SEL-451 Relay

Protection, Automation, and Control System

Instruction Manual

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Preface

This manual provides information and instructions for installing and operating the SEL-451 Relay. The three volumes that comprise this manual are for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples. While this manual gives reasonable examples and illustrations of relay uses, you must exercise sound judgment at all times when applying the SEL-451 in a power system. Throughout the manual, we provide margin notes next to the text explaining a feature to specify the availability of that feature in the SEL-451-1 and SEL-451-2 versions of the relay.

Manual Overview

The SEL-451 Relay Manual consists of three volumes:

- User's Guide
- Applications Handbook
- Reference Manual

In addition, the SEL-451 Relay Manual contains a comprehensive Index that encompasses the entire manual. The index appears at the end of each printed volume. In the electronic version of the manual, the index appears once; hyperlinks take you to material referenced in the index. Also included is a glossary that lists and defines technical terms used throughout the manual.

The SEL-451 Relay Manual is a comprehensive work covering all aspects of relay application and use. Read the sections that pertain to your application to gain valuable information about using the SEL-451. For example, to learn about relay protection functions, read the protection sections of this manual and skim the automation sections, then 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.

Preface. Describes manual organization and conventions used to present information (appears once in the electronic form of the manual; repeated in each printed volume).

User's Guide

Section 1: Introduction and Specifications. Introduces SEL-451 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, PTs, and a GPS receiver); explains basic connections for the relay communications ports and how to install optional communications cards (such as the SEL-2701 Ethernet Processor).

Section 3: PC Software. Explains 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, operating relay control outputs and control inputs, and using relay features to make relay commissioning easier.

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-451; 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.

Applications Handbook

Section 1: Protection Application Examples. Provides the following protection schemes with explanations and settings:

- 25 kV Overhead Distribution Line Example
- Auto-Reclose Example
- Auto-Reclose and Synchronism check Example
- Circuit Breaker Failure Application Examples

Section 2: Monitoring and Metering. Describes how to use the circuit breaker monitors and the substation dc battery monitors; provides information on viewing fundamental and rms metering quantities for voltages and currents, as well as power and energy metering data.

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

Section 4: Time-Synchronized Measurements. Explains synchronized phasor measurements and estimation of power system states using the SEL-451 high-accuracy time-stamping capability; presents real-time load flow/power flow application ideas.

Section 5: Bay Control. Describes the features of the SEL-451-4 Bay Control Relay; presents circuit breaker and disconnect switch logic, one-line diagram display, settings example, and predefined bay configurations.

Section 6: SEL Communications Processor Applications. Provides examples of how to use the SEL-451 with the SEL-2032, SEL-2030, and SEL-2020 Communications Processors for total substation automation solutions.

Section 7: 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 function of various relay protection elements; describes how the relay processes these elements; gives detailed specifics on protection scheme logic for POTT, DCB, and DCUB; provides trip logic diagrams, and current and voltage source selection details.

Section 2: Auto-Reclosing and Synchronism Check. Explains how to operate the SEL-451 two-circuit breaker multi-shot recloser; shows selection of the lead and follow circuit breakers; explains how to set and apply synchronism-check elements for automatic and manual closing.

Section 3: SELOGIC Control Equations. Describes multiple setting groups and 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 4: Communications Interfaces. Explains the physical connection of the SEL-451 to various communications network topologies.

Section 5: 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 6: DNP3 Communications. Describes the DNP 3.00 communications protocol and how to apply this protocol to substation integration and automation; provides an example for implementing DNP 3.00 in a substation.

Section 7: Synchrophasors. Describes the Phasor Measurement Unit (PMU) functions of the SEL-451; provides details on synchrophasor measurement; describes the IEEE C37.118 synchrophasor protocol settings; describes the SEL Fast Message synchrophasor protocol settings.

Section 8: 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 9: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 10: Settings. Provides a list of all SEL-451 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.

CD-ROM

The CD-ROM contains the SEL-451 Relay manual in an electronic form that you can search easily.

Conventions

Typographic Conventions

There are three ways to communicate with the SEL-451:

- Using a command line interface in a PC terminal emulation window.
- 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-451 Instruction Manual, certain SEL trademarks appear in small caps. These include SELOGIC control equations, MIRRORED BITS communications, and the 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.

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-451. These examples are for demonstration purposes only; the firmware identification information or settings values included in these examples may not necessarily match those in the current version of your SEL-451.

Notes

Margin notes serve two purposes in the SEL-451 Relay Manual. 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.

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>

Step-by-Step Procedures

The SEL-451 Relay 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-451 Relay 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 format of a single step is the following:

- Synopsis of the step (if the step involves multiple actions)
- Tasks to perform the step (listed as a., b., c., etc. if the step involves multiple actions)
- Explanatory text or how the relay responds (if applicable)

The following text shows sample steps. Steps include explanations, text references, table references, and figure references to further illustrate the step.

Synopsis

Step 1. Establish communication.

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

Tasks

b. 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 2. Confirm that you have loaded the correct passwords in ACSELERATOR.

a. Click **Communication > Port Parameters**.

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

Step 3. Click **Settings > Read** to read the present configuration in the SEL-451.

The relay sends all configuration and settings data to ACSELERATOR.

Step 4. Select settings by clicking 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 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.

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 o 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.

Logic Diagrams

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

NAME	SYMBOL	FUNCTION
COMPARATOR		Input A is compared to input B. Output C asserts if A is greater than B.
INPUT FLAG		Input A comes from other logic.
OR		Either input A or input B asserted cause output C to assert.
EXCLUSIVE OR		If either A or B is asserted, output C is asserted. If A and B are of the same state, C is deasserted.
NOR		If neither A nor B asserts, output C asserts.
AND		Input A and input B must assert to assert output C.
AND W/ INVERTED INPUT		If input A is asserted and input B is deasserted, output C asserts. Inverter "0" inverts any input or output on any gate.
NAND		If A and/or B are deasserted, output C is asserted.
TIME DELAYED PICK UP AND/OR TIME DELAYED DROP OUT		X is a time-delay-pickup value; Y is a time-delay-dropout value. B asserts time X after input A asserts; B will not assert if A does not remain asserted for time X. If X is zero, B will assert when A asserts. If Y is zero, B will deassert when A deasserts.
EDGE TRIGGER TIMER		Rising edge of A starts timers. Output B will assert time X after the rising edge of A. B will remain asserted for time Y. If Y is zero, B will assert for a single processing interval. Input A is ignored while the timers are running.
SET RESET FLIP FLOP		Input S asserts output Q until input R asserts. Output Q deasserts or resets when R asserts.
FALLING EDGE		B asserts at the falling edge of input A.

SEL-451 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 Equipment damage can result from connecting ac circuits to Hybrid (high-current-interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.	**⚠ATTENTION** Des dommages à l'appareil pourraient survenir si un circuit CA était raccordé aux contacts de sortie à haut pouvoir de coupure de type "Hybrid." Ne pas raccorder de circuit CA aux contacts de sortie de type "Hybrid." Utiliser uniquement du CC avec les contacts de sortie de type "Hybrid."
⚠CAUTION Substation battery systems that have either a high resistance to ground (greater than 10 kΩ) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.	**⚠ATTENTION** Les circuits de batterie de postes qui présentent une haute résistance à la terre (plus grande que 10 kΩ) ou sont isolés peuvent présenter un biais de tension CC entre les deux polarités de la batterie quand utilisés avec plusieurs entrées à couplage direct. Des conditions similaires peuvent exister pour des systèmes de surveillance de batterie qui utilisent des circuits d'équilibrage à haute résistance ou des masses flottantes. Pour ce type d'applications, SEL peut fournir en option des contacts d'entrée isolés (par couplage optoélectronique). De surcroît, SEL a publié des recommandations relativement à cette application. Contacter l'usine pour plus d'informations.
⚠CAUTION If you are planning to install an INT4 I/O Interface Board in your relay (see Table 2.3 and Table 2.4 for board descriptions), first check the firmware version of the relay—see Firmware Version Number on page U.6.36. If the firmware version is R111 or lower, you must first upgrade the relay firmware to the newest version and verify that the firmware upgrade was successful before installing the new board. Failure to install the new firmware first will cause the I/O Interface Board to fail, and it may require factory service. Complete firmware upgrade instructions are provided when new firmware is ordered.	**⚠ATTENTION** Si vous avez l'intention d'installer une Carte d'Interface INT4 I/O dans votre relais (voit Table 2.3 et Table 2.4 pour la description de la carte), vérifiez en premier la version du logiciel du relais (voir l'indentification de la Version du logiciel [Firmware Version Number on page U.6.36]). Si la version est R111 ou antérieure, vous devez mettre à jour le logiciel du relais avec la version la plus récente et vérifier que la mise à jour a été correctement installée sur la nouvelle carte. Les instructions complètes de mise à jour sont fournies quand le nouveau logiciel est commandé.
⚠CAUTION Field replacement of I/O boards INT1, INT2, INT5, INT6, INT7, or INT8 with INT4 can cause I/O contact failure. The INT4 board has a pickup and dropout delay setting range of 0–1 cycle. For all other I/O boards, pickup and dropout delay settings (IN201PU–IN224PU, IN201DO–IN224DO, IN301PU–IN324PU, and IN301DO–IN324DO) have a range of 0–5 cycles. Upon replacing any I/O board with an INT4 board, manually confirm reset of pickup and dropout delays to within the expected range of 0–1 cycle.	**⚠ATTENTION** Le remplacement en chantier des cartes d'entrées/sorties INT1, INT2, INT5, INT6, INT7 ou INT8 par une carte INT4 peut causer la défaillance du contact d'entrée/sortie. La carte INT4 présente un intervalle d'ajustement pour les délais de montée et de retombée de 0 à 1 cycle. Pour toutes les autres cartes, l'intervalle de réglage du délai de montée et retombée (IN201PU–IN224PU, IN201DO– IN224DO, IN301PU–IN324PU, et IN301DO–IN324DO) est de 0 à 5 cycles. Quand une carte d'entrées/sorties est remplacée par une carte INT4, vérifier manuellement que les délais de montée et retombée sont dans l'intervalle de 0 à 1 cycle.

English	French
⚠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 opération intempestive du relais pourrait résulter suite à l'installation d'un cavalier entre les positions J18A et J18D.
⚠CAUTION Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.	**⚠ATTENTION** Un niveau d'isolation insuffisant peut entraîner une détérioration sous des conditions anormales et causer des dommages à l'équipement. Pour les circuits externes, utiliser des conducteurs avec une isolation suffisante de façon à éviter les claquages durant les conditions anormales d'opération.
⚠CAUTION Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.	**⚠ATTENTION** Une opération intempestive du relais peut résulter par le branchement de tensions et courants secondaires non conformes aux spécifications. Avant de brancher un circuit secondaire, vérifier la tension ou le courant nominal sur la plaque signalétique à l'arrière.
⚠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 graves d'alimentation et de terre peuvent survenir sur les ports de communication de cet appareil si des câbles d'origine autre que SEL sont utilisés. Ne jamais utiliser de câble de modem nul avec cet équipement.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	**⚠ATTENTION** Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠CAUTION The outputs in the SEL-451-4 are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current interrupting capacity must clear the coil current in the disconnect motor before the output on the SEL-451-4 opens. Failure to observe this safeguard could result in damage to the SEL-451-4 output contacts.	**⚠ATTENTION** Les contacts de sortie du relais SEL-451-4 ne peuvent pas interrompre le courant de bobine du moteur de sectionneur. Un contact auxiliaire avec un pouvoir de coupure adéquat doit couper le courant de la bobine du moteur du sectionneur avant que le contact de sortie du SEL-451-4 ne s'ouvre. La non-conformité à cette règle de sécurité pourrait endommager les contacts de sortie du SEL-451-4.
⚠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.
⚠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.
⚠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.

English	French
⚠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.
⚠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.

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Section 1

Protection Functions

This section provides a detailed explanation for each of the many SEL-451 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.

- *Current and Voltage Source Selection on page R.1.2*
- *Frequency Estimation on page R.1.14*
- *Time-Error Calculation on page R.1.15*
- *Fault Location on page R.1.17*
- *Open Phase Detection Logic on page R.1.27*
- *Pole Open Logic on page R.1.27*
- *Loss-of-Potential Logic on page R.1.28*
- *Fault Type Identification Selection Logic on page R.1.33*
- *Ground Overcurrent Elements Directional Control on page R.1.33*
- *Negative-Sequence/Phase Overcurrent Elements Directional Control on page R.1.44*
- *Directional Element Routing on page R.1.45*
- *Load-Encroachment Logic on page R.1.46*
- *Instantaneous/Definite-Time Line Overcurrent Elements on page R.1.48*
- *Inverse-Time Overcurrent Elements on page R.1.55*
- *Switch-Onto-Fault Logic on page R.1.70*
- *Communications-Assisted Tripping Logic on page R.1.72*
- *Directional Comparison Blocking Scheme on page R.1.73*
- *Permissive Overreaching Transfer Tripping Scheme on page R.1.77*
- *Directional Comparison Unblocking Scheme Logic on page R.1.82*
- *Trip Logic on page R.1.86*
- *Circuit Breaker Status Logic on page R.1.91*
- *Circuit Breaker Failure Protection on page R.1.92*

Current and Voltage Source Selection

The SEL-451 has two sets of three-phase current inputs (IW and IX) and two sets of three-phase voltage inputs (VY and VZ), as shown in *Figure 1.1*. Currents IW and IX are also combined internally (COMB = IW + IX) on a per-phase basis and made available as the line current option for protection, metering, etc. You can select the current and voltage sources for a wide variety of applications, using the global settings in *Table 10.14 on page R.10.10*. The SEL-451 provides five default application settings (ESS := N, 1, 2, 3, or 4) that cover common applications (see *Table 1.1*). When you set ESS := Y, you can set the current and voltage sources for other applications (see *Table 1.2* and *Table 1.3*). ESS settings examples are given later in this subsection.

Figure 1.1 Current and Voltage Source Connections for the SEL-451 Relay

Current Source Switching

Figure 1.2 through *Figure 1.4* show the basic application of some of these settings. *Figure 1.2* shows an alternate breaker that can be substituted for the main breaker (bus switching details not shown). Normally, current IW (main breaker) is used as the line current source. But, if the alternate breaker substitutes for the main breaker, then current IX is used as the line current source, instead. SELOGIC setting ALTI controls the switching between currents IW and IX as the line current source (assert setting ALTI to switch to designated alternate line current ALINEI := IX). Alternate line current source settings ALINEI and ALTI are not used often and thus are usually set to NA. Setting ALTI is automatically hidden and set to NA if ALINEI := NA (no line current switching can occur).

NOTE: If a current source is set to "combine" (e.g., LINEI := COMB), then the current transformer ratios for the respective IW and IX secondary circuits have to be the same (i.e. group settings CTRW = CTRX).

Figure 1.3 shows combined currents IW and IX (see COMB = IW + IX in *Figure 1.1*) set for line protection, metering, etc. (LINEI := COMB). In order to combine these currents correctly inside the relay to produce the effective line current, the current transformer ratios for the respective IW and IX secondary circuits have to be the same.

Figure 1.4 shows the assignment of breaker currents for up to two circuit breakers. These assigned breaker currents are used in breaker monitoring and breaker failure functions. These same breaker currents can also be assigned as line currents (e.g., line current assignment LINE1 := IW in *Figure 1.2*).

Figure 1.2 Main and Alternate Line Current Source Assignments

Figure 1.3 Combined Currents for Line Current Source Assignment

Figure 1.4 Breaker Current Source Assignments

All the available current and voltage source selection settings combinations are covered in *Table 1.1*, *Table 1.2*, and *Table 1.3*. Notice that global setting NUMBK (Number of Breakers in Scheme; see *Table 10.3*) influences available settings combinations covered in *Table 1.1*, *Table 1.2*, and *Table 1.3*. In general, if NUMBK := 1, then no settings directly involving a second circuit breaker are made (i.e., Breaker 2 current source setting BK2I is automatically set to NA and hidden, as indicated with the shaded cells in the BK2I columns in *Table 1.1* and *Table 1.2*). Also, for source-selection setting ESS := N, the settings are forced to certain values and hidden, as indicated with the shaded cells in the ESS := N rows in *Table 1.1*.

Table 1.1 Available Current Source Selection Settings Combinations

NUMBK (number of breakers)	ESS (source selection)		LINEI (line current source)	ALINEI (alternate line current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
1	Y		see *Table 1.2*				
1	N		IW	NA	IW	NA	NA
1	1		IW	IX	IW	NA	NA
1	1		IW	NA	IW	NA	IAX, IBX, ICX, or NA
1	2		IW	IX	IX	NA	NA
1	2		IW	NA	IX	NA	NA
1	3		not allowed				
1	4		not allowed				
2	Y		see *Table 1.3*				
2	N		IW	NA	IW	NA	NA
2	1		not allowed				
2	2		not allowed				
2	3		COMB	NA	IW	IX	NA
2	4		IW	NA	IX	COMB	NA

NA = not applicable
Shaded cells indicate settings forced to given values and hidden.

Table 1.2 Available Current Source Selection Settings Combinations When ESS := Y, NUMBK := 1

NUMBK (number of breakers)	ESS (source selection)		LINEI (line current source)	ALINEI (alternate line current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
1	Y		IW	IX	IW	NA	NA
1	Y		IW	IX	IX	NA	NA
1	Y		IW	IX	NA	NA	NA
1	Y		IW	NA	IW	NA	IAX, IBX, ICX, or NA
1	Y		IW	NA	IX	NA	NA
1	Y		IW	NA	NA	NA	IAX, IBX, ICX, or NA
1	Y		COMB	IX	IW	NA	NA
1	Y		COMB	IX	IX	NA	NA
1	Y		COMB	IX	NA	NA	NA
1	Y		COMB	NA	IW	NA	NA
1	Y		COMB	NA	IX	NA	NA
1	Y		COMB	NA	NA	NA	NA

NA = not applicable
Shaded cells indicate settings forced to given values and hidden

Table 1.3 Available Current Source Selection Settings Combinations When ESS := Y, NUMBK := 2

NUMBK (number of breakers)	ESS (source selection)		LINEI (line current source)	ALINEI (alternate line current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
2	Y		IW	IX	IW	IX	NA
2	Y		IW	IX	IW	COMB	NA
2	Y		IW	IX	IW	NA	NA
2	Y		IW	IX	IX	COMB	NA
2	Y		IW	IX	IX	NA	NA
2	Y		IW	IX	NA	IX	NA
2	Y		IW	IX	NA	COMB	NA
2	Y		IW	IX	NA	NA	NA
2	Y		IW	NA	IW	IX	NA
2	Y		IW	NA	IW	COMB	NA
2	Y		IW	NA	IW	NA	IAX, IBX, ICX, or NA
2	Y		IW	NA	IX	COMB	NA
2	Y		IW	NA	IX	NA	NA
2	Y		IW	NA	NA	IX	NA
2	Y		IW	NA	NA	COMB	NA
2	Y		IW	NA	NA	NA	IAX, IBX, ICX, or NA
2	Y		COMB	IX	IW	IX	NA
2	Y		COMB	IX	IW	NA	NA
2	Y		COMB	IX	IX	NA	NA
2	Y		COMB	IX	NA	IX	NA
2	Y		COMB	IX	NA	NA	NA
2	Y		COMB	NA	IW	IX	NA
2	Y		COMB	NA	IW	NA	NA
2	Y		COMB	NA	IX	NA	NA
2	Y		COMB	NA	NA	IX	NA
2	Y		COMB	NA	NA	NA	NA

NA = not applicable

Current Source Uses

Refer to the global settings in *Table 10.14*. Line current source setting LINEI and alternate line current source settings ALINE1 and ALTI, if used, identify the currents used in the following elements/features described later in this section and in other sections:

- Fault location
- Open-phase detection logic
- LOP (loss-of-potential) logic
- FIDS (fault-type identification selection) logic
- Directional elements
- Load-encroachment logic
- Instantaneous line overcurrent elements
- Inverse-time overcurrent elements
- DCUB (directional comparison unblocking) trip scheme logic
- *Metering on page A.2.22*, except synchrophasors

NOTE: Starting in firmware version R104, synchrophasor measurements are no longer affected by the line current source settings ALINEI and LINEI. See Synchrophasors on page R.7.1.

Breaker current-source settings (BK1I and BK2I) identify the currents used in the following elements/features described in later in this section and in other sections:

- Open-phase detection logic
- Inverse-time overcurrent elements
- Circuit breaker failure protection
- *Circuit Breaker Monitor on page A.2.1*
- *Metering on page A.2.22*

Polarizing current-source setting IPOL identifies the single current input connected to a zero-sequence current source (e.g., transformer bank neutral). This zero-sequence current is used as a reference in the zero-sequence current-polarized directional element. Such a directional element is applied to ground overcurrent elements (see *Table 1.29* and *Figure 1.30*). Setting IPOL is not used often and thus is usually set to NA. Notice that in *Table 1.1*, *Table 1.2* and *Table 1.3* there are relatively few scenarios where setting IPOL can be set to a current channel selection (only those cases where three-phase current input IX is not used for any other function). An example of using setting IPOL is found later in this subsection.

Voltage Source Switching and Uses

Refer to the global settings in *Table 10.14*. Alternate voltage source switching between VY and VZ in *Figure 1.1* is more straightforward (as shown in *Table 1.4*) than the preceding discussion on current-source selection/switching (compare to *Table 1.1* through *Table 1.3*).

Table 1.4 Available Voltage Source-Selection Setting Combinations

NUMBK (number of breakers)	ESS (source selection)		Line Voltage Source	ALINEV (alternate line voltage source)
1	Y		VY	VZ or NA
1	N		VY	NA
1	1		VY	VZ or NA
1	2		VY	VZ or NA
1	3		not allowed	
1	4		not allowed	
2	Y		VY	VZ or NA
2	N		VY	NA
2	1		not allowed	
2	2		not allowed	
2	3		VY	VZ or NA
2	4		VY	VZ or NA

NA = not applicable
Shaded cells indicate settings forced to given values and hidden

SELOGIC setting ALTV controls the switching between voltages VY and VZ for line voltage (assert setting ALTV to switch to designated alternate line voltage ALINEV := VZ). Setting ALTV is automatically hidden and set to NA if ALINEV := NA (no voltage switching can occur). Reasons for switching from one three-phase voltage to another may be for loss-of-potential or bus switching/rearrangement.

During an ALTV controlled switching of the voltages, the relay will momentarily disable and then restart. This condition is normal, and must be done to assure that the new voltage measurements are accurate. The time in the disabled state is t less than 10 cycles.

Default line voltage source VY and alternate line voltage source settings (ALINEV and ALTV) identify the voltages used in the following elements/ features described later in this section and in other sections:

- Fault location
- Open-phase detection logic
- LOP (loss-of-potential) logic
- FIDS (fault-type identification selection) logic
- Directional elements
- Load-encroachment logic
- SOTF (switch-onto-fault) logic
- POTT (permissive overreaching transfer tripping) scheme logic
- *Metering on page A.2.22*, including synchrophasors

Default Applications

Use setting ESS (Voltage and Current Source Selection) to easily configure the relay for your particular application. Five application settings (ESS := N, 1, 2, 3, or 4) cover both single circuit breaker and two circuit breaker configurations. If you select one of these five setting choices, the relay automatically determines the following settings:

NOTE: Setting BK2I is hidden if setting NUMBK, Number of Breakers in the Scheme, is set to 1.

- LINEI—Line Current Source (IW, COMB)
- BK1I—Breaker 1 Current Source (IW, IX, NA)
- BK2I—Breaker 2 Current Source (IX, COMB, NA)

ESS := N, Single Circuit Breaker Configuration–One Current Input

Set ESS to N for single circuit breaker applications with one current input. *Figure 1.5* illustrates this application along with the corresponding current and voltage sources. When ESS equals N, you cannot use alternate sources (ALINEI and ALINEV) and the relay hides the Global settings LINEI, ALINEI, ALTI, BK1I, BK2I, IPOL, ALINEV, and ALTV.

Table 1.5 ESS := N, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW, COMB)	IW	Hidden
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW	Hidden
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA	Hidden

ESS := 1, Single Circuit Breaker Configuration–One Current Input

Set ESS to 1 for single circuit breaker applications with one current input. *Figure 1.5* illustrates this application along with the corresponding current and voltage sources.

With ESS := 1, the IX current channels have the option to be used as an alternate line current source (ALINEI := IX) or as a polarized current channel (e.g., IPOL := IBX), but not both (see *Table 1.1*).

Analog Input	Function
IW	CB1 protection, line protection
VY	Line protection
VAZ	Synchronism check

Figure 1.5 ESS := 1, Single Circuit Breaker Configuration

Table 1.6 ESS := 1, Current and Voltage Source Selection (Sheet 1 of 2)

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Line Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC equation)	NA	Hidden[a]

Table 1.6 ESS := 1, Current and Voltage Source Selection (Sheet 2 of 2)

Setting	Description	Entry	Comments
BK1I	Breaker 1 Current Source (IW)	IW	Automatic
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

ESS := 2, Single Circuit Breaker Configuration—Two Current Inputs

Set ESS to 2 for single circuit breaker applications using two current sources. *Figure 1.6* illustrates this application along with the corresponding current and voltage sources. The relay uses current source IW for line relaying and current source IX for Circuit Breaker 1 failure protection.

Analog Input	Function
IW	CB1 protection, line protection
IX	CB1 breaker failure
VY	Line protection
VAZ	Synchronism check

Figure 1.6 ESS := 2, Single Circuit Breaker Configuration

Table 1.7 ESS := 2, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Line Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IX)	IX	Automatic
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

ESS := 3, Double Circuit Breaker Configuration—Independent Current Inputs

Set ESS to 3 for circuit breaker-and-a-half applications using independent current sources. *Figure 1.7* illustrates this application along with the corresponding current and voltage sources. This selection provides independent circuit breaker failure protection for Circuit Breaker 1 and Circuit Breaker 2.

Analog Input	Function
IW+IX	Line protection
IW	CB1 protection
IX	CB2 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.7 ESS := 3, Double Circuit Breaker Configuration

Table 1.8 ESS := 3, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (COMB)	COMB	Automatic
ALINEI	Alternate Line Current Source (NA)	NA	Automatic
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IW)	IW	Automatic
BK2I	Breaker 2 Current Source (IX)	IX	Automatic
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

ESS := 4, Double Circuit Breaker Configuration—Common Current Inputs

Set ESS to 4 for circuit breaker-and-a-half applications using combined current input IW. *Figure 1.8* illustrates this application along with the corresponding current and voltage sources. Current input IX provides circuit breaker failure protection for Circuit Breaker 1; the corresponding CTs are located on the line-side of Circuit Breaker 1. The relay calculates the current

flowing through Circuit Breaker 2 ($I_{CB2} = IW + IX = I_{CB1} + I_{CB2} + IX = I_{CB1} + I_{CB2} - I_{CB1}$) to provide independent circuit breaker failure for Circuit Breaker 2.

Analog Input	Function
IW+IX	CB2 protection
IW	Line protection
IX	CB1 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.8 ESS := 4, Double Circuit Breaker Configuration

Table 1.9 ESS := 4, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Current Source (NA)	NA	Automatic
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IX)	IX	Automatic
BK2I	Breaker 2 Current Source (COMB)	COMB	Automatic
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

ESS := Y, Other Applications

Set ESS to Y for applications that are not covered under the five default applications.

Tapped Line

Figure 1.9 illustrates the tapped overhead transmission line with an MOD (motor operated disconnect) on the high side of a power transformer and two circuit breakers on the low side.

Set NUMBK (Number of Breakers in Scheme) to 2 so you can program the recloser function and synchronism-check elements to control both of the low-side circuit breakers.

Analog Input	Function
IW	Line protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.9 ESS := Y, Tapped Line

Table 1.10 ESS := Y, Tapped Line

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (IW, COMB)	IW	
ALINEI	Alternate Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IW, IX, NA)	NA	
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA	
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	Default
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

Single Circuit Breaker With Current Polarizing Source

Figure 1.10 shows a single circuit breaker situated by a wye-grounded transformer. The SEL-451 uses the neutral CT as a current polarizing source for the zero-sequence current polarized ground directional element, 32I. Use current input IAX as a polarizing source for the ground directional element, 32G.

Analog Input	Function
IW	Line protection
IAX	Ground directional element current polarization
VY	Line protection
VAZ	Synchronism check

Figure 1.10 ESS := Y, Single Circuit Breaker With Current Polarizing Source

Table 1.11 ESS := Y, Current Polarizing Source

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW, COMB)	IW	
ALINEI	Alternate Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW	
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	IAX	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	Default
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

Using ALTI and ALTV

SELOGIC control equations ALTI and ALTV give great flexibility in choosing alternate CT and PT inputs to the SEL-451. The relay switches immediately to the alternate source when these SELOGIC control equations become true. The relay delays a subsequent ALTI or ALTV switch for 8 cycles after the initial switch to give time for the system to settle.

Test the SELOGIC control equation programming that you use to switch ALTI and ALTV alternate sources. It is possible to create a toggling condition where the relay repeatedly switches between sources. Examine each line of SELOGIC control equation programming to verify that this toggling condition does not occur in your protection/control scheme.

One method for exercising caution when implementing alternate current source and alternate voltage source switching is to use SELOGIC control equation protection latches (PLT01–PLT32) to switch alternate sources. For example, to switch to an alternate voltage, set ALINEV to VZ (enables setting

ALTV) and then set ALTV to PLT31. To perform the switch, use the protection latch control inputs PLT31S and PLT31R (Set and Reset, respectively).

Frequency Estimation

The SEL-451 measures power system frequency based on fixed rate sampled voltages. The relay measures the time between zero crossings, filters the time measurement, and processes the measurement with an algorithm to remove line anomalies.

The output of the frequency estimation routine is used to alter the protection algorithm sample rate which is in samples per cycle. The protection algorithms are processed at 8 samples per power system cycle.

In most applications, no settings changes are required for frequency estimation. Advanced Global settings (see *Table 1.12*) are provided for special cases, and these allow selection of the voltage input terminal(s) to be used as frequency estimation inputs. An alternate frequency source may also be enabled and selected by control from a SELOGIC control equation.

Table 1.12 Frequency Estimation[a]

Label	Prompt	Default Value
EAFSRC	Alternate Frequency Source (SELOGIC Equation)	NA
VF01	Local Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
VF02	Local Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBY
VF03	Local Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCY
VF11	Alternate Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF12	Alternate Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF13	Alternate Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO

[a] These settings are available only if you have enabled Global advanced settings, EGADVS := Y.

Table 1.13 Frequency Estimation Analog Quantity

Name	Description	Type
FREQ	Measured system frequency	Analog Quantity
FREQOK	Measured frequency valid[a]	Relay Word bit

[a] Deasserts approximately two seconds after all frequency estimation voltages drop out.

If all selected voltage signals dropout, the measured frequency reverts to the nominal frequency (Global setting NFREQ := 50 or 60 Hz) after approximately two seconds. In this situation, Relay Word bit FREQOK deasserts.

Figure 1.11 Frequency Estimation for Protection Functions

Frequency Estimation Provided by Synchrophasor

The frequency and rate of change of frequency is estimated using synchrophasors. These measurements are included in the synchrophasor data packet and can be viewed by the **MET PM** command. The rate of change of frequency (DFDT) is also included as an analog quantity that can be used in SELOGIC equation. Note that DFDT is not available if synchrophasors are not enabled or active.

NOTE: The DFDT calculation is only performed when Global setting EPMU := Y.

Time-Error Calculation

Description and Settings

The Time-Error calculation function in the SEL-451 measures the amount of time that an ac clock running from the same line frequency measured by the relay would differ from a reference clock. The relay integrates the difference between the measured power system frequency and the nominal frequency (Global setting NFREQ) to create a time-error analog quantity, TE.

NOTE: The LOADTE SELOGIC equation is processed once per cycle. A momentary assertion must be conditioned to be at least one cycle in duration. A rising edge operator (R_TRIG) should not be used in the LOADTE setting.

A correction feature allows the present time-error estimate (TE) to be discarded, and a new value (TECORR) loaded when SELOGIC control equation LOADTE asserts. For example, if the TECORR value is set to zero, and then LOADTE is momentarily asserted, the TE analog quantity will be set to 0.000 seconds.

The TECORR analog quantity can be pre-loaded by the **TEC** Command (see *TEC on page R.9.58*), or via DNP3, object 40, 41 index 01 (see *Table 6.10 on page R.6.18*). In either case, Relay Word bit PLDTE asserts for approximately 1.5 cycles to indicate that the preload was successful.

A separate SELOGIC control equation, STALLTE, when asserted, causes time-error calculation to be suspended.

Table 1.14 lists the inputs and outputs of the time-error function.

Table 1.14 Time-Error Calculation Inputs and Outputs

INPUTS	Description
Analog Quantities	
FREQ	Measured system frequency (see *Table 1.13*).
TECORR	Time-error correction factor. This value can be preloaded via the **TEC** command, or DNP3.
Global Settings	
NFREQ	Nominal frequency (see *Table 10.3*)
LOADTE	Load Time-Error Correction Factor (SELOGIC control equation). A rising edge will cause the relay to load the TECORR analog quantity into TE. LOADTE has priority over STALLTE.
STALLTE	Stall Time-Error Calculation (SELOGIC control equation). A logical 1 will stall (freeze) the time-error function. The TE value will not change when STALLTE is asserted (unless LOADTE asserts).
Relay Word bit	
FREQOK	Frequency Measurement valid. If this Relay Word bit deasserts, the TE quantity is frozen (see *Table 1.13*).
OUTPUTS	**Description**
Analog Quantity	
TE	Time-Error estimate, in seconds. Positive numbers indicate that the ac clock would be fast (ahead of the reference clock). Negative numbers indicate that the ac clock would be slow (behind the reference clock).
Relay Word bit	
PLDTE	Preload Time-Error value updated. This element asserts for approximately 1.5 cycles after TECORR is changed by the **TEC** command or by DNP3.

Time Error Command (TEC)

The **TEC** serial port command provides easy access to the time-error function. See *TEC on page R.9.58* for command access level information.

Enter the **TEC** command to view the time-error status. A sample display is given in *Figure 1.12*.

```
=>TEC <Enter>

Relay 1                                    Date: 11/02/2004  Time: 11:25:50.460
Station A                                  Serial Number: 0000000000

Time Error Correction Preload Value
TECORR = 0.000 s

Relay Word Elements
LOADTE = 0, STALLTE = 0, FREQOK = 1

Accumulated Time Error
TE = -7.838 s

=>
```

Figure 1.12 Sample TEC Command Response

Enter the **TEC** command with a single numeric argument n ($-30.000 \geq n \leq 30.000$) to preload the TECORR value. This operation does not affect the TE analog quantity until the SELOGIC control equation LOADTE next asserts. *Figure 1.13* shows an example of the **TEC *n*** command in use.

```
==>TEC 2.25 <Enter>

Relay 1                                    Date: 11/02/2004  Time: 11:53:12.701
Station A                                  Serial Number: 0000000000

Change TECORR to 2.250 s:

Are you sure (Y/N)?Y <Enter>

Time Error Correction Preload Value
TECORR = 2.250 s

Relay Word Elements
LOADTE = 0, STALLTE = 0, FREQOK = 1

Accumulated Time Error
TE = -5.862 s

==>
```

Figure 1.13 Sample TEC n Command Response

Fault Location

The SEL-451 computes distance to fault from data stored in the event reports. The relay calculates distance to fault upon satisfaction of all three of the following conditions:

- The fault locator is enabled, setting EFLOC := Y.
- A phase overcurrent, residual ground overcurrent, negative-sequence, or time-overcurrent element picks up no later than 15 cycles after the event report trigger.
- The fault duration is greater than one cycle, as determined by the previously listed asserted protection element(s).

Table 1.15 Fault Location Triggering Elements

Fault Type	Protection Element
Ground Faults	67G1–67G4 67Q1–67Q4 51S1–51S6[a]
Phase Faults	67P1–67P4 67Q1–67Q4 51S1–51S6[b]

[a] Corresponding group setting 51SkO must be set to 3I2L or 3I0L (k=1-6).
[b] Corresponding group setting 51SkO must be set to IAL, IBL, ICL, I1L, 3I2L, IMAXL, IALR, IBLR, ICLR, or IMAXLR (k=1-6).

The relay calculates distance to fault in per unit of the positive-sequence line impedance, Z_1. Use the relay setting LL, Line Length, to determine the units that the relay reports for the distance to a fault. For example, if a fault occurs at the midpoint of the protected line and you set LL to 126 for a line length of 126 kilometers, the result of the relay distance-to-fault calculation is 63.

Distance-to-fault calculation results range from –999.99 to 999.99. If the calculation cannot be determined (e.g., insufficient information) or if the result is outside the specified range, the relay reports the fault location as `$$$$.$$`.

The relay provides an analog fault location value labeled FLOC (see *Table B.1*). This Analog quantity contains the fault location of the most recent fault. It can be reset by momentarily asserting the RSTFLOC SELOGIC equation (located in Global Settings). RSTFLOC has no effect on the fault location information in event summaries and event reports.

The relay specifies fault type along with the distance to fault. The fault type can be one of the types listed in *Table 1.16*.

Table 1.16 Fault Type

Label	Fault Type
AG	A-phase-to-ground
BG	B-phase-to-ground
CG	C-phase-to-ground
AB	A-phase-to-B-phase
BC	B-phase-to-C-phase
CA	C-phase-to-A-phase
ABG	A-phase-to-B-phase-to-ground
BCG	B-phase-to-C-phase-to-ground
CAG	C-phase-to-A-phase-to-ground
ABC	Three-phase

Table 1.17 Fault Location Settings

Name	Description	Range	Default (5 A)
Z1MAG	Positive-Sequence Line Impedance Magnitude (Ω)	(0.25–1275)/I_{NOM}	2.14
Z1ANG	Positive-Sequence Line Impedance Angle (°)	5.00–90	68.86
Z0MAG	Zero-Sequence Line Impedance Magnitude (Ω)	(0.25–1275)/I_{NOM}	6.38
Z0ANG	Zero-Sequence Line Impedance Angle (°)	5.00–90	72.47
EFLOC	Fault Location	Y, N	Y
LL	Line Length	0.10–999	4.84

Table 1.18 Fault Location Relay Word Bit

Name	Description
RSTFLOC	Fault locator analog quantity reset in progress[a]

[a] Use global setting RSTFLOC shown in Table 10.11 to reset the stored fault location analog quantity FLOC. Relay Word bit RSTFLOC will assert momentarily while the clearing action proceeds.
While reset, the value contained in FLOC is set to a very large number (greater that 10^{37}). Resetting this value has no effect on the event reports stored in the SEL-451, nor does it have an effect on DNP3 event access.

High-Impedance Fault Detection

NOTE: Detecting high-impedance faults has challenged utilities and researchers for years, especially in situations where a fault occurs on asphalt or dry sand or generates little or virtually no fault current. As is commonly known, not all HIFs are detectable. Detecting HIFs potentially reduces the risks associated with these faults. The SEL HIF detection method increases the likelihood that an HIF will be detected.

High-impedance faults (HIF) are short-circuit faults with fault currents smaller than what a traditional overcurrent protective relay can detect. The main causes of HIFs are tree branches touching a phase conductor, failing or dirty insulators that cause flashovers between a phase conductor and the ground or downed conductors. Almost all HIFs involve the ground directly or indirectly.

Staged downed-conductor fault tests in North America indicate that downed-conductor HIFs generate quite small fault currents. The HIF current of multigrounded systems depends highly on the surface types upon which a conductor falls, and the fault current varies from zero to less than 100 amperes.

Because of small fault currents, HIFs generally do not affect distribution system operations. The primary motivation for detecting and clearing HIFs is to improve public safety. The SEL Technical Paper *High-Impedance Fault Detection—Field Tests and Dependability Analysis by Daqing Hou* details additional information about HIF characteristics and detection methods.

High-impedance fault detection is available in select SEL-451 models. The part number indicates whether the relay supports high-impedance fault detection.

The high-impedance fault (HIF) detection method shown in *Figure 1.14* incorporates the following key elements:

- An informative quantity that reveals HIF signatures as much as possible without being affected by loads and other system operation conditions.
- A running average of the quantity that provides a stable prefault reference.
- An adaptive tuning feature that learns and tunes out feeder ambient noise conditions.
- Decision logic to differentiate an HIF condition from other system conditions such as switching operations and noisy loads.

The HIF detection element derives a Sum of Difference Current (SDI) that represents the total non-harmonic contents of the phase and residual currents in order to detect an HIF signature. An averaging filter generates a stable reference of SDI and adapts to the ambient conditions of feeder loads. In turn, an adapted detection threshold is established based on the trends of the measured SDI and decision logic is used to separate normal trending from the existence of an HIF on the distribution system. The SEL Technical Paper *Detection of High-Impedance Faults in Power Distribution Systems by Daqing Hou*, details additional information about this HIF detection method.

Additional HIF detection logic measures the total odd-harmonic content (ISM), maintains long-term and short-term histograms of ISM, and generates HIF alarms by comparing the difference between two histograms. Use the **HSG** command to display the long-term and short-term histograms (see *Table 9.78*). When the difference between the two histograms is not substantial, the long-term histogram is updated through an IIR filtering

process from the short-term histogram. The long-term histogram therefore adapts to the feeder ambient load conditions and increases the overall HIF detection security.

Figure 1.14 Block Diagram of HIF detection

HIF Detection Settings

Table 1.19 lists the relay settings corresponding to high-impedance fault detection.

Table 1.19 High-Impedance Fault (HIF) Detection Settings

Label	Prompt	Default Value
EHIF	EHIF Enable High Impedance Fault Detection (Y,N,T)	N
HIFMODE	HIF Detection Sensitivity (SELOGIC Equation)	0
HIFER	HIF Event Report Ext. Trigger (SELOGIC Equation)	0

Enable high-impedance fault detection with group setting EHIF := Y or T. When EHIF is set to Y, the detection algorithm initiates a 24-hour tuning window. During the initial tuning process, the algorithm tunes into background noise and establishes pre-fault references and parameters that the relay then uses for high-impedance fault detection. With the relay in initial tuning mode, no high-impedance fault or alarm RWB will assert. Uninterrupted, this process takes 24 hours and results in the assertion of ITUNE_x. Interruption of the initial tuning process can occur for the following conditions: the EHIF setting changes to a new value other than N; positive current impulse; manual entry of INI HIF (See *INI HIF on page R.9.30* for more information on the **INI HIF** command.); FRZCLR_x conditions (voltage drop resulting from an external fault, for example). Should any of these conditions occur, security considerations require that the algorithm initiate a new 24-hour initial tuning window. After the initial tuning process, the relay enters normal tuning mode. By comparing the present measured data and the established references and parameters, the relay runs the decision algorithms and detects high-impedance faults. During normal tuning mode, if the line remains de-energized for longer than four hours, the relay reenters initial tuning mode upon detecting a positive current impulse. Otherwise, it remains in normal tuning mode. When EHIF is set to T, the detection algorithm bypasses the 24 -hour tuning process and is available immediately to provide testing. The relay must be tracking frequency for the high-impedance fault detection algorithm to operate; the algorithm is disabled if the relay is not tracking frequency.

High-impedance fault detection sensitivity is controlled by group SELOGIC control equation setting HIFMODE. Assertion of this logic equation sets relay word bit HIFMODE and increases the sensitivity of the detection algorithm.

EXAMPLE 1.1 HIFMODE Programming and Operation

As detailed above, assertion of the HIFMODE SELOGIC control equation controls the sensitivity of the high-impedance fault detection algorithm. Field experience may suggest that downed conductor events that lead to high-impedance faults might occur more frequently during periods of storm activity. Furthermore, conductor configuration could make it likely that a downed conductor might initially create a high-current fault by making temporary contact with another conductor. This fault would be detected and cleared; disappearing upon a successful auto-reclosure. The downed conductor would then be creating a high-impedance fault. It is during this time that it would be desirable to increase the sensitivity of the high-impedance fault detection algorithm. In this example a successful reclosure triggers a timer input. The dropout period of the timer is set to the period of time that is desired for increased detection sensitivity.

Enter the following Group Settings:

EHIF := Y

HIFMODE := PCT16Q AND 52AA1 # HIFMODE SELOGIC control equation variable follows the timer output

Enter the following Logic Settings:

PCT16PU := 0.0 # Pickup set to 0.0 cycles

PCT16DO := 108000.0 # Dropout set to 30.0 minutes on a 60 Hz system

PCT16IN := R_TRIG 3PRCIP # Three-Pole Reclaim In-Progress (in reclose cycle state)

While the recloser is timing towards the reset state after a successful reclosure Relay Word 3PRCIP asserts the output for Protection Conditioning Timer 16. The timer stays asserted for the duration of the dropout setting, which is 30 minutes in this example. During this 30 minutes, the timer assertion maintains the assertion of HIFMODE, assuring a window of time for increased sensitivity of the HIF detection algorithm.

Group SELOGIC control equation setting HIFER allows for the automatic triggering of HIF detection event reports. Assertion of HIFER will set relay word bit HIFREC and trigger an event report.

HIF Detection Logical Outputs

The SEL-451 indicates HIF detection through the Relay Word Bit outputs detailed in *Table 1.20*. Relay word bits can be used in custom logic programming to indicate high-impedance fault detection activity.

Table 1.20 HIF Relay Word Bits

HIF Activity	Relay Word Bits
HIF SDI ALARM	HIA1_A, HIA1_B, HIA1_C
HIF SDI ALARM	HIA2_A, HIA2_B, HIA2_C
HIF SDI FAULT	HIF1_A, HIF1_B, HIF1_C
HIF SDI FAULT	HIF2_A, HIF2_B, HIF2_C
HIF Externally Triggered Event	HIFER
HIF Detection Mode Sensitivity	HIFMODE
HIF Event Report is being collected	HIFREC

HIF Detection Event Reports and Histories

The SEL-451 stores HIF detection information as oscillography in binary format and as event summaries and histories. See *High-Impedance Fault Event Summary on page A.3.37*, *High-Impedance Fault Event History on page A.3.40*, and *High-Impedance Fault Event Oscillography on page A.3.11* for more information.

Ground Overcurrent High-Impedance Fault Detection

An additional and wholly seperate method of detecting high-impedance fault activitiy is the ground overcurrent high-impedance fault (50G HIZ) detection method. The 50G HIZ detection method counts the number of times an instantaeous ground overcurrent element (50G) asserts and deasserts at a very low pickup threshold within a settable period of time. This activity could indicate the presence of a small magnitude arcing fault on the sytem. Some hysteresis is built into the (50G) element in order to minimize element chatter due to non-fault activity. The SEL-451 stores 50G HIZ detection information in a report that is obtained with the **HIZ** command. See *HIZ on page R.9.28* for more information on the **HIZ** command. See *Figure 1.15* for a sample HIZ report.

```
=>HIZ

Relay 1                                    Date: 06/10/2007  Time: 08:04:16.698
Station A                                  Serial Number: 0000000000

Begining Date/Time           Ending Date/Time            Counts
2007/06/02 14:56:18.038      2006/08/02 14:56:23.663     9
2007/06/02 14:56:29.537      2006/08/02 14:56:39.166     18
```

Figure 1.15 Sample HIZ Report

50G HIZ Detection Settings

Table 1.21 lists the relay settings corresponding to ground overcurrent high-impedance fault detection.

Table 1.21 50G High-Z (HIZ) Fault Detection Settings

Label	Prompt	Default Value
50GHIZP	50G HIZ Overcurrent Pickup (OFF,0.25-100 amps,sec)	OFF
NPUD0	50G HIZ Element Pickup/Dropout Counts (1-1000)	10
TPUD0	NPUDO Time Window (0.01-20 seconds)	2.00
NHIZ	HIZ Counts [1 HIZ count = NPUDO counts] (1-1000)	100
THIZ	NHIZ Time Window (1.00-200 seconds)	60.00
NHIZR	HIZ Counts Reporting Threshold (1-1000)	95
HIZRST	HIZ Alarm Reset (SELOGIC Equation)	0

Ground overcurrent high-impedance fault detection is enabled by group setting 50GHIZP. When 50GHIZP is set to any value other than OFF, ground instantaneous overcurrent element 50GHIZ is enabled to initiate 50G HIZ fault detection. *Figure 1.16* shows the operating logic for element 50GHIZ.

Figure 1.16 Ground Instantaneous Overcurrent Element 50GHIZ

The assertion and deassertion of 50GHIZ causes counter CPUDO to increment (HIZ173, *Figure 1.19*). Group setting NPUDO establishes a threshold that counter CPUDO must meet in order for 50G HIZ fault detection to continue. Group setting TPUDO establishes a time window within which counter CPUDO must meet the NPUDO threshold. If CPUDO reaches NPUDO within TPUDO, counter CHIZ is then incremented (HIZ174, *Figure 1.19*). If it does not, counter CPUDO is reset (HIZ180, *Figure 1.20*) and the logic starts over.

Group setting NHIZ establishes a threshold that counter CHIZ must meet in order for 50G HIZ fault detection to continue. Group setting THIZ establishes a time window within which counter CHIZ must meet the NHIZ threshold. If CHIZ reaches NHIZ within THIZ, relay word bit 50GHIZA is asserted (HIZ175, *Figure 1.19*) and latched; group SELOGIC setting HIZRST resets 50GHIZA. Group setting NHIZR establishes a separate threshold at which HIZ report entries are generated. Refer to the following section for an example of how these settings can be utilized to for 50G HIZ fault detection.

50G HIZ Detection Logic Example

Figure 1.17 and *Figure 1.18* (along with *Figure 1.19* and *Figure 1.20*) show how the example HIZ report entries in *Figure 1.15* are generated. Compared to the settings ranges given in *Table 1.19*, the following example settings NHIZR = 6 and NHIZ = 18 appear especially small and are for illustrative purposes only.

Figure 1.17 Counter CPUDO for Assertion/Deassertion of Ground Fault Overcurrent Element 50GHIZ

Figure 1.17 shows counter CPUDO incrementing from 0 up to NPUDO = 9. This has to be done within time TPUDO (0.5 seconds in this example), else counter CPUDO is reset (HIZ180, *Figure 1.20*). Notice in the middle of

Figure 1.17 that an increment attempt only got as far as counter CPUDO = 3, before time TPUDO = 0.5 seconds expired and counter CPUDO was reset to zero (0). Each time counter CPUDO reaches NPUDO, counter CHIZ is then incremented (HIZ174, *Figure 1.19*) and counter CPUDO resets (HIZ180, *Figure 1.20*). When counter CHIZ first increments to CHIZ = 1, the corresponding date/time is recorded for possible report logging later.

Figure 1.18 Counter CHIZ for High-Impedance Ground Fault Detection

Figure 1.18 shows counter CHIZ incrementing, with time stamps t1, t2, t3, and t4 corresponding back to *Figure 1.17*.

If counter CHIZ increments to NHIZ or greater, within THIZ time, then the activity is logged in the HIZ report. Notice in *Figure 1.18* that both incrementing attempts exceed level NHIZR = 6 (CHIZ = Counter HIZ = 9 and CHIZ = Counter HIZ = 18) and thus are displayed in the HIZ report in *Figure 1.15*. Notice that each report entry has a time stamp for Counter HIZ = 1 and a time stamp for the highest Counter HIZ level reached, within time THIZ = 10 secondes. These time stamp differences allow for the determination of the relative activity of ground overcurrent high impedance fault detection. Such analysis may result in modifying settings 50GHIZP, NPUDO, TPUDO, NHIZ, THIZ, or NHIZR.

The first incrementing attempt in *Figure 1.18* only got as far as counter CHIZ = 9, before time THIZ = 10 seconds expired (HIZ192, *Figure 1.21*) and counter CHIZ was reset to zero (0). The second incrementing attempt in *Figure 1.18* reached CHIZ = NHIZ within THIZ time (HIZ175, *Figure 1.19*). Then counter CHIZ was reset to zero (0) (HIZ190, *Figure 1.21*).

Upon reaching stage HIZ175 (*Figure 1.19*), relay word bit 50GHIZA is asserted and latched; group SELOGIC setting HIZRST resets 50GHIZA. Relay word bit 50GHIZA can be used in custom logic programming to indicate ground overcurrent high-impedance fault detection activity.

Figure 1.19 50G High-Impedance Fault (50G HIZ) Detection Logic

Figure 1.20 50G HIZ Counter CPUDO Logic

Figure 1.21 50G HIZ Counter CHIZ Logic

Open Phase Detection Logic

Some line relaying applications (e.g., circuit breaker failure protection) benefit from fast open phase detection. The resetting time of the instantaneous overcurrent elements using filtered quantities can be extended after the corresponding phase(s) is open if subsidence current is present. The SEL-451 open phase detector senses an open phase in less than one cycle. This information is used for purposes such as quickly disabling instantaneous overcurrent elements in the circuit breaker failure schemes and open pole detection.

The open phase detection logic uses both the half-cycle and one-cycle cosine digital filter data shown in *Figure 3.1 on page A.3.3* to achieve the high-speed response to an open phase condition. *Table 1.22* lists the output Relay Word bits.

Table 1.22 Open Phase Detection Relay Word Bits

Name	Description
B1OPHA	Breaker 1 A-phase open
B1OPHB	Breaker 1 B-phase open
B1OPHC	Breaker 1 C-phase open
B2OPHA	Breaker 2 A-phase open
B2OPHB	Breaker 2 B-phase open
B2OPHC	Breaker 2 C-phase open
LOPHA	Line A-phase open
LOPHB	Line B-phase open
LOPHC	Line C-phase open

Pole Open Logic

The SEL-451 pole open logic detects pole open conditions. Pole open logic supervises various protection elements and functions that use analog inputs from the power system (e.g., directional elements and LOP logic).

Table 1.23 Pole Open Logic Settings

Name	Description	Range	Default
EPO	Pole Open Detection	52, V	52
27PO	Undervoltage Pole Open Threshold (V)[a]	1–200	40
3POD	Three-Pole Open Dropout Delay (cycles)	0.000–60	0.500

[a] 1 V steps

Setting EPO (Enable Pole Open) offers two options for deciding the conditions that signify an open pole. These options are listed in *Table 1.24*.

Table 1.24 EPO Setting Selections

Selection	Description
52	Phase undercurrent and circuit breaker auxiliary contact input status
V	Phase undercurrent and phase undervoltage

NOTE: The 3PO Relay Word bit is used in some protective elements of the SEL-451. Separate Relay Word bits 3POLINE, 3POBK1, and 3POBK2 are not affected by the EPO setting, and are used in the auto-reclose logic only, see Figure 2.6, Figure 2.7, and Figure 2.8.

Set EPO to V only if you use line-side potential transformers for relaying purposes. Do not select option V if shunt reactors are applied because the voltage decays slowly after the circuit breaker(s) opens. If you select EPO := V, the relay cannot declare an open pole when LOP is asserted.

Table 1.25 Pole Open Logic Relay Word Bits

Name	Description
3PO	All three poles open
27APO	A-phase undervoltage
27BPO	B-phase undervoltage
27CPO	C-phase undervoltage

Figure 1.22 Pole-Open Logic Diagram

Loss-of-Potential Logic

Fuses or molded case circuit breakers often protect the secondary windings of the power system potential transformers. Operation of one or more fuses or molded case circuit breakers results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from discriminating fault distance and direction properly.

An occasional loss-of-potential at the secondary inputs of a directional relay is unavoidable but detectable. The relay detects a loss-of-potential condition and asserts Relay Word bits LOP (Loss-of-Potential Detected) and ILOP (Internal

Loss-of-Protection From ELOP Setting). This allows you to block or enable forward-looking directional overcurrent elements, and issue an alarm for any true LOP condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect a three-phase LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect an LOP when the circuit breaker(s) closes again.

The SEL-451 also asserts LOP upon circuit breaker closing for one or two missing PTs. If the relay detects a voltage unbalance with balanced currents at circuit breaker close, then the relay declares a loss-of-potential condition.

Inputs into the LOP logic are as follows:

- 3PO—three-pole open condition
- V_1—positive-sequence voltage (V secondary)
- I_1—positive-sequence current (A secondary)
- V_0—zero-sequence voltage (V secondary)
- I_0—zero-sequence current (A secondary)

All three poles of the circuit breaker(s) must be closed (i.e., Relay Word bit 3PO equals logical 0) for the LOP logic to operate.

The relay declares an LOP condition (Relay Word bit LOP equals logical 1) if V_1 drops in magnitude by at least ten percent and there is no corresponding change in I_1 or I_0 magnitude or angle. An LOP condition persisting for 15 cycles causes the LOP logic to latch. LOP resets (Relay Word bit LOP equals logical 0) when V_1 returns to a level greater than 85 percent nominal voltage and V_0 is less than 10 percent V_1.

The LOP logic requires no settings other than enable setting ELOP.

Setting ELOP := N

If you set ELOP to N, the LOP logic operates but does not disable any voltage-polarized elements. This option is for indication only.

Setting ELOP := Y

If you set ELOP to Y and an LOP condition occurs, the voltage-polarized directional elements are disabled. The forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.

Setting ELOP := Y1

If you set ELOP to Y1 and an LOP condition occurs, the voltage-polarized directional elements are disabled. This setting for ELOP also disables the overcurrent elements that these voltage-polarized directional elements control.

Table 1.26 LOP Logic Setting

Name	Description	Range	Default
ELOP	Loss-of-potential	Y, Y1, N	Y

Table 1.27 LOP Logic Relay Word Bits

Name	Description
ILOP	Internal loss-of-potential from ELOP setting
LOP	Loss-of-potential detected

Figure 1.23 illustrates how the LOP logic processes an LOP decision. *Figure 1.24* provides a logic diagram for the LOP logic.

Figure 1.23 LOP Logic Process Overview

The following text gives additional description of the steps shown in *Figure 1.23*:

(1) Magnitude of positive-sequence voltage is decreasing. Measure positive-sequence voltage magnitude (called $|V_{1(k)}|$, where k represents the present processing interval result) and compare it to $|V_1|$ from one power system cycle earlier (called $|V_{1(k-1\ cycle)}|$). If $|V_{1(k)}|$ is less than or equal to 90 percent $|V_{1(k-1\ cycle)}|$, assert LOP if all of the conditions in the next four steps are satisfied. This is the decreasing delta change in V_1 ($-\Delta|V_1| > 10\%$) shown as an input in the logic diagram of *Figure 1.24*.

(2) Positive-sequence current magnitude not changing. Measure positive-sequence current magnitude ($|I_{1(k)}|$) and compare it to $|I_{1(k-1\ cycle)}|$ from one cycle earlier. If this difference is greater than two percent nominal current, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\Delta|I_1| > 2\%$ in *Figure 1.24*.

(3) Positive-sequence current angle is not changing. Measure positive-sequence current angle ($\angle I_{1k}$) and compare it to $\angle I_{1(k-1\ cycle)}$ from one cycle earlier. If this difference is greater than 5 degrees, the condition

measured is not an LOP, even if all other conditions are met. This input is labeled as $\angle I_1 > 5°$ in *Figure 1.24*. If $|I_1|$ is less than five percent nominal current (I_{NOM}), this angle check does not block LOP.

(4) Zero-sequence current magnitude is not changing. Measure zero-sequence current magnitude ($|I_{0k}|$) and compare it to $|I_{0(k-1\ cycle)}|$ from one cycle earlier. If this difference is greater than six percent nominal current, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\Delta|I_0| > 6\%$ in *Figure 1.24*.

(5) Zero-sequence current angle is not changing. Measure zero-sequence current angle ($\angle I_{0k}$) and compare it to $\angle I_{0(k-1\ cycle)}$. If this difference is greater than 5 degrees, the condition measured is not an LOP even if all other conditions are met. This input is labeled as $\angle I_0 > 5°$ in *Figure 1.24*. For security, this declaration requires that $|I_0|$ be greater than five percent of nominal current to override an LOP declaration.

If the criteria identified in all five steps listed above are met, the LOP logic declares an LOP condition.

The relay resets LOP logic when the following conditions are true for 30 cycles:

1. a decreasing delta change in V_1 is less than 10 percent (see point (1) above), and
2. the magnitude of V_1 is larger than 85 percent of V_{NOM}, and
3. the magnitude of $|V_0|$ is not larger than 10 percent of magnitude $|V_1|$

Figure 1.24 LOP Logic

Fault Type Identification Selection Logic

NOTE: Voltage inputs are required for the Fault Identification logic.

This logic identifies the faulted phase(s) for all faults involving ground by comparing the angle between I_0 and I_2.

For cases where only zero-sequence current flows through the relay terminal (that is, no negative-sequence current and no positive-sequence current), the Fault Type Identification Selection (FIDS) Logic uses single-phase undervoltage elements for faulted phase selection.

Table 1.28 FIDS Relay Word Bits

Name	Description
FIDEN	FIDS logic enabled
FSA	A-phase-to-ground fault or B-phase to C-phase-to-ground fault selected
FSB	B-phase-to-ground fault or C-phase to A-phase-to-ground fault selected
FSC	C-phase-to-ground fault or A-phase to B-phase-to-ground fault selected

Ground Overcurrent Elements Directional Control

The SEL-451 offers a choice of three independent directional elements to supervise the directional residual ground overcurrent elements (67G*n*, where *n* equals 1 through 4) during ground faults. Internal logic selects the best choice automatically. *Table 1.29* lists the directional elements the relay uses to provide ground directional decisions.

Table 1.29 Directional Elements Supervising Ground Overcurrent Elements

Directional Elements	Description	Forward Output	Reverse Output
32QG	Negative-sequence voltage polarized for ground faults	F32QG	R32QG
32V	Zero-sequence voltage polarized	F32V	R32V
32I	Zero-sequence current polarized	F32I	R32I

The negative-sequence voltage polarized directional element 32QG listed in *Table 1.29* supervises the residual ground directional overcurrent elements. The negative-sequence voltage polarized directional element 32Q illustrated in *Figure 1.33* only supervises the negative-sequence and phase directional overcurrent elements.

The relay internal logic selects the best choice for directional supervision according to prevailing power system conditions during the ground fault. The logic determines the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), or the zero-sequence current-polarized directional element (32I).

Table 1.30 lists the relay settings corresponding to the ground directional element.

Table 1.30 Ground Directional Element Settings

Setting	Description	Range	Default (5 A)
E32	Directional Control	Y, AUTO, N	N
ORDER	Ground Directional Element Priority	combine Q, V, I	QV
50FP	Forward Directional Overcurrent Pickup (A)	(0.05–1) • I_{NOM}	0.60
50RP	Reverse Directional Overcurrent Pickup (A)	(0.05–1) • I_{NOM}	0.40
Z2F	Forward Directional Z2 Threshold (Ω)	±320/I_{NOM}	1.07
Z2R	Reverse Directional Z2 Threshold (Ω)	±320/I_{NOM}	1.17
a2	Positive-Sequence Restraint Factor, I2/I1	0.02–0.5	0.10
k2	Zero-Sequence Restraint Factor, I2/I0	0.1–1.2	0.20
Z0F	Forward directional Z0 threshold (Ω)	±320/I_{NOM}	3.19
Z0R	Reverse directional Z2 threshold (Ω)	±320/I_{NOM}	3.29
a0	Positive-Sequence restraint factor, I0/I1	0.02–0.5	0.10
E32IV	Zero-sequence voltage current enable	SELOGIC equation	1

If you set E32 to AUTO, the relay automatically calculates the settings shown in *Table 1.31*.

If you set E32 to N, the built-in directional control for the instantaneous/definite-time overcurrent elements is disabled, and the remaining settings in *Table 1.30* are hidden. See *E32 := N on page R.1.46* for more information.

Table 1.31 Ground Directional Element Settings AUTO Calculations

Setting	Equation
50FP	0.12 • I_{NOM}
50RP	0.08 • I_{NOM}
Z2F	0.5 • Z1MAG
Z2R	Z2F + 1/(2 • I_{NOM})
a2	0.10
k2	0.20
Z0F	0.5 • Z0MAG
Z0R	Z0F + 1/(2 • I_{NOM})
a0	0.10

Detailed Settings Description

If you set E32 to Y, you can change the settings listed in *Table 1.31*.

50FP and 50RP

Setting 50FP is the threshold for the current level detector that enables forward decisions for both the negative- and zero-sequence voltage-polarized directional elements. If the magnitude of $3I_2$ or $3I_0$ is greater than 50FP, the corresponding directional element can process a forward decision.

Setting 50RP is the threshold for the current level detector that enables reverse decisions for both the negative- and zero-sequence voltage-polarized directional elements. If the magnitude of $3I_2$ or $3I_0$ is greater than 50RP, the corresponding directional element can process a reverse decision.

Z2F and Z2R

Setting Z2F is the forward threshold for the negative-sequence voltage-polarized directional element. If the relay measures the apparent negative-sequence impedance z2 less than Z2F, the relay declares the fault to be forward.

Setting Z2R is the reverse threshold for the negative-sequence voltage-polarized directional element. If the relay measures apparent negative-sequence impedance z2 greater than Z2R, the relay declares the fault to be reverse.

a2 and k2

Positive-sequence current restraint factor a2 compensates for highly unbalanced systems. Unbalance is typical in systems that have many untransposed lines. This factor also helps prevent misoperation during current transformer saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current, $|I_2|/|I_1|$. If the measured ratio exceeds a2, the negative-sequence voltage-polarized directional element is enabled. Typically, you can apply the default calculations in *Table 1.31*.

Zero-sequence current restraint factor k2 also compensates for highly unbalanced systems. This factor is the ratio of the magnitude of negative-sequence current to the magnitude of zero-sequence current, $|I_2|/|I_0|$. If the measured ratio exceeds k2, the negative-sequence voltage-polarized directional element is enabled. Typically, you can apply the default calculations that appear in *Table 1.31*.

Z0F and Z0R

Setting Z0F is the forward threshold for the zero-sequence voltage-polarized directional element. If the relay measures apparent zero-sequence impedance z0 less than Z0F, the relay declares the fault to be forward.

Setting Z0R is the reverse threshold for the zero-sequence voltage-polarized directional element. If the relay measures apparent zero-sequence impedance z0 greater than Z0R, then the relay declares the fault to be reverse.

Typically, you can apply the default calculations that appear in *Table 1.31* for the settings Z2F, Z2R, Z0F, and Z0R. The forward threshold setting must be less than corresponding reverse threshold setting to avoid the situation where the measured apparent impedance satisfies both forward and reverse conditions.

a0

Positive-sequence current restraint factor a0 is the ratio of the magnitude of zero-sequence current to the magnitude of positive-sequence current, $|I_0|/|I_1|$. If the relay measures a ratio greater than a0, the zero-sequence voltage-polarized directional element is enabled. Typically you can apply the default calculations that appear in *Table 1.31*.

ORDER

The SEL-451 uses Best Choice Ground Directional™ logic to determine the order in which the relay selects 32QG, 32V, or 32I to provide directional control to the residual ground directional overcurrent elements. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element (32QG)
- V—Zero-sequence voltage-polarized directional element (32V)
- I—Zero-sequence current-polarized directional element (32I)

You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority that these elements operate to provide the ground directional element (see *Figure 1.27*).

Set E32 := Y to edit the ground directional element settings. If you set E32 := Y the relay hides certain relay settings depending on the setting ORDER.

If ORDER does not contain Q, the relay hides the Z2F, Z2R, a2, and k2 settings. If ORDER does not contain V, the relay hides the Z0F and Z0R settings. If ORDER contains only Q, the relay hides settings a0, E32IV, Z0F, and Z0R.

E32IV

SELOGIC control equation setting E32IV must be asserted to enable the zero-sequence voltage-polarized or zero-sequence current-polarized directional elements. This provides a method of disabling directional control of the directional residual ground overcurrent elements for temporary conditions.

Directional Element Enables

The Relay Word bits shown in *Table 1.32* indicate when the relay has enabled the ground directional element.

Table 1.32 Ground Directional Element Enables

Name	Description
32QE	Negative-sequence voltage-polarized directional element enable—phase faults
32QGE	Negative-sequence voltage-polarized directional element enable—ground faults
32VE	Zero-sequence voltage-polarized directional element enable—ground faults
32IE	Zero-sequence current-polarized directional element enable—ground faults

Figure 1.25 and *Figure 1.26* correspond to *Table 1.32*.

Figure 1.25 32Q and 32QG Enable Logic Diagram

Figure 1.26 32V and 32I Enable Logic Diagram

Table 1.33 Ground Directional Element Relay Word Bits

Name	Description
50QF	Forward negative-sequence supervisory current level detector
50QR	Reverse negative-sequence supervisory current level detector
32QE	32Q internal enable
32QGE	32QG internal enable
50GF	Forward zero-sequence supervisory current level detector
50GR	Reverse zero-sequence supervisory current level detector
32VE	32V internal enable
32IE	32I internal enable
32GF	Forward ground directional declaration
32GR	Reverse ground directional declaration
F32I	Forward current polarized zero-sequence directional element
R32I	Reverse current polarized zero-sequence directional element
F32V	Forward voltage polarized zero-sequence directional element
R32V	Forward voltage polarized zero-sequence directional element
F32QG	Forward negative-sequence ground directional element
R32QG	Forward negative-sequence ground directional element

Figure 1.27 Best Choice Ground Directional Logic
① From Figure 1.25, ② From Figure 1.26, ③ To Figure 1.28, ④ To Figure 1.29, ⑤ To Figure 1.30

Figure 1.28 Negative-Sequence Voltage-Polarized Directional Element Logic
① From Figure 1.25; ② From Figure 1.27

Figure 1.29 Zero-Sequence Voltage-Polarized Directional Element Logic
① From Figure 1.26; ② From Figure 1.27

Figure 1.30 Zero-Sequence Current-Polarized Directional Element Logic

① From Figure 1.26; ② From Figure 1.27

Figure 1.31 Ground Directional Element Output Logic Diagram

Table 1.34 Reference Table for Figure 1.28, Figure 1.29, and Figure 1.30

Name	Description
z2	Negative-sequence voltage-polarized directional element impedance calculation
Z2FTH	Negative-sequence voltage-polarized directional element forward threshold calculation
Z2RTH	Negative-sequence voltage-polarized directional element reverse threshold calculation
z0	Zero-sequence voltage-polarized directional element impedance calculation
Z0FTH	Zero-sequence voltage-polarized directional element forward threshold calculation
Z0RTH	Zero-sequence voltage-polarized directional element reverse threshold calculation
32I	Zero-sequence current-polarized directional element calculation
32IFTH	Zero-sequence current-polarized directional element forward threshold calculation
32IRTH	Zero-sequence current-polarized directional element reverse threshold calculation

Ground Directional Element Equations

For legibility, these equations use vector quantities, defined in *Table 1.35*. The analog quantities are listed in *Table B.2*.

Table 1.35 Vector Definitions for Equation 1.1–Equation 1.11

Vector	Analog Quantities	Description
V_2	1/3 [3V2FIM] ∠ 3V2FIA	Negative-sequence voltage
V_0	1/3 [3V0FIM] ∠ 3V0FIA	Zero-sequence voltage
I_2	1/3 [L3I2FIM] ∠ L3I2FIA	Negative-sequence current
IG	LIGFIM ∠ LIGFIA	Zero-sequence current
IP	IPFIM ∠ IPFIA[a]	Polarizing current

[a] The polarizing current angle quantity, IPFIA, is an internal quantity only and is not available as an analog quantity.

32QG

Directional Calculation

$$z2 = \frac{\mathrm{Re}[V_2 \bullet (I_2 \bullet 1\angle Z1ANG)^*]}{|I_2|^2}$$

Equation 1.1

Forward Threshold

If Z2F is less than or equal to 0:

$$Z2FTH = 0.75 \bullet Z2F - 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.2

Z2F is greater than 0:

$$Z2FTH = 1.25 \bullet Z2F - 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.3

Reverse Threshold

If Z2R is greater than or equal to 0:

$$Z2RTH = 0.75 \bullet Z2R + 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.4

If Z2R is less than 0:

$$Z2RTH = 1.25 \bullet Z2R + 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.5

32V

Directional Calculation

$$z0 = \frac{Re[3V_0 \bullet (I_G \bullet 1\angle Z0ANG)^*]}{|I_G|^2}$$

Equation 1.6

Forward Threshold

If Z0F is less than or equal to 0:

$$Z0FTH = 0.75 \bullet Z0F - 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.7

If Z0F is greater than 0:

$$Z0FTH = 1.25 \bullet Z0F - 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.8

Reverse Threshold

If Z0R is greater than or equal to 0:

$$Z0RTH = 0.75 \bullet Z0R + 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.9

If Z0R is less than 0:

$$Z0RTH = 1.25 \bullet Z0R + 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.10

32I

Directional Calculation

$$32I = Re[I_G \bullet I_P^*]$$

Equation 1.11

where:

I_P = Polarizing Current

Forward Threshold

$$32IFTH = 0.01 \bullet (\text{InX nominal rating}) \bullet (\text{nominal current rating})$$

Equation 1.12

Reverse Threshold

$$32IRTH = -0.01 \bullet (\text{InX nominal rating}) \bullet (\text{nominal current rating})$$

Equation 1.13

Negative-Sequence/Phase Overcurrent Elements Directional Control

With directional control enable setting E32 := Y or AUTO, phase (32P) and negative-sequence voltage-polarized (32Q) directional elements supervise the Negative-Sequence and Phase Overcurrent elements. The 32Q element has priority over 32P as shown in *Figure 1.32*. Relay Word bit ZLOAD (Load Impedance Detected) disables the 32P element. The 32Q element operates for all unbalanced faults, shown in *Figure 1.33*.

When E32 := AUTO, you do not need to enter settings for 32Q or 32P elements. However, if you set E32 (Directional Control) to Y, the settings you enter for 50FP, 50RP, Z2F, Z2R, and a2 affect the 32Q element (see *Ground Overcurrent Elements Directional Control on page R.1.33* for more details).

The SEL-451 uses a positive-sequence voltage memory quantity to polarize the phase directional element. This memory will operate the phase directional elements even for close-in, zero-voltage faults, provided that the fault is cleared within approximately two seconds (for nominal voltages of 115 V L-L or higher). Sufficient polarizing voltage is available.

Table 1.36 Phase and Negative-Sequence Directional Elements Relay Word Bits

Name	Description
F32P	Forward phase directional declaration
R32P	Reverse phase directional declaration
F32Q	Forward negative-sequence directional declaration
R32Q	Reverse negative-sequence directional declaration
32QF	Forward negative-sequence overcurrent directional declaration
32QR	Reverse negative-sequence overcurrent directional declaration

Figure 1.32 32P, Phase Directional Element Logic Diagram

Figure 1.33 32Q, Negative-Sequence Directional Element Logic Diagram

Directional Element Routing

The SEL-451 instantaneous/definite-time overcurrent elements feature a directional control option with two fixed-forward and two settable levels of directional control.

E32 := Y or AUTO

The 67P*n*, 67P*n*T, 67G*n*, 67G*n*T, 67Q*n*, and 67Q*n*T instantaneous/definite-time overcurrent elements are automatically configured to use directional control as shown in *Figure 1.36*, *Figure 1.37*, and *Figure 1.38*.

The first two levels ($n = 1$ and $n = 2$) always respond to forward direction faults.

The remaining levels ($n = 3$ and $n = 4$) either respond to forward (F) or reverse (R) faults, according to settings DIR3 and DIR4, respectively (see *Table 1.37*).

Table 1.37 Level Directional Settings

Setting	Description	Range	Default
DIR3	Level 3 Directional Control	F, R	R
DIR4	Level 4 Directional Control	F, R	F

This directional control option is performed in addition to the regular torque control settings for each element (the torque control setting acts as a supervisory input).

The selectable operating quantity time-overcurrent elements do not have any built-in directional control. The torque control settings (51S1TC, 51S2TC, 51S3TC, 51S4TC, 51S5TC, 51S6TC) can be used to achieve directional control, as shown in *25 kV Overhead Distribution Line Example on page A.1.1*.

E32 := N

When setting E32 := N, the directional control option is defeated, and the instantaneous/definite-time overcurrent elements are only supervised by their respective torque control settings (see *Figure 1.36*, *Figure 1.37*, and *Figure 1.38*).

The directional element settings (*Table 1.30*) are hidden when E32 := N, however the directional element logic remains functional. The directional element Relay Word bits (*Table 1.33* and *Table 1.35*) should not be used in SELOGIC equations when E32 := N, because the settings are not accessible.

The factory default Event Report digitals (*Figure 3.11 on page A.3.25*) include several directional element Relay Word bits, which may show activity during faults, even when E32 := N.

Load-Encroachment Logic

The load-encroachment logic prevents load from causing phase protection to operate. You can set the phase overcurrent elements independent of load. Two independent positive-sequence impedance characteristics monitor the positive-sequence load impedance (Z_1) for both export and import load. The positive-sequence voltage-polarized directional element (32P) is blocked when the load-encroachment logic is enabled and load is detected.

Figure 1.34 illustrates the load-encroachment logic. The logic operates only if the positive-sequence current (I_1) is greater than the positive-sequence threshold (10 percent of the nominal relay current). Relay Word bit ZLOUT indicates that load is flowing out with respect to the relay (an export condition). Relay Word bit ZLIN indicates that load is flowing in with respect to the relay (an import condition). *Figure 1.35* illustrates load-encroachment settings and corresponding characteristics in the positive-sequence impedance plane. Either Relay Word bit ZLOUT or ZLIN asserts if the relay measures a positive-sequence impedance that lies within the corresponding hatched region. Relay Word bit ZLOAD is the OR combination of ZLOUT and ZLIN.

Figure 1.34 Load-Encroachment Logic Diagram

Figure 1.35 Load-Encroachment Characteristics

Table 1.38 Load-Encroachment Logic Relay Settings

Name	Description	Range	Default (5 A)
ELOAD	Load Encroachment	Y, N	N
ZLF	Forward Load Impedance (Ω)	$(0.25–320)/I_{NOM}$	9.22
ZLR	Reverse Load Impedance (Ω)	$(0.25–320)/I_{NOM}$	9.22
PLAF	Forward Load Positive Angle (°)	–90.0 to +90	30.0
NLAF	Forward Load Negative Angle (°)	–90.0 to +90	–30.0
PLAR	Reverse Load Positive Angle (°)	90.0–270	150.0
NLAR	Reverse Load Negative Angle (°)	90.0–270	210.0

Table 1.39 Load-Encroachment Logic Relay Word Bits

Name	Description
ZLOAD	ZLIN OR ZLOUT
ZLIN	Import load impedance detected
ZLOUT	Export load impedance detected

Instantaneous/Definite-Time Line Overcurrent Elements

The SEL-451 calculates instantaneous overcurrent elements for phase (P) residual ground (G, vector sum of I_A, I_B, and I_C), and negative-sequence (Q) quantities. Four levels of instantaneous elements are available named 50P1–50P4, 50Q1–50Q4, and 50G1–50G4, as shown in *Table 1.43* through *Table 1.45*, with settings shown in *Table 1.40* through *Table 1.42*.

These overcurrent elements always operate on the line current (W terminal current or the sum of the W and X terminal currents) according to the setting LINEI (Line Current Source).

NOTE: The 67xn and 67xnP elements operate from the pickup values set for the 50xnP elements. The 67xn elements and settings access are controlled by the E50x settings.

The instantaneous overcurrent elements are inputs to the instantaneous directional (67P*n*, 67Q*n*, 67G*n*, where *n* = 1–4) and definite-time directional overcurrent elements (67P*n*T, 67Q*n*T, 67G*n*T, where *n* = 1–4). See *Directional Element Routing on page R.1.45* for details on the directional control option.

Each of the instantaneous directional elements includes a torque control setting (67P*n*TC, 67Q*n*TC, 67G*n*TC, where *n* = 1–4) to supervise the element operation.

The enable settings (E50P, E50Q, E50G) control how many of each type of instantaneous/definite-time overcurrent elements are available. For example, if E50P := 2, only 50P1, 67P1, 67P1T, 50P2, 67P2, and 67P2T are processed. The remaining phase instantaneous/definite-time overcurrent elements (*n* = 3–4) are defeated, and the output Relay Word bits are forced to logical 0.

Table 1.40 Phase Overcurrent Element Settings

Setting	Description	Range	Default (5 A)
Phase Instantaneous Overcurrent Elements			
E50P	Phase Inst./Def.-Time O/C Elements	N, 1–4	1
50P1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{NOM}	15.00
50P2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50P3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50P4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
Phase Definite-Time Overcurrent Elements			
67P1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67P2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67P3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67P4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67P1TC	Level 1 Torque Control	SELOGIC Equation	1
67P2TC	Level 2 Torque Control	SELOGIC Equation	1
67P3TC	Level 3 Torque Control	SELOGIC Equation	1
67P4TC	Level 4 Torque Control	SELOGIC Equation	1

Table 1.41 Negative-Sequence Overcurrent Element Settings

Setting	Description	Range	Default (5 A)
Negative-Sequence Instantaneous Overcurrent Elements			
E50Q	Neg.-Seq. Inst./Def.-Time O/C Elements	N, 1–4	N
50Q1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50Q2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50Q3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50Q4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
Negative-Sequence Definite-Time Overcurrent Elements			
67Q1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67Q2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67Q3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67Q4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67Q1TC	Level 1 Torque Control	SELOGIC Equation	1
67Q2TC	Level 2 Torque Control	SELOGIC Equation	1
67Q3TC	Level 3 Torque Control	SELOGIC Equation	1
67Q4TC	Level 4 Torque Control	SELOGIC Equation	1

Table 1.42 Residual Ground Overcurrent Element Settings

Setting	Description	Range	Default (5 A)
Residual Ground Instantaneous Overcurrent Elements			
E50G	Residual Ground Inst./Def.-Time O/C Elements	N, 1–4	N
50G1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50G2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50G3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50G4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
Residual Ground Definite-Time Overcurrent Elements			
67G1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67G2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67G3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67G4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67G1TC	Level 1 Torque Control	SELOGIC Equation	1
67G2TC	Level 2 Torque Control	SELOGIC Equation	1
67G3TC	Level 3 Torque Control	SELOGIC Equation	1
67G4TC	Level 4 Torque Control	SELOGIC Equation	1

Table 1.43 Phase Instantaneous and Definite-Time Line Overcurrent Relay Word Bits

Name	Description
50P1	Level 1 instantaneous phase overcurrent element
50P2	Level 2 instantaneous phase overcurrent element
50P3	Level 3 instantaneous phase overcurrent element
50P4	Level 4 instantaneous phase overcurrent element
67P1	Level 1 phase directional overcurrent element
67P2	Level 2 phase directional overcurrent element
67P3	Level 3 phase directional overcurrent element
67P4	Level 4 phase directional overcurrent element
67P1T	Level 1 definite-time phase directional overcurrent element
67P2T	Level 2 definite-time phase directional overcurrent element
67P3T	Level 3 definite-time phase directional overcurrent element
67P4T	Level 4 definite-time phase directional overcurrent element

Table 1.44 Negative-Sequence Instantaneous and Definite-Time Line Overcurrent Relay Word Bits

Name	Description
50Q1	Level 1 instantaneous negative-sequence overcurrent element
50Q2	Level 2 instantaneous negative-sequence overcurrent element
50Q3	Level 3 instantaneous negative-sequence overcurrent element
50Q4	Level 4 instantaneous negative-sequence overcurrent element
67Q1	Level 1 negative-sequence directional overcurrent element
67Q2	Level 2 negative-sequence directional overcurrent element
67Q3	Level 3 negative-sequence directional overcurrent element
67Q4	Level 4 negative-sequence directional overcurrent element
67Q1T	Level 1 definite-time negative-sequence directional overcurrent element
67Q2T	Level 2 definite-time negative-sequence directional overcurrent element
67Q3T	Level 3 definite-time negative-sequence directional overcurrent element
67Q4T	Level 4 definite-time negative-sequence directional overcurrent element

Table 1.45 Residual Ground Instantaneous and Definite-Time Line Overcurrent Relay Word Bits

Name	Description
50G1	Level 1 instantaneous residual ground overcurrent element
50G2	Level 2 instantaneous residual ground overcurrent element
50G3	Level 3 instantaneous residual ground overcurrent element
50G4	Level 4 instantaneous residual ground overcurrent element
67G1	Level 1 residual ground directional overcurrent element
67G2	Level 2 residual ground directional overcurrent element
67G3	Level 3 residual ground directional overcurrent element
67G4	Level 4 residual ground directional overcurrent element
67G1T	Level 1 definite-time residual ground directional overcurrent element
67G2T	Level 2 definite-time residual ground directional overcurrent element
67G3T	Level 3 definite-time residual ground directional overcurrent element
67G4T	Level 4 definite-time residual ground directional overcurrent element

Figure 1.36 Phase Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

Figure 1.37 Residual Ground Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

Figure 1.38 Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

Inverse-Time Overcurrent Elements

The SEL-451 provides six selectable operating quantity inverse-time overcurrent elements. Ten different time-overcurrent characteristics (5 US and 5 IEC curves) are available.

Each time-overcurrent element can be configured to operate on the line current (i.e., W terminal current or the sum of the W and X terminal currents) depending upon setting LINEI (Line Current Source); or circuit breaker operating quantities, with the terminal source depending upon settings BK1I and BK2I.

Both filtered magnitudes and rms magnitudes are available for the phase and maximum-phase quantities. Symmetrical component current quantities are available only for the line current source. *Table 1.46* defines the available setting choices for operating quantities and the corresponding analog quantity name as found in *Appendix B*.

NOTE: In the SEL-451, the time-overcurrent elements are not directionally controlled in the internal logic. Directional control may be achieved through the use of the torque control settings, as shown in 25 kV Overhead Distribution Line Example on page A.1.1. Also refer to Directional Element Routing on page R.1.45.

Each time-overcurrent element has a torque control SELOGIC equation 51S*k*TC (k = 1 to 6) that enables the element when the equation evaluates to logical 1, and disables the element when the equation evaluates to logical 0. See *Figure 1.49* for a logic diagram of the time-overcurrent elements, including the torque control input.

The enable setting (E51S) controls how many time-overcurrent elements are available. For example, if E51S := 1, only 51S1 is processed. The remaining time-overcurrent elements 51S*k* (k = 2 – 6) are defeated, and the output Relay Word bits are forced to logical 0.

Table 1.46 Selectable Current Quantities[a]

Quantity	Description	Analog Quantities
Filtered Magnitudes		
IA*n*	A-Phase	LIAFIM, B1IAFIM, B2IAFIM
IB*n*	B-Phase	LIBFIM, B1IBFIM, B2IBFIM
IC*n*	C-Phase	LICFIM, B1ICFIM, B2ICFIM
IMAX*n*	Maximum Phase	
I1L	Line positive-sequence current	LI1FIM
3I2L	Line negative-sequence current	L3I2FIM
3I0*n*	Zero-sequence current	LIGFIM, B1IGFIM, B2IGFIM
RMS Magnitudes		
IA*n*R	A-Phase (see *Figure 3.1 on page A.3.3*)	LIARMS, B1IARMS, B2IARMS[b]
IB*n*R	B-Phase (see *Figure 3.1 on page A.3.3*)	LIBRMS, B1IBRMS, B2IBRMS[b]
IC*n*R	C-Phase (see *Figure 3.1 on page A.3.3*)	LICRMS, B1ICRMS, B2ICRMS[b]
IMAX*n*R	Maximum Phase (see *Figure 3.1 on page A.3.3*)	

[a] Parameter n is L for Line, 1 for Breaker 1, and 2 for Breaker 2.
[b] The 51Sk element will operate using instantaneous rms quantities. These 10-cycle average rms current analog quantities are shown for reference purposes (the instantaneous rms quantities are not available as analog quantities; see Table B.2).

Table 1.47 Selectable Inverse-Time Overcurrent Settings[a] (Sheet 1 of 2)

Setting	Description	Range	Default (5 A)
E51S	Selectable Inverse-Time Overcurrent Element	N, 1–6	2
51S1O	Operating Quantity Element 1	IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*	IMAXL
51S1P	51S1 O/C Pickup Element 1 (A)	(0.05–3.2) • I_{NOM}	5.00
51S1C	51S1 Inverse Time O/C Curve Element 1	U1–U5 C1–C5	U3
51S1TD	51S1 Inverse Time O/C Time Dial Element 1	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.00
51S1RS	51S1 Inverse Time O/C Electromechanical Reset Element 1	Y, N	N
51S1TC	51S1 Inverse Time O/C Torque Control Element 1	SELOGIC Equation	1
51S2O	Operating Quantity Element 2	IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*	3I0L
51S2P	51S2 O/C Pickup Element 2 (A)	(0.05–3.2) • I_{NOM}	1.50
51S2C	51S2 Inverse Time O/C Curve Element 2	U1–U5 C1–C5	U3
51S2TD	51S2 Inverse Time O/C Time Dial Element 2	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.00
51S2RS	51S2 Inverse Time O/C Electromechanical Reset Element 2	Y, N	N
51S2TC	51S2 Inverse Time O/C Torque Control Element 2	SELOGIC Equation	PLT01
51S3O	Operating Quantity Element 3	IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*	IMAXL
51S3P	51S3 O/C Pickup Element 3 (A)	OFF, (0.05–3.2) • I_{NOM}	5.00
51S3C	51S3 Inverse Time O/C Curve Element 3	U1–U5 C1–C5	U3
51S3TD	51S3 Inverse Time O/C Time Dial Element 3	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.00
51S3RS	51S3 Inverse Time O/C Electromechanical Reset Element 3	Y, N	N
51S3TC	51S3 Inverse Time O/C Torque Control Element 3	SELOGIC Equation	1
51S4O	Operating Quantity Element 4	IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*nR*, IC*nR*, IMAX*nR*, I1L, 3I2L, 3I0*n*	IMAXL
51S4P	51S4 O/C Pickup Element 4 (A)	(0.05–3.2) • I_{NOM}	5.00
51S4C	51S4 Inverse Time O/C Curve Element 4	U1–U5 C1–C5	U3
51S4TD	51S4 Inverse Time O/C Time Dial Element 4	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.00

Table 1.47 Selectable Inverse-Time Overcurrent Settings[a] (Sheet 2 of 2)

Setting	Description	Range	Default (5 A)
51S4RS	51S4 Inverse Time O/C Electromechanical Reset Element 4	Y, N	N
51S4TC	51S4 Inverse Time O/C Torque Control Element 4	SELOGIC Equation	1
51S5O	Operating Quantity Element 5	IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*nR*, IC*nR*, IMAX*nR*, I1L, 3I2L, 3I0*n*	IMAXL
51S5P	51S5 O/C Pickup Element 5 (A)	(0.05–3.2) • I_{NOM}	5.00
51S5C	51S5 Inverse Time O/C Curve Element 5	U1–U5 C1–C5	U3
51S5TD	51S5 Inverse Time O/C Time Dial Element 5	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.00
51S5RS	51S5 Inverse Time O/C Electromechanical Reset Element 5	Y, N	N
51S5TC	51S5 Inverse Time O/C Torque Control Element 5	SELOGIC Equation	1
51S6O	Operating Quantity Element 6	IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*nR*, IC*nR*, IMAX*nR*, I1L, 3I2L, 3I0*n*	IMAXL
51S6P	51S6 O/C Pickup Element 6 (A)	OFF, (0.05–3.2) • I_{NOM}	5.00
51S6C	51S6 Inverse Time O/C Curve Element 6	U1–U5 C1–C5	U3
51S6TD	51S6 Inverse Time O/C Time Dial Element 6	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.00
51S6RS	51S6 Inverse Time O/C Electromechanical Reset Element 6	Y, N	N
51S6TC	51S6 Inverse Time O/C Torque Control Element 6	SELOGIC Equation	1

[a] Parameter n is L for Line, 1 for Breaker 1, and 2 for Breaker 2.
[b] Parameter x is a number from 1–5 indicating the operating curve (see Figure 1.39 through Figure 1.48).

Table 1.48 Selectable Inverse-Time Overcurrent Relay Word Bits (Sheet 1 of 2)

Name	Description
51S1	Inverse-Time Overcurrent Element 1 pick-up
51S1T	Inverse-Time Overcurrent Element 1 timed out
51S1R	Inverse-Time Overcurrent Element 1 reset
51S2	Inverse-Time Overcurrent Element 2 pick-up
51S2T	Inverse-Time Overcurrent Element 2 timed out
51S2R	Inverse-Time Overcurrent Element 2 reset
51S3	Inverse-Time Overcurrent Element 3 pick-up
51S3T	Inverse-Time Overcurrent Element 3 timed out
51S3R	Inverse-Time Overcurrent Element 3 reset
51S4	Inverse-Time Overcurrent Element 4 pick-up

Table 1.48 Selectable Inverse-Time Overcurrent Relay Word Bits
(Sheet 2 of 2)

Name	Description
51S4T	Inverse-Time Overcurrent Element 4 timed out
51S4R	Inverse-Time Overcurrent Element 4 reset
51S5	Inverse-Time Overcurrent Element 5 pick-up
51S5T	Inverse-Time Overcurrent Element 5 timed out
51S5R	Inverse-Time Overcurrent Element 5 reset
51S6	Inverse-Time Overcurrent Element 6 pick-up
51S6T	Inverse-Time Overcurrent Element 6 timed out
51S6R	Inverse-Time Overcurrent Element 6 reset

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 1.39–Figure 1.48* conform to *IEEE C37.112–1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays*.

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 1.49 Equations Associated With U.S. Curves

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 1.39*
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 1.40*
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 1.41*
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 1.42*
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 1.43*

Table 1.50 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 1.44*
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 1.45*
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 1.46*
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 1.47*
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 1.48*

Figure 1.39 U.S. Moderately Inverse Curve: U1

Figure 1.40 U.S. Inverse Curve: U2

Figure 1.41 U.S. Very Inverse Curve: U3

Figure 1.42 U.S. Extremely Inverse Curve: U4

Figure 1.43 U.S. Short-Time Inverse Curve: U5

Figure 1.44 IEC Standard Inverse Curve: C1

Figure 1.45 IEC Very Inverse Curve: C2

Figure 1.46 IEC Extremely Inverse Curve: C3

Figure 1.47 IEC Long-Time Inverse Curve: C4

Figure 1.48 IEC Short-Time Inverse Curve: C5

Figure 1.49 Selectable Inverse-Time Overcurrent Element Logic Diagram

Switch-Onto-Fault Logic

The switch-onto-fault (SOTF) logic permits specified protection elements to trip for a settable time after the circuit breaker closes. Specify these elements in the SELOGIC control equation TRSOTF (switch-onto-fault trip). The SOTF logic works in two stages: validating a possible SOTF condition (which asserts SOTFE) and initiating (enabling) the SOTF protection duration.

The relay validates an SOTF condition by sensing the following:

- **Upon circuit breaker opening**: detection of a pole open condition (3PO) when setting 52AEND (52A Pole Open Qualifying Time Delay) is other than OFF
- **Upon circuit breaker closing**: detection of a pole open condition (3PO) when setting CLOEND (Close Enable Time Delay) is other than OFF

Select either or both methods for the validating procedure.

The relay initiates SOTF protection at these corresponding instances:

- **Circuit breaker opening**: 52AEND timer timeout
- **Circuit breaker closing**: CLOEND time timeout and SELOGIC control equation CLSMON assertion

Circuit Breaker Opened SOTF Logic

Set ESOTF to Y and set 52AEND to other than OFF to enable the circuit breaker-opened SOTF logic. When the circuit breaker opens, the 52AEND timer operates when three poles open (3PO asserts). When the 3PO condition lasts longer than the 52AEND timer, the relay asserts Relay Word bit SOTFE (SOTF Enable).

When the circuit breaker closes, Relay Word bit 3PO deasserts after the 3POD dropout time. When 3PO deasserts, the relay continues to assert Relay Word bit SOTFE for dropout time SOTFD or until the logic detects a healthy voltage condition (if EVRST := Y, see *SOTF Options*).

Circuit Breaker Closed SOTF Logic

You can detect circuit breaker close bus assertion by monitoring the dc close bus. Connect a control input on the SEL-451 to the dc close bus. The control input energizes whenever a manual close or automatic reclosure occurs. Set SELOGIC control equation CLSMON (Close Signal Monitor) to monitor the control input (e.g., CLSMON := IN102) and consequently detect close bus assertion.

Set ESOTF to Y and set CLOEND to other than OFF to enable the circuit breaker-closed SOTF logic. The CLOEND timer operates when three poles open (3PO asserts). If the 3PO condition continues longer than the CLOEND time and the close bus asserts (SELOGIC control equation CLSMON equals logical 1), Relay Word bit SOTFE asserts and remains asserted for dropout time setting SOTFD or until the logic detects a healthy voltage condition (if EVRST := Y, see *SOTF Options*).

SOTF Options

If the setting EVRST (Voltage Reset Enable) is enabled (EVRST := Y), Relay Word bit SOTFE resets automatically when the relay measures healthy balanced positive-sequence voltage at greater than 85 percent nominal voltage.

Table 1.51 SOTF Settings

Setting	Description	Range	Default (5 A)
ESOTF	Switch-Onto-Fault	Y, N	Y
EVRST	Switch-Onto-Fault Voltage Reset	Y, N	Y
52AEND	52A Pole Open Time Delay (cycles)	OFF, 0.000–16000	10.000
CLOEND	CLSMON or Single Pole Open Delay (cycles)	OFF, 0.000–16000	OFF
SOTFD	Switch-Onto-Fault Enable Duration (cycles)	0.500–16000	10.000
CLSMON	Close Signal Monitor	SELOGIC Equation	NA

Table 1.52 SOTF Relay Word Bits

Name	Description
SOTFE	Switch-onto-fault trip logic enabled

Figure 1.50 SOTF Logic Diagram

Communications-Assisted Tripping Logic

Communications-assisted tripping schemes provide unit protection for transmission lines without any need for external coordination devices. The relay includes the following three schemes.

- POTT—Permissive-Overreaching Transfer Trip
- DCUB—Directional Comparison Unblocking
- DCB—Directional Comparison Blocking

All of these schemes work in both two-terminal and three-terminal line applications. For the DCUB scheme, you have separate settings choices for these applications (ECOMM equals DCUB1 or DCUB2) because of unique DCUB logic considerations.

The directional elements must be enabled (SET E32 := Y or AUTO) and the Level 3 elements set in the reverse direction (DIR3 := R) for all three schemes. In the following descriptions, the terms zone and level can be used interchangeably.

Table 1.53 ECOMM Setting

Setting	Description	Range	Default (5 A)
ECOMM	Communications-Assisted Tripping	N, DCB, POTT, DCUB1, DCUB2	N

Figure 1.51 Required Zone Directional Settings

Directional Comparison Blocking Scheme

The Directional Comparison Blocking (DCB) trip scheme performs the following tasks:

- Provides carrier coordination timers that allow time for the block trip signal to arrive from the remote terminal. The 67SD timer is for the Level 2 overcurrent elements 67P2, 67Q2, and 67G2.
- Instantaneously keys the communications equipment to transmit block trip for reverse faults and extends this signal for a settable time (Z3XD) following the dropout of all Level 3 directional overcurrent elements.
- Latches block trip send condition by the phase directional elements following a close-in zero voltage three-phase fault when the polarizing memory expires; return of polarizing memory voltage or interruption of fault current removes the latch.
- Extends the received block trip signal by a settable time (BTXD).

The DCB scheme consists of four sections:

- Coordination timers
- Starting elements
- Extension of the blocking signal
- Stopping elements

Coordination Timers

Momentarily delaying the forward-looking Level 2 elements that provide high-speed tripping at the local terminal ensures that the local circuit breaker does not trip for external faults behind the remote terminal. This delay provides time for the nondirectional and reverse-looking elements at the remote terminal to send a blocking signal to the local terminal during out-of-section faults. This particular time delay is the coordination time for the DCB scheme. The 67SD setting is used to achieve coordination time between the local and remote end of the line.

The recommended setting for the 67SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Level 3 nondirectional low-set overcurrent element maximum operating time
- Maximum communications channel time

The output of Level 2 delay timer 67SD is Relay Word bit 67QG2S (Level 2 Overcurrent Short Delay).

If the control input time delay on pickup debounce timer is zero, the maximum recognition time for the control input is 0.125 cycles.

Starting Elements

You can select nondirectional elements, directional elements, or both to detect external faults behind the local terminal. These elements send a blocking signal to the remote station to prevent unwanted high-speed tripping during out-of-section faults. Nondirectional elements do not process a directional decision, so nondirectional elements are always faster than directional elements.

Nondirectional Start

Relay Word bit NSTRT (Nondirectional Start) is assigned to a contact output to start transmitting the blocking signal. NSTRT asserts if either 50Q3 or 50G3 pick up.

Directional Start

Relay Word bit DSTRT (Directional Start) asserts if any of the following elements pick up:

- Level 3 phase directional overcurrent element
- Level 3 negative-sequence directional overcurrent element
- Level 3 zero-sequence directional overcurrent element

Relay Word bit DSTRT is useful when a bolted close-in three-phase fault occurs behind the relay. Should the polarizing voltage for the directional elements collapse to zero, the corresponding Level 3 supervisory current level detectors will cause the Level 3 phase directional elements to latch.

Use timer Z3XD (Zone [Level] 3 Reverse Time Delay on Dropout) to extend the blocking signal during current reversals. Use timer Z3XPU (Zone [Level] 3 Reverse Time Delay on Pickup) to prevent extension of the blocking signal resulting from Z3XD if a reverse-looking element picks up during a transient. This pickup delay ensures high-speed tripping for internal faults.

Extension of the Blocking Signal

The directional comparison blocking scheme typically uses an on/off carrier signal to block high-speed tripping at the remote terminal for out-of-section faults. Connect the carrier receive block signal output contact from the teleprotection equipment to a control input assigned to SELOGIC equation BT (Block Trip Received). This input must remain asserted to block the forward-looking elements after the coordination timers expire. If the blocking signal drops out momentarily, the relay can trip for out-of-section faults.

Timer BTXD (Block Trip Extension) delays dropout of the control input assigned to Relay Word bit BT so that unwanted tripping does not occur during momentary lapses of the blocking signal (carrier holes). This timer maintains the blocking signal at the receiving relay by delaying the dropout of Relay Word bit BTX.

Three-Terminal Line

If you apply the DCB scheme to a three-terminal line, program SELOGIC control equation BT as follows:

BT := **IN105 OR IN106** Block Trip Received (SELOGIC Equation)

Relay inputs IN105 or IN106 assert when the relay receives a blocking signal from either of the two other terminals. The relay cannot high-speed trip if either control input asserts. These two control inputs were chosen for this particular example. Use appropriate control inputs for your application.

Stopping Elements

Level 2 directional overcurrent elements detect that the fault is in the tripping direction and stop the starting elements from transmitting the blocking signal to the remote terminal. Program an output contact to stop carrier by energizing an input of the communications equipment transmitter.

The stopping elements must have priority over the nondirectional starting elements; however, directional starting elements must have priority over the stopping elements. *Figure 1.52* shows that the directional starting elements have internal priority over the stopping elements. Use SELOGIC control equations to make sure that the stopping elements have priority over the nondirectional starting elements:

OUT101 := **NSTRT AND NOT STOP OR DSTRT** Output (SELOGIC Equation)

Table 1.54 DCB Settings

Setting	Description	Range	Default (5 A)
Z3XPU	Zone 3 Reverse Pickup Delay (cycles)	0.000–16000	1.000
Z3XD	Zone 3 Reverse Dropout Time Delay (cycles)	0.000–16000	6.000
BTXD	Block Trip Receive Extension Time (cycles)	0.000–16000	1.000
67SD	Level 2 Overcurrent Short Delay (cycles)	0.000–16000	2.000
BT	Block Trip Received	SELOGIC Equation	NA

Table 1.55 DCB Relay Word Bits

Name	Description
Z3XT	Current reversal guard timer
67QG2S	Level 2 overcurrent short delay element
DSTRT	Directional start element
NSTRT	Nondirectional start element
STOP	Stop element
BTX	Blocking signal extended

Figure 1.52 DCB Logic Diagram

Permissive Overreaching Transfer Tripping Scheme

Use MIRRORED BITS communications to implement a Permissive Overreaching Transfer Tripping (POTT) scheme efficiently and economically. MIRRORED BITS communications technology improves security and improves the overall operating speed. If the communications channel is reliable and noise-free (as with fiber-optic channels), then POTT provides both security and reliability. You can also implement a POTT scheme with other conventional communications channels such as leased telephone lines and microwave. The DCUB trip scheme is a better choice if the communications channel is less than perfect, but communications channel failures are unlikely to occur during external faults.

POTT Scheme Selection

The SEL-451 offers a conventional POTT scheme designed for an application with a single communications channel.

POTT Scheme Logic

The POTT scheme logic performs the following tasks:

- Keys the communications equipment to send permissive trip (PT) when any element you include in the TRCOMM SELOGIC control equation asserts and the current reversal logic is not asserted
- Prevents keying and tripping by the POTT logic following a current reversal
- Echoes the received permissive signal to the remote terminal
- Prevents channel lockup during echo and test
- Provides a secure means of tripping for weak- and/or zero-infeed terminals

The POTT scheme logic consists of the following:

- Current reversal guard logic
- Echo
- Weak infeed logic

Current Reversal Guard Logic

Use current reversal guard for parallel line applications if the Level 2 reach extends beyond the midpoint of the parallel transmission line. With current reversal guard, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal when the reverse-looking protection sees an external fault. The Zone (Level) 3 Reverse Block Delay (Z3RBD) timer extends these two actions after a current reversal ceases and the reverse-looking elements drop out.

Echo

If the local circuit breaker is open, or a weak infeed condition exists, the remote relay permissive signal can echo back to itself and issue a high-speed trip for faults beyond the remote relay Level 1 reach. The SEL-451 includes logic that echoes the received permissive signal back to the remote terminal after specific conditions are satisfied. This echo logic includes timers for qualifying the permissive signal and timers to block the echo logic during specific conditions.

Use the Echo Block Time Delay (EBLKD) to block the echo logic after dropout of local permissive elements. The recommended time setting for the EBLKD timer is the sum of the following:

- Remote terminal circuit breaker opening time
- Communications channel round-trip time
- Safety margin

An echo delay ensures that the reverse-looking elements at the receiving end have sufficient time to operate and block the received echo signal for external faults behind the remote terminal. This delay also guards the echo and weak infeed logic against noise bursts that can occur on the communications channel during close-in external faults. Typically, these noise bursts coincide with faults external to the line section.

Because of the brief duration of noise bursts and the pickup for the reverse-looking elements, a received signal must be present for a short time to allow the POTT scheme to echo the permissive signal back to the remote terminal. The Echo Time Delay Pickup (ETDPU) timer specifies the time a permissive trip signal must be present.

The Echo Duration Time Delay (EDURD) limits the duration of the echoed permissive signal. Once the echo signal begins, it should remain for a minimum period of time and then stop, even if a terminal receives a continuous permissive signal. This cessation of the echo signal prevents the permissive trip signal from latching between the two terminals.

Weak-Infeed Logic

The SEL-451 provides weak-infeed logic to high-speed trip both line terminals for internal faults near the weak terminal. The weak terminal echoes the permissive signal back to the strong terminal and allows the strong terminal to trip. After satisfaction of specific conditions, the weak terminal trips by converting the echoed permissive signal to a trip signal.

In some applications, one terminal might not contribute enough fault current to operate the protective elements, even with all sources in. It is important to trip the weak-infeed terminal to prevent low-level fault current from maintaining the fault arc (i.e., the fault will restrike following auto-reclose at the strong terminal). Because the strong terminal is beyond the Level 1 reach, it cannot trip for end-zone faults.

The faulted phase voltage(s) is depressed at the weak-infeed terminal, a condition that generates significant residual voltage during ground faults. The SEL-451 uses phase-to-phase undervoltage level detectors and a residual overvoltage level detector to qualify a weak-infeed condition. If setting EWFC := Y, the relay enables the weak-infeed logic and settings 27PPW and 59NW are active.

The weak-infeed logic sets the ECTT (Echo Conversion to Trip) element upon satisfaction of the following:

- No reverse-looking elements have picked up (the reverse-looking elements override operation of the weak-infeed and echo logic for faults behind the relay location)
- LOP is deasserted when the setting ELOP equals Y1

- At least one phase-to-phase undervoltage element or the residual overvoltage element operates
- The local circuit breaker(s) is closed
- A permissive trip signal is received for ETDPU time period

The EWFC setting enables the weak-infeed feature of the relay. When the setting EWFC := Y, the ECTT (Echo Conversion to Trip) logic is enabled. ECTT logic is disabled when EWFC := N.

Three-Terminal Lines

If you apply the POTT scheme to a three-terminal line, program SELOGIC control equation PT1 as follows:

PT1 := **IN105 AND IN106** General Permissive Trip Received (SELOGIC Equation)

Relay control inputs IN105 and IN106 assert when the relay receives a permissive signal from each of the two other terminals. The relay cannot high-speed trip until both inputs assert. These two control inputs were chosen for this particular example. Use control inputs that are appropriate for your application.

Table 1.56 POTT Settings

Setting	Description	Range	Default (5 A)
Z3RBD	Level 3 Reverse Block Time Delay (cycles)	0.000–16000	5.000
EBLKD	Echo Block Time Delay (cycles)	0.000–16000	10.000
ETDPU	Echo Time Delay Pickup (cycles)	0.000–16000	2.000
EDURD	Echo Duration Time Delay (cycles)	0.000–16000	4.000
EWFC	Weak Infeed Trip	Y, N	N
27PPW	Weak Infeed Undervoltage Pickup ($V_{\phi\phi}$)	0.1–300	80.0
59NW	Weak Infeed Zero-Sequence Overvoltage Pickup (V)	0.1–200	5.0
PT1	General Permissive Trip Received	SELOGIC Equation	NA

Table 1.57 POTT Relay Word Bits

Name	Description
PT	Permission to trip received
Z3RB	Current reversal guard asserted
KEY	Transmit permission to trip
EKEY	Echo received permission to trip
ECTT	Echo conversion to trip
WFC	Weak-infeed detected

Figure 1.53 Permissive Trip Receiver Logic Diagram

Figure 1.54 POTT Logic Diagram

Directional Comparison Unblocking Scheme Logic

The Directional Comparison Unblocking (DCUB) tripping scheme in the SEL-451 provides a good combination of security and reliability, even when a communications channel is less than perfect. Communications channel failures are unlikely to occur during external faults. You can use the DCUB trip scheme with conventional communications channels such as PLC (power line carrier). Use improved methods such as MIRRORED BITS communications to implement the DCUB tripping scheme efficiently and economically. MIRRORED BITS communications and the DCUB tripping scheme give secure, high-speed operation.

Through a control input programmed to the LOG (loss-of-guard) function, the relay monitors the LOG output from the communications receiver. If LOG asserts, and no trip permission is received, the relay can high-speed trip during a short window using selected overreaching elements. The relay then asserts permissive trip blocking signal UBB and locks out permissive trip Relay Word bit PTRX. The typical DCUB application is a POTT scheme with the addition of a frequency shift-keying (FSK) carrier as the communications medium.

Enable the DCUB logic by setting ECOMM to DCUB1 or DCUB2. You must provide the relay all POTT settings plus the settings exclusive to the DCUB scheme. The following is an explanation of the differences between setting choices DCUB1 and DCUB2:

- DCUB1—directional comparison unblocking scheme for two-terminal lines (i.e., communication from ***one*** remote terminal)
- DCUB2—directional comparison unblocking scheme for three-terminal lines (i.e., communication from ***two*** remote terminals)

The DCUB logic takes the loss-of-guard and permissive trip outputs from the communications receivers and makes permissive trip (PTRX1 and PTRX2) outputs and permissive trip (unblock) blocking (UBB1 and UBB2) outputs.

PTRX1 asserts for loss of channel or for an actual received permissive trip in two-terminal line applications (e.g., setting ECOMM to DCUB1).

PTRX1 or PTRX2 assert for loss of channel or for an actual received permissive trip (for the respective Channel 1 or 2) in three-terminal line applications (e.g., setting ECOMM to DCUB2).

Enable setting ECOMM (when set to DCUB1 and DCUB2) determines the routing of Relay Word bits PTRX1 and PTRX2 to control Relay Word bit PTRX. Relay Word bit PTRX is the permissive trip receive input into the trip logic.

Three-Terminal Lines

If you apply the DCUB scheme to a three-terminal line, program SELOGIC control equation PT1 and PT2 as follows:

PT1 := **IN105** General Permissive Trip Received (SELOGIC Equation)

PT2 := **IN106** Channel 2 Permissive Trip Received (SELOGIC Equation)

Relay control inputs IN105 or IN106 assert when the relay receives a permissive signal from one of the two other terminals. The relay cannot high-speed trip until both inputs assert. These two control inputs were chosen for this example. Use control inputs that are appropriate for your application.

In addition, for a three-terminal line, program SELOGIC control equations LOG1 and LOG2 as follows:

LOG1 := **IN205** Channel 1 Loss-of-Guard

LOG2 := **IN206** Channel 2 Loss-of-Guard

Relay control inputs IN205 or IN206 assert when the relay receives a loss-of-guard signal from either of the two other terminals. When SELOGIC control equation LOG1 (Channel 1 Loss-of-Guard) asserts, the relay asserts Relay Word bit UBB1 (Block Permissive Trip on Receiver 1) and removes the possibility that Relay Word bit PTRX1 (Permissive Trip on Receiver 1) will assert. These two control inputs were chosen for this particular example. Use control inputs that are appropriate for your application.

See *Table 1.58* for the DCUB settings. The first portion of the settings (from Z3RBD to PT1) are identical to the settings for the ECOMM := POTT scheme; (see *POTT Scheme Logic on page R.1.77*).

Table 1.58 DCUB Settings

Setting	Description	Range	Default (5 A)
Z3RBD	Zone 3 Reverse Block Time Delay (cycles)	0.000–16000	5.000
EBLKD	Echo Block Time Delay (cycles)	0.000–16000	10.000
ETDPU	Echo Time Delay Pickup (cycles)	0.000–16000	2.000
EDURD	Echo Duration Time Delay (cycles)	0.000–16000	4.000
EWFC	Weak Infeed Trip	Y, N	N
27PPW[a]	Weak Infeed Undervoltage Pickup ($V_{\phi\phi}$)	0.1–300	80.0
59NW[a]	Weak Infeed Zero-Sequence Overvoltage Pickup (V)	0.1–200	5.0
PT1	General Permissive Trip Signal Received	SELOGIC Equation	NA
GARD1D	Guard Present Security Delay (cycles)	0.000–16000	120.000
UBDURD	DCUB Disabling Time Delay (cycles)	0.000–16000	180.000
UBEND	DCUB Duration Time Delay (cycles)	0.000–16000	20.000
PT2[b]	Channel 2 Permissive Trip Received	SELOGIC Equation	NA
LOG1	Channel 1 Loss-of-Guard	SELOGIC Equation	NA
LOG2[b]	Channel 2 Loss-of-Guard	SELOGIC Equation	NA

[a] Make setting when EWFC := Y
[b] Make setting when ECOMM := DCUB2

Timer Setting Recommendations

GARD1D: Guard-Present Delay

This timer determines the minimum time before the relay reinstates permissive tripping following a loss-of-channel condition. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

UBDURD: DCUB Disable Delay

This timer prevents high-speed tripping via the POTT scheme logic after a settable time following a loss-of-channel condition; a typical setting is nine cycles. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

UBEND: DCUB Duration Delay

This timer determines the minimum time before the relay declares a loss-of-channel condition; a typical setting is 0.5 cycles. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

Table 1.59 DCUB Relay Word Bits

Name	Description
UBB1	Block permissive trip on Receiver 1
PTRX1	Permissive trip received on Channel 1
UBB2	Block permissive trip on Receiver 2
PTXR2	Permissive trip received on Channel 2
UBB	Block permissive trip received on Channel 1 or Channel 2
PTRX	Permissive trip received on Channel 1 and Channel 2

Figure 1.55 Permissive Trip Received Logic Diagram

Figure 1.56 DCUB Logic Diagram

Trip Logic

Use the SEL-451 trip logic to configure the relay for tripping one or two circuit breakers. Set the SEL-451 to trip unconditionally (as with time-overcurrent elements) or with the aid of a communications channel (as with the POTT, DCUB, DCB, and DTT schemes).

Trip SELogic Control Equations

You select the appropriate relay elements for unconditional, switch-onto-fault (SOTF), and communications-assisted tripping. Set these SELogic control equations for tripping:

- TR—Unconditional tripping
- TRSOTF—SOTF tripping
- TRCOMM—Communications-assisted tripping

Include the instantaneous and time-delayed tripping elements in the TR SELogic control equation. You would typically set instantaneous high-set current level detectors in the TRSOTF SELogic control equation. You would also set instantaneous Level 2 overcurrent short delay element 67QG2S in the TRCOMM SELogic control equation.

TR

The TR SELogic control equation determines which elements trip unconditionally. You would typically set all instantaneous and time-delayed tripping elements (instantaneous and time-overcurrent protection conditions) in the TR SELogic control equation.

TRSOTF

The TRSOTF control equation defines which elements trip while SOTF protection is active. These elements trip instantaneously if they assert during the SOTFD time, when Relay Word bit SOTFE is asserted.

TRCOMM

The TRCOMM SELogic control equation determines which elements trip via the communications-based scheme logic. You would typically set the Level 2 directional overcurrent short delay element in the TRCOMM SELogic control equation.

Trip Unlatch Options

Unlatch the trip contact output after the trip to remove dc voltage from the trip coil. The SEL-451 provides three settings to unlatch trip contact outputs after a protection trip has occurred:

- TULO—following a protection trip using either current dropout, breaker open status, or both
- ULTR—following a protection trip, by SELogic control equation
- RSTTRGT—Target reset SELogic equation

NOTE: With factory settings, the **TAR R** command and the **TARGET RESET** pushbutton also operate the unlatch trip logic. If you do not want this functionality, remove the TRGTR Relay Word bit from the ULTR SELogic equation in Group Settings.

TULO

Table 1.60 shows the four trip unlatch options for setting TULO.

Table 1.60 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that all poles of the line terminal are open and the Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contacts from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

ULTR

Use ULTR, the unlatch trip SELOGIC control equation, to define the conditions that unlatch the trip contact outputs.

Timers

The SEL-451 provides a dedicated timer for minimum trip duration for the trip logic.

Minimum Trip Duration

The minimum trip duration timer setting, TDUR3D, determines the minimum length of time that Relay Word bits T3P1, T3P2, TRIP, and 3PT assert. Use these timers for the designated trip control outputs. The trip output occurs for the TDURD3 time or the duration of the trip condition, whichever is greater.

Trip Output Signals

There are three Relay Word bits (T3P1, T3P2, and 3PT) that you can program to drive contact outputs to trip circuit breakers. Relay Word bits T3P1 and T3P2 are the trip outputs, respectively, for Breaker 1 and Breaker 2. Relay Word bit 3PT is not breaker specific, so it does not respond to the manual trip SELOGIC control equations. The TRIP Relay Word bit functions identically to 3PT.

Manual Trip Logic

The SEL-451 also has additional logic for manually tripping the circuit breakers. Use SELOGIC control equations BK1MTR and BK2MTR to trip the circuit breakers manually. Use SELOGIC control equations ULMTR1 and ULMTR2 to unlatch manual trips for Circuit Breaker 1 and Circuit Breaker 2, respectively.

Trip Logic Settings and Relay Word Bits

The trip logic settings are shown in *Table 1.61*, and the Relay Word bits in *Table 1.62*. Some of the settings are only required in certain situations, as noted.

Table 1.61 Trip Logic Settings (Sheet 1 of 2)

Setting	Description	Range	Default (5 A)
TR	Trip	SELOGIC Equation	51S1T or 51S2T
TRCOMM[a]	Communications-Assisted Trip	SELOGIC Equation	NA
TRSOTF[b]	Switch-Onto-Fault Trip	SELOGIC Equation	50P1

Table 1.61 Trip Logic Settings (Sheet 2 of 2)

Setting	Description	Range	Default (5 A)
BK1MTR	Breaker 1 Manual Trip—BK1	SELOGIC Equation	OC1 OR PB8_PUL
BK2MTR[c]	Breaker 2 Manual Trip—BK2	SELOGIC Equation	NA
ULTR	Unlatch Trip	SELOGIC Equation	TRGTR
ULMTR1	Unlatch Manual Trip—BK1	SELOGIC Equation	NOT 52AA1
ULMTR2[c]	Unlatch Manual Trip—BK2	SELOGIC Equation	NA
TULO	Trip Unlatch Option	1, 2, 3, 4	3
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (cycles)	2.000–8000	12.000
ER	Event Report Trigger Equation	SELOGIC Equation	R_TRIG 51S1 OR R_TRIG 51S2

[a] Make setting when ECOMM ≠ N
[b] Make setting when ESOTF := Y
[c] Make setting when NUMBK := 2

Table 1.62 Trip Logic Relay Word Bits

Name	Description
RXPRM	Receiver trip permission
COMPRM	Communications-assisted trip permission
TRPRM	Trip permission
SOTFT	Switch-onto-fault trip
ULTRA	Unlatch trip
ULTR	Unlatch all protection trips
TRIP	Trip
3PT	Three-pole trip (follows TRIP)
ULMTR1	Circuit Breaker 1 unlatch manual trip
ULMTR2	Circuit Breaker 2 unlatch manual trip
T3P1	Three-pole-trip circuit breaker 1
T3P2	Three-pole-trip circuit breaker 2

Figure 1.57 Trip Logic Diagram

Figure 1.58 Two Circuit Breakers Trip Logic Diagram

Figure 1.59 Trip Unlatch Logic

Circuit Breaker Status Logic

The SEL-451 relay uses the 52A (normally open) auxiliary contact to report the status of the circuit breaker. Because the 52B contact is not always available and for the purpose of reducing the number of I/O required, the breaker status logic does not include the 52B contact. Emulate the 52B contact by using the NOT 52A condition in logic. The open phase detection logic supervises the 52A contact (see *Open Phase Detection Logic on page R.1.27*). If a discrepancy exists between the open phase detection logic and the 52A contact for five cycles, the logic generates an alarm. The alarm indicates the following conditions:

- An auxiliary contact supply voltage failure
- A failure in an auxiliary contact connection circuit

Table 1.63 Circuit Breaker Status Logic Inputs

Name	Description
52AA1	Circuit Breaker 1 Status (52AA1 Global SELOGIC control equation)
52AA2	Circuit Breaker 2 Status (52AA2 Global SELOGIC control equation)
B1OPHA	Circuit Breaker 1 A-phase open phase detection logic
B1OPHB	Circuit Breaker 1 B-phase open phase detection logic
B1OPHC	Circuit Breaker 1 C-phase open phase detection logic
B2OPHA	Circuit Breaker 2 A-phase open phase detection logic
B2OPHB	Circuit Breaker 2 B-phase open phase detection logic
B2OPHC	Circuit Breaker 2 C-phase open phase detection logic

Table 1.64 Circuit Breaker Status Logic Relay Word Bits

Name	Description
52ACL1	Circuit Breaker 1, Closed
52BCL1	Circuit Breaker 1, Closed
52CCL1	Circuit Breaker 1, Closed
52ACL2	Circuit Breaker 2, Closed
52BCL2	Circuit Breaker 2, Closed
52CCL2	Circuit Breaker 2, Closed
52AAL1	Circuit Breaker 1, Alarm
52BAL1	Circuit Breaker 1, Alarm
52CAL1	Circuit Breaker 1, Alarm
52AAL2	Circuit Breaker 2, Alarm
52BAL2	Circuit Breaker 2, Alarm
52CAL2	Circuit Breaker 2, Alarm

Figure 1.60 illustrates the circuit breaker one-status logic in the SEL-451. Circuit breaker two-status logic is identical. When Relay Word bit 52AA1 asserts, Relay Word bits 52ACL1, 52BCL1, and 52CCL1 assert. When Relay Word bit 52AA1 deasserts and current is not detected in the open-phase detection logic, Relay Word bits 52ACL1, 52BCL1, and 52CCL1 deassert. If the open-phase detection logic does not detect current within five cycles of the Relay Word bit 52AA1 deasserting, a circuit breaker alarm condition does not

exist. If the current still flows five cycles after Relay Word bit 52AA1 deasserts, the circuit breaker status logic declares a circuit breaker alarm condition, and asserts Relay Word bits 52AAL1, 52BAL1, and 52CAL1.

Figure 1.60 Circuit Breaker One-Status Logic Diagram

Circuit Breaker Failure Protection

Use the SEL-451 to provide circuit breaker failure protection for as many as two circuit breakers. The circuit breaker failure protection logic includes the following schemes:

- Failure to interrupt fault current for phase currents
- Failure to interrupt load current
- No current/residual current circuit breaker failure protection
- Flashover protection while the circuit breaker is open

All schemes incorporate three-pole retrip. Three-pole initiations are available for circuit breaker failure, including extended breaker failure initiation. The circuit breaker failure logic also includes breaker failure trip latching logic.

The failure-to-interrupt-fault-current logic is basic circuit breaker failure that is useful for most applications. The failure-to-trip-load-current logic uses the circuit breaker failure initiation input for three-pole trips. The flashover protection logic does not need voltage information.

Open phase detection logic causes the SEL-451 50Fϕ*n* elements to reset in less that one cycle (see *Figure 1.63*, *Figure 1.65*, and *Figure 1.66*). The open phase detection logic output is B*n*OPHϕ (see *Table 1.14*).

Most of the discussion in this subsection refers to Circuit Breaker 1. The same applies to Circuit Breaker 2, where applicable.

Failure to Interrupt Fault Current

Circuit Breaker Failure Protection Logic

The logic shown in *Figure 1.61* applies to most circuit breaker configurations. Fault current causes 50FA1 (Breaker 1 A-Phase Instantaneous Overcurrent Element) to assert immediately following fault inception and just prior to the assertion of Relay Word bit BFI3P1 (Breaker 1 Breaker Failure Initiation). At circuit breaker failure initiation, timer BFPU1 (Breaker 1 Circuit Breaker Failure Time Delay on Pickup Timer) starts timing. If 50FA1 remains asserted when the BFPU1 timer expires, Relay Word bit FBF1 asserts. Use this Relay Word bit in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Circuit Breaker Failure Trip Logic on page R.1.96*). If the protected circuit breaker opens successfully, 50FA1 drops out before the BFPU1 timer expires and FBF1 does not assert.

Figure 1.61 Circuit Breaker Failure to Interrupt Fault Current Logic Diagram

Retrip Logic

Some three-pole circuit breakers have two separate trip coils. If one trip coil fails, the local protection can attempt to energize the second trip coil 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 time delay timer expires.

RTPU1 (Retrip Time Delay on Pickup Timer) begins timing when BFI3P1 asserts. Relay Word bit RT1 (Breaker 1 Retrip) asserts immediately after RTPU1 times out. Assign a control output to trip the circuit breaker when Relay Word bit RT1 asserts.

Circuit Breaker Failure Initiation Dropout and Seal-In

The SEL-451 circuit breaker failure protection features breaker failure initiation extension and a breaker failure seal-in latch. *Figure 1.63* shows the dropout and seal-in logic.

Seal-In

If circuit breaker-failure initate seal-in is required, include the circuit breaker failure extended initiation Relay Word bit, BFI3PT*n*, in the SELOGIC equation BFI3P*n*.

For example, on circuit breaker 1,

BFI3P1 := T3P1 **OR BFI3PT1**

With the above setting, the circuit breaker-failure initiate signal is sealed-in, without delay, and will remain sealed-in until all 50FA1, 50FB1, 50FC1 elements have deasserted *and* the circuit breaker failure initate dropout time, BFIDO1, expires.

Dropout Delay

Set timer BFIDO1 (Breaker Failure Initiate Dropout Delay—BK1) to stretch a short pulsed circuit breaker failure initiation. Use this feature for protecting dual circuit breakers when separate 86 BF lockout relays have differing energizing times.

Seal-In Delay

When using the seal-in scheme described above, also set breaker failure initiate seal-in delay BFISP1 := 0.000 cycles. In *Figure 1.63*, if the output BFI3PT*n* is routed to the input BFI3P1, the upper timer is effectively bypassed, and seal-in occurs instantaneously. The 0.000 cycle setting will minimize the chance of misunderstanding when the scheme is tested.

Continuing with the circuit breaker 1 example, if the BFI3P1 setting did not contain BFI3PT1, the timer settings BFISP1 and BFIDO1 are not relevant with the factory logic. In other words, Relay Word bit BFI3PT1, circuit breaker 1 failure extended initiation, will operate as shown is *Figure 1.63*, but this Relay Word bit does not control any other logic. Because of this situation, the breaker failure initiate seal-in delay function built-in to the SEL-451 Breaker Failure logic cannot be used as intended.

Special Considerations for Seal-In Delay

One way to use a breaker failure initiate seal-in with delay is to duplicate the breaker failure initiate seal-in logic from *Figure 1.63* using protection free-form SELOGIC control equations. Implement the required pickup and dropout time delays using protection conditioning timers, and include the output of the new logic in the BFI3P1 equation. The built-in circuit breaker 1 failure extended initiation Relay Word bit, BFI3PT1, is not used. Instead, the output of the protection free-form SELOGIC seal-in implementation is used in the BFI3P1 setting.

See *Circuit Breaker Failure Protection—Example 2 on page A.1.42* for an example implementation using this method.

No Current/Residual Current Circuit Breaker Failure Protection Logic

The SEL-451 has separate circuit breaker failure logic that operates on zero-sequence current rather than phase current. Use this logic to detect a circuit breaker failure and take appropriate action when a weak source drives the fault or if the protected circuit breaker fails to trip during a high-resistance ground fault. The residual current input to this logic is the 50R1 residual overcurrent element (see *Figure 1.62*). Setting 50RP1 (Residual Current Pickup—BK1) is the pickup threshold setting for the 50R1 element.

Figure 1.62 No Current/Residual Current Circuit Breaker Failure Protection Logic Diagram

Relay Word bit NBF1 (Breaker 1 Low Current Breaker Failure) asserts when timer NPU1 (Low Current Breaker Failure Time Delay on Pickup) expires and one of the following conditions exists:

- Circuit Breaker 1 residual overcurrent element 50R1 is asserted and the relay does not detect an open pole in any of the three phases for Circuit Breaker 1 (i.e., NOT B1OPHA, NOT B1OPHB, or NOT B1OPHC)
- Relay Word bit BFIN1 (No Current Breaker Failure Initiation) is asserted

For no current applications, such as a digital signal indicating a loss-of-field from a generator, use inputs BFI3P1 and BFIN*n*. Circuit breaker failure clearing can occur after timer NPU1 times out. For no current/residual current breaker failure trips, insert NBF1 in the circuit breaker failure trip SELOGIC control equation BFTR1 (see *Figure 1.67*).

Failure to Interrupt Load Current Protection Logic

The circuit breaker failure protection used during load conditions is independent from circuit breaker failure protection that you use during fault conditions. Use circuit breaker failure protection for load conditions either alone or in addition to circuit breaker failure protection for fault conditions as a second level of breaker failure protection. *Figure 1.65* shows that the output of the load current protection is Relay Word bit LCBF1 (Load Current Breaker Failure). Use this output to activate an external alarm, retrip the circuit breaker, or energize a lockout relay.

Load Current Detection: 50LP1

This scheme detects failures of the circuit breaker to open when circuit breaker current is greater than the 50LP1 setting. The 50LP1 element should pick up when the protected circuit breaker is closed.

If the protected circuit breaker is in a ring-bus or circuit breaker-and-a-half arrangement, set 50LP1 to pick up for the line-charging current of the shortest line that circuit breaker services. Use the following equation to calculate the charging current for a given line:

$$I_c = V_g \bullet B_c \text{ A primary} \qquad \textbf{Equation 1.14}$$

where:

V_g = Line-to-ground voltage
B_c = Total line capacitive susceptance

Time Delay on Pickup: LCPU1

The time delay setting for this protection scheme is typically longer than fault current conditions because of lower current duties associated with this type of circuit breaker failure operation. Extending the time delay allows more time for a slow but operative circuit breaker to clear a low-current fault. A disadvantage with the extended time delay is that a fault continues if the circuit breaker fails. Weigh these considerations when selecting time delays for this scheme. Please note that some circuit breakers take more time than other circuit breakers to break low amounts of current; consult the manufacturer of the protected circuit breaker for details.

The recommended setting for LCPU1 is the sum of the following:

- Nominal circuit breaker operate time
- 50LP1 dropout time
- Safety margin

Calculate the safety margin by subtracting all conditions required to isolate the fault during a circuit breaker failure condition from the maximum acceptable fault clearing time. The safety margin will be longer in this case than for the fault current logic because the total acceptable time to clear the fault at these lower fault duties is longer.

Load Current Circuit Breaker Failure Initiation: BFILC1

Program SELOGIC control equation BFILC1 (Load Current Breaker Failure Initiation) to initiate this scheme. For example, use the auxiliary contacts from the circuit breaker to detect when the circuit breaker is open. Relay Word bit LCBF1 asserts if Relay Word bit BFILC1 remains asserted for time LCPU1 and the relay detects load current.

Circuit Breaker Flashover Protection

Circuit breaker failure protection during flashover conditions is independent of the other circuit breaker protection functions. Use this protection either alone or in addition to the other protection.

Figure 1.66 shows the flashover circuit breaker failure logic. Flashover timer FOPU1 (Flashover Time Delay—BK1) starts timing if the circuit breaker is open and current exceeds setting 50FO1 (Flashover Current Pickup—BK1). The relay uses pole-open logic BnOPHϕ to determine whether the circuit breaker is open.

The output of the flashover protection is Relay Word bit FOBF1. Use this output to activate an external alarm, retrip the circuit breaker, or energize a lockout relay.

Circuit Breaker Failure Trip Logic

The SEL-451 has dedicated circuit breaker failure trip logic (see *Figure 1.67*). Set SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) to assert for circuit breaker failure trips from Relay Word bits FBF1, NBF1, LCBF1, and FOBF1.

When this SELOGIC control equation asserts, the relay sets Relay Word bit BFTRIP1 (Breaker Failure Trip for Circuit Breaker BK1) to logical 1 until BFTR1 deasserts, timer TDUR3D times out, and an unlatch or reset condition is active.

Unlatch Circuit Breaker Failure Trip Equation

Use SELOGIC control equation BFULTR1 (Breaker Failure Unlatch Trip—BK1) to define the conditions that unlatch the control outputs that assert during a circuit breaker failure trip. BFULTR1 unlatches the circuit breaker trip condition BFTRIP1.

The **TAR R** command, and **TARGET RESET** pushbutton can also unlatch the circuit breaker failure trip condition. Relay Word bit TRGTR asserts momentarily (see *Figure 1.67*) and is used in the target LED reset logic.

Table 1.65 Circuit Breaker Failure Protection Logic Settings[a]

Setting	Description	Range	Default (5 A)
50FP1	Phase Fault Current Pickup—BK1 (A)	0.50–50	6.000
BFPU1	Breaker Failure Time Delay—BK1 (cycles)	0.000–6000	9.000
RTPU1	Retrip Time Delay—BK1 (cycles)	0.000–6000	3.000
BFI3P1	Three-Pole Breaker Failure Initiate—BK1	SELOGIC Equation	NA
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (cycles)	0.000–1000	1.500
BFISP1	Breaker Fail Initiate Seal-In Delay—BK1 (cycles)	0.000–1000	2.000
ENCBF1	No Current/Residual Current Logic—BK1	Y, N	N
50RP1	Residual Current Pickup—BK1 (A)	0.25–50	1.00
NPU1	No Current Breaker Failure Delay—BK1 (cycles)	0.000–6000	12.000
BFIN1	No Current Breaker Failure Initiate—BK1	SELOGIC Equation	NA
ELCBF1	Load Current Breaker Logic Failure—BK1	Y, N	N
50LP1	Phase Load Current Pickup—BK1 (A)	0.25–50	0.50
LCPU1	Load Pickup Time Delay—BK1 (cycles)	0.000–6000	9.000
BFILC1	Breaker Failure Load Current Initiation—BK1	SELOGIC Equation	NA
EFOBF1	Breaker Failure Flashover Logic—BK1	Y, N	N
50FO1	Flashover Current Pickup—BK1 (A)	0.25–50	0.50
FOPU1	Flashover Time Delay—BK1 (cycles)	0.000–6000	9.000
BLKFOA1	Block A-Phase Flashover—BK1	SELOGIC Equation	NA
BLKFOB1	Block B-Phase Flashover—BK1	SELOGIC Equation	NA
BLKFOC1	Block C-Phase Flashover—BK1	SELOGIC Equation	NA
BFTR1	Breaker Failure Trip—BK1	SELOGIC Equation	NA
BFULTR1	Breaker Failure Unlatch Trip—BK1	SELOGIC Equation	NA

[a] For Circuit Breaker 2, replace 1 with 2 in the setting label.

Table 1.66 Circuit Breaker Failure Relay Word Bits[a]

Name	Description
BFI3P1	Three-pole circuit breaker failure initiation
BFIN1	No current circuit breaker failure initiation
BFILC1	Load current breaker failure initiation
BFI3PT1	Circuit breaker failure extended initiation
FBFA1	A-phase circuit breaker failure
FBFB1	B-phase circuit breaker failure
FBFC1	C-phase circuit breaker failure
FBF1	Circuit breaker failure
NBF1	No current/residual current circuit breaker failure
LCBF1	Load current circuit breaker failure
BLKFOA1	Block A-phase flashover detection
BLKFOB1	Block B-phase flashover detection
BLKFOC1	Block C-phase flashover detection
FOA1	A-phase flashover detected
FOB1	B-phase flashover detected
FOC1	C-phase flashover detected
FOBF1	Flashover detected
RT1	Retrip
50FA1	A-phase current threshold
50FB1	B-phase current threshold
50FC1	C-phase current threshold
50R1	Residual current threshold
50LCA1	A-phase load current threshold
50LCB1	B-phase load current threshold
50LCC1	C-phase load current threshold
50FOA1	A-phase flashover current threshold
50FOB1	B-phase flashover current threshold
50FOC1	C-phase flashover current threshold
BFTRIP1	Breaker 1 circuit breaker failure trip
TRGTR	**TARGET RESET** pushbutton or **TAR R** command active

[a] For Circuit Breaker 2, replace 1 with 2 in the setting label.

Figure 1.63 Circuit Breaker Failure Seal-In Logic Diagram

Raw current samples I*x*BK*n* (*x* = A, B, C and *n* = 1, 2) are used to check for zero-crossing and change in current with respect to time (dI/dT). The logic also checks for a saturated A/D converter, which could cause a false zero dI/dT. Detecting no zero-crossing, no dI/dT for 5/8-cycle, and no subsequent A/D saturation will cause the output of the element (B*n*ROPH*x*) to assert.

The A/D converter will saturate at approximately 35 • Inom, where Inom = 1 A or 5 A depending on the relay.

The zero-crossing is determined by evaluating the phase currents rising above a CAL level setting OPHDO*n* provisionally set at 0.05 A for a 5 A relay.

Figure 1.64 Raw Current Sample Logic Diagram

Figure 1.65 Failure to Interrupt Load Current Logic Diagram

Figure 1.66 Flashover Protection Logic Diagram

Figure 1.67 Circuit Breaker Failure Trip Logic Diagram

Section 2

Auto-Reclosing and Synchronism Check

This section describes the operation of auto-reclose logic in the SEL-451 Relay. Also included in this section is a discussion of Voltage Check logic and Synchronism Check logic that can be used with auto-reclosing, or applied independently. This section covers the following topics:

- *Auto-Reclosing on page R.2.2*
- *One-Circuit-Breaker Auto-Reclosing on page R.2.4*
- *Two-Circuit-Breaker Auto-Reclosing on page R.2.6*
- *Auto-Reclose Logic Diagrams on page R.2.18*
- *Manual Closing on page R.2.26*
- *Voltage Checks for Auto-Reclosing and Manual Closing on page R.2.29*
- *Settings and Relay Word Bits for Auto-Reclosing and Manual Closing on page R.2.31*
- *Synchronism Check on page R.2.35*

The SEL-451 auto-reclose and synchronism-check functions provide complete control for single circuit breaker and two circuit breaker reclosing schemes. The auto-reclose function accommodates three-pole reclosing. You can set the SEL-451 for a total of four reclose shots. The reclose shots have individual dead times. You can designate the leader and follower circuit breakers in a two circuit breaker configuration; the SEL-451 recloser can dynamically change leader and follower designations based on settings and operating conditions.

You can program the auto-reclose logic to perform one shot of high-speed reclose. This high-speed shot replaces one of the four delayed time shots. There is no difference between a shot of high-speed reclose and a shot of delayed auto-reclose; simply select the open interval time accordingly.

Two auto-reclose modes are available when using the SEL-451 to control two circuit breakers:

- Combined two-breaker mode (setting E79 := Y) – both circuit breakers must trip before any reclosing can occur.
- Independent two-breaker mode (setting E79 := Y1) – the follower circuit breaker can trip and reclose even when the lead breaker has not operated. This is useful on both ring bus and breaker-and-a-half schemes, where the follower breaker is a tie breaker that can be tripped by protection on either side.

For single circuit breaker applications, use setting E79 := Y.

NOTE: The SEL-451 voltage check elements (for bus and line voltages) may be used without the synchronism check feature, however, for certain voltage connections, some of the synchronism check settings need to be entered to ensure that the correct voltages are used.

The SEL-451 synchronism-check function uses single-phase input voltages V_{S1}, V_{S2} (source voltages), and reference V_P (polarizing voltage) to provide synchronism check for one or two circuit breakers. The relay determines when V_{S1} and V_{S2} are within programmable voltage magnitudes and slip frequency

windows compared to V_P. In addition, the synchronism-check function can use settable circuit breaker closing times and the measured slip frequencies to compensate the angle difference calculation between V_{S1} and V_P (plus V_{S2} and V_P). The relay checks this angle difference calculation in a programmable synchronism angle window.

Auto-Reclosing

Logical States

The auto-reclose logic for either circuit breaker can be in one of four states (see *Figure 2.1*):

- Start (common to both circuit breakers) (79STRT)
- Reset per circuit breaker (BK1RS, BK2RS)
- Auto-reclose cycle (common to both circuit breakers) (79CY3)
- Lockout, per circuit breaker (BK1LO, BK2LO)

Start (79STRT)

The auto-reclose logic is in the Start state for both circuit breakers during the following conditions:

- Power up
- Restart
- Any relay settings change

The SEL-451 stores the previous reclosing state for Relay Word bits 79CY3, BK1LO, BK2LO, BK1RS, and BK2RS when a restart or any relay settings change occurs.

At power up, the recloser logic goes from the start state to the lockout state. For a restart or a settings change, the recloser logic enters the start state, then goes to lockout if the circuit breakers were open before the restart or settings change. If the circuit breakers were previously closed, then the recloser logic proceeds through the 3PMRCD (Manual Close Reclaim Time Delay) time and then goes to the ready state.

Reset (BK1RS, BK2RS)

The auto-reclose logic is in the Reset (Ready) state for either circuit breaker when the circuit breaker is ready to begin an auto-reclose cycle. There are two Reset state timers. After a successful reclose cycle, the relay goes to the reset state after reclaim time 3PRCD (Three-Pole Reclaim Time Delay) for automatic reclosing. If the recloser has been in a lockout condition, the Reset state cannot occur until the 3PMRCD (Manual Close Reclaim Time Delay) timer has expired. Setting 79BRCT (Block Reclaim Timer) prevents timing of reclaim timers 3PRCD and 3PMRCD.

Auto-Reclose Cycle (79CY3)

The auto-reclose logic is in an auto-reclose cycle for either circuit breaker if the following conditions are satisfied:

- Trip occurs
- Condition(s) to initiate an auto-reclose cycle are satisfied
- Circuit breaker(s) is in-service and ready to begin an auto-reclose cycle (BK*n*RS is asserted)

Lockout (BK1LO, BK2LO)

The lockout state is the default state of any circuit breaker after power up. Other conditions place the recloser in the LO state. The SEL-451 recloser has a drive-to-lockout function that you can program for any external or internal condition; use setting 79DTL. A circuit breaker also can go to lockout by either of the following:

- If Relay Word bit 3P*n*CLS (Reclose Supervision) does not assert within the BK*n*CLSD Reclose Supervision time
- If the circuit breaker does not close within the BKCFD close failure time

In applications using two circuit breakers, you can designate one circuit breaker as the leader and the other circuit breaker as the follower. The relay freezes the leader/follower decision during an auto-reclose cycle unless the auto-reclose logic receives another initiation.

If the recloser receives another initiation, the logic re-evaluates the leader and follower circuit breakers to determine the number of circuit breakers in a scheme (NBK*n*), the leader circuit breaker (LEADBK*n*), and the follower circuit breaker (FOLBK*n*). This determination is based on the service status of the circuit breakers. The logic considers a circuit breaker out of service if the circuit breaker is in lockout. The logic considers a circuit breaker to be in service as soon as the circuit breaker closes and is no longer in lockout.

State Diagram

NOTE: The SEL-451 auto-reclose function runs at once per power-system cycle. To ensure that the logic detects transient element state changes that initiate closing, you should extend the assertion time of transient element states to 1 cycle.

Figure 2.1 illustrates how the auto-reclose logic moves from one state to another with respect to Circuit Breaker 1. (This diagram is identical for Circuit Breaker 2; replace the **1** in the Relay Word bits with **2**.) The Relay Word bits that correspond to each state are shown (see *Table 2.1*). A solid path between two states indicates that the logic can move in only one direction. Two broken paths between two states indicate the logic can move in either direction between the two states. The dashed vertical line that runs through the center of the figure indicates the states common to both circuit breakers.

Table 2.1 describes each of the five states with respect to Circuit Breaker 1, along with the corresponding Relay Word bits.

Figure 2.1 Auto-Reclose State Diagram for Circuit Breaker 1

Table 2.1 Auto-Reclose Logical States for Circuit Breaker 1

State	Description	Relay Word Bit
Start	Power up, or relay settings change	79STRT
Reset	Circuit Breaker 1 reset	BK1RS
Auto-reclose cycle	Auto-reclose cycle	79CY3
Lockout	Lockout	BK1LO

One-Circuit-Breaker Auto-Reclosing

Operation

Relay setting E3PR1 (Three-Pole Reclose Enable—BK1) enables auto-reclosing (see *Recloser Mode Enable on page R.2.6*). This setting is an input to the recloser initiation Relay Word bit 3PARC (Three-Pole Reclose Initiate Qualified); see *Figure 2.8*. Relay Word bit 3PARC asserts when all necessary conditions to begin an auto-reclose cycle are satisfied (E3PR1, for example) and the recloser receives a reclose initiation 3PRI.

For other recloser settings, see *Enable Auto-Reclose Logic for One Circuit Breaker on page R.2.6*.

Figure 2.9 shows the one circuit breaker auto-reclose cycle 79CY3. The cycle starts when Relay Word bit 3PARC asserts. The recloser checks SELOGIC control equation 79SKP at this point to determine whether to increment the shot counter. The recloser waits indefinately for the circuit breaker to open, as indicated by Relay Word bit 3POLINE. The recloser begins timing 3POID1 (Three-Pole Open Interval 1 Delay) when the circuit breaker opens. After the open interval time 3POID1 expires, the relay asserts Relay Word bit BK1CL to reclose the circuit breaker if supervisory condition 3P1CLS (Three-Pole BK1 Reclose Supervision) is satisfied within the duration of timer BK1CLSD (BK1 Reclose Supervision Delay).

At the reclose command BK1CL, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the circuit breaker fails to close, the recloser goes to lockout (BK1LO) after timer BKCFD expires.

3PRCD Reclaim Timing

If the circuit breaker closes, the recloser starts timer 3PRCD (Three-Pole Reclaim Time Delay). The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit 3PLSHT (Three-Pole Reclose Last Shot).

3PLSHT Deasserted (Three-Pole Shot Remains). The recloser exhibits three possible state transitions when 3PLSHT is not asserted:

- If no further trip conditions occur, the recloser goes to the reset state BK1RS after timer 3PRCD expires.
- If a fault occurs during the 3PRCD reclaim time, the recloser asserts Relay Word bit 3PARC if all auto-reclose initiate conditions are satisfied (E3PR1 is logical 1, for example) and returns to the beginning of the 79CY3 cycle state.
- If a fault occurs during the 3PRCD reclaim time, and the reclose conditions are not satisfied (E3PR1 is logical 0, for example), the recloser exits the 79CY3 cycle state and goes to the lockout state BK1LO.

3PLSHT Asserted (Last Shot). The recloser exits the 79CY3 state via two methods while 3PLSHT is asserted:

- If no further trip conditions occur, the recloser goes to the reset state BK1RS after reclaim timer 3PRCD expires.
- If a fault occurs during the 3PRCD reclaim time, then the recloser exits the 79CY3 cycle state and goes to the lockout state BK1LO.

Lockout State from 79CY3

The recloser goes to lockout (BK1LO) when:

- The number of trips exceeds the maximum number of shots (N3PSHOT)–Relay Word bit 3PLSHT asserts to logical 1
- Reclose Supervision condition 3P1CLS fails to assert in BK1CLSD (Reclose Supervision) time
- Relay Word bit 3POLINE asserts for a circuit breaker manual opening (no qualified auto-reclose initiation 3PARC)
- The circuit breaker fails to close within BK1CFD (close failure) time
- Any