled by serial port commands, including the **CONTROL** command, a binary Fast Operate command, DNP binary output operation, or an IEC 61850 control operation.
Report Settings	Event report and Sequential Events Recorder settings.
Retrip	A subsequent act of attempting to open the contacts of a circuit breaker after the failure of an initial attempt to open these contacts.
Rising Edge	Transition from logical 0 to logical 1, or the beginning of an operation.
RMS	Root-mean-square. This is the effective value of the current and voltage measured by the relay, accounting for the fundamental frequency and higher order harmonics in the signal.
RTU	Remote Terminal Unit.
RXD	Received data.
SCADA	Supervisory control and data acquisition.
SCD File	IEC 61850 Substation Configuration Description file. XML file that contains information on all IEDs within a substation, communications configuration data, and a substation description.

SCL IEC 61850 Substation Configuration Language. An XML-based configuration language that supports the exchange of database configuration data among different software tools that can be from different manufacturers. There are four types of SCL files used within IEC 61850: CID, ICD, SCD, and SSD.

Self-Description A feature of the IEC 61850 protocol. A master device can request a description of all of the Logical Nodes and data within the IED.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates detection of an out-of-tolerance condition. The SEL-487B has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as a control output) using a logical combination of relay element outputs and fixed logic outputs.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR software for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

Sequencing Timers Timers designed for sequencing automated operations.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a list that you set in the relay. SER provides a useful way to determine the order and timing of events of a relay operation.

SER Sequential Events Recorder or the relay serial port command to request a report of the latest 1000 sequential events.

Settle/Settling Time Time required for an input signal to result in an unvarying output signal within a specified range.

Single-CT Application Tie breaker with only one CT available for busbar protection.

Single Relay Application Stations with as many as 18 per-phase CTs require only one SEL-487B. Stations with more than 18 and as many as 54 per-phase CTs require three SEL-487B relays.

SIN Operator Operator in math SELOGIC control equations that provides the sine function.

SQRT Operator Math SELOGIC control equation operator that provides square root.

SSD File IEC 61850 System Specification Description file. XML file that describes the single-line diagram of the substation and the required logical nodes.

Status Failure A severe out-of-tolerance internal operating condition. The relay issues a status failure message and enters a protection-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise relay protection, yet are beyond expected limits. The relay issues a status warning message and continues to operate.

Strong Password A mix of valid password characters in a six-character combination that does not spell common words in any portion of the password. Valid password characters are numbers, upper- and lowercase alphabetic characters, period (.), and hyphen (-).

Subnet Mask The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

Subsidence Current See CT subsidence current.

Telnet An Internet protocol for exchanging terminal data that connects a computer to a network server and allows control of that server and communication with other servers on the network.

Terminal Any equipment with at least a current transformer and a circuit breaker.

Terminal-to-Bus-Zone Connection Variable SELOGIC variable stating the conditions when the relay considers the current input from a particular terminal in the differential calculations of a particular bus-zone.

Thermal Withstand Capability The capability of equipment to withstand a predetermined temperature value for a specified time.

Three-Phase Fault A fault involving all three phases of a three-phase power system.

Three-Pole Trip A circuit breaker operation that occurs when the circuit breaker opens all three poles at the same time.

Three-Relay Application Stations with more than 18 and as many as 54 per-phase CTs require three SEL-487B relays. Stations with as many as 18 per-phase CTs require only one SEL-487B.

Tie Breaker See buscoupler and bus sectionalizer.

Time Delay on Pickup The time interval between initiation of a signal at one point and detection of the same signal at another point.

Time Dial A control that governs the time scale of the time-overcurrent characteristic of a relay. Use the time-dial setting to vary relay operating time.

Time-Delayed Tripping Tripping that occurs after expiration of a predetermined time.

Time-Overcurrent Element An element that operates according to an inverse relationship between input current and time, with higher current causing faster relay operation.

Torque Control A method of using one relay element to supervise the operation of another.

Total Clearing Time The time interval from the beginning of a fault condition to final interruption of the circuit.

TXD Transmitted data.

UCA2 Utility Communications Architecture version 2. A network-independent protocol suite that serves as an interface for individual intelligent electronic devices.

Unbalanced Fault All faults that do not include all three phases of a system.

Unbuffered Report IEC 61850 IEDs can issue immediate unbuffered reports of internal events (caused by trigger options data-change, quality-change, and data-update) on a "best efforts" basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

User ST Region in GOOSE for user-specified applications.

V01, V02, V03 Voltage input terminals.

Virtual Terminal Connection A mechanism that uses a virtual serial port to provide the equivalent functions of a dedicated serial port and a terminal.

VT Voltage transformer. Also referred to as a potential transformer or PT.

Warm Start The reset of a running system without removing and restoring power.

Wye A phase-to-neutral connection of circuit elements, particularly voltage transformers or loads. To form a wye connection using transformers, connect the nonpolarity side of each of three voltage transformer secondaries in common (the neutral), and take phase to neutral voltages from each of the remaining three leads. When properly phased, these leads represent the A-phase-, B-phase-, and C-phase-to-neutral voltages. This connection is frequently called four-wire wye, alluding to the three phase leads plus the neutral lead.

XML Extensible Markup Language. This specification developed by the W3C (World Wide Web Consortium) is a pared-down version of SGML designed especially for web documents. It allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data among applications and organizations.

Zero Sequence Use the following expression to calculate the zero-sequence voltage:

$$3V_0 = V_A + V_B + V_C$$

Z-Number That portion of the relay FID string that identifies the proper ACSELERATOR software relay driver version and HMI driver version when creating or editing relay settings files.

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Page numbers appearing in bold mark the location of the topic's primary discussion.

A=Applications Handbook U=User's Guide R=Reference Manual

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SEL-487B Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
AACCESS	Go to Access Level A (automation control)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor relay and control circuit breakers)
BNAME	ASCII names of all relay status bits (Fast Meter)
CASCII	Generate the Compressed ASCII response configuration message
CEVENT	**EVENT** command for the Compressed ASCII response
CHISTORY	**HISTORY** command for the Compressed ASCII response
COMM *c*	Display relay-to-relay MIRRORED BITS® communications data (*c* = A is channel A; *c* = B is channel B; *c* = M is either enabled single channel)
CONTROL *nn*	Set, clear, or pulse an internal remote bit (*nn* is the remote bit number from 01–96)
COPY *m n*	Copy settings between instances in the same class (*m* and *n* are instance numbers; for example: *m* = 1 is Group 1; *n* = 2 is Group 2)
CSER	**SER** command for the Compressed ASCII response
CSTATUS	**STATUS** command for the Compressed ASCII response
CSUMMARY	**SUMMARY** command for the Compressed ASCII response
DATE	Display and set the date
DNAME X	ASCII names of all relay digital I/O (Fast Meter)
DNP	Access or modify serial port DNP3 settings (similar to **SHOW D** and **SET D**)
EVENT	Display and acknowledge event reports
FILE	Transfer data between the relay and external software
GROUP	Display the active group number or select the active group
HELP	Display available commands or command help at each access level
HISTORY	View event summaries/histories; clear event data
ID	Display the firmware id, user id, device code, part number, and configuration information
LOOPBACK	Connect MIRRORED BITS data from transmit to receive on the same port
MAP 1	Analyze the communications card database
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output control)
OPEN *n*	Open the circuit breaker (*n* = 1–18)
PACCESS	Go to Access Level P (protection control)
PASSWORD	Change relay passwords
PORT	Connect to a remote relay via MIRRORED BITS® virtual terminal (for port number *p* = 1–3 and F), or to the Ethernet card (port *p* = 5)
PULSE OUT*nnn*	Pulse a relay control output (OUT*nnn* is a control output number)
QUIT	Reduce access level to Access Level 0 (exit relay control)
SER	View Sequential Events Recorder reports
SET[c]	Enter relay settings
SHOW[c]	Display relay settings

Command[a, b]	Description
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Report or clear relay status and SELOGIC® control equation errors
SUMMARY	View summary event reports
TARGET	Display relay elements for a row in the Relay Word table
TEST DB	Display or place values in the communications card database (useful for Ethernet protocol read tests)
TEST DNP	Display or place values in the serial port DNP3 object map
TEST FM	Display or place values in metering database (Fast Meter)
TIME	Display and set the internal clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configurations
VIEW 1	View data from the communications card database
ZONE	Display the terminal and bus names associated with all active protective zones

[a] See Section 7: ASCII Command Reference in the Reference Manual.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.
[c] See the table below for **SET/SHOW** options.

SET/SHOW Command Options

Option	Setting Type	Description
[S] *n*	Group Settings 1–6	Particular application settings
A *n*	Automation Logic Block 1–10	Automation SELOGIC control equations
D	DNP3	Direct Network Protocol remapping (serial port only)
F	Front Panel	Front-panel HMI settings
G	Global	Relay-wide settings
L *n*	Protection Logic Group 1–6	Protection SELOGIC control equations
O	Outputs	Output SELOGIC control equations
P *n*	Port 1–3, F, 5	Communications port settings
R	Report	Event report and SER settings
T	Alias	Alias names for analog quantities and Relay Word bits
Z *n*	Zone Configuration Group 1–6	Zone configuration settings

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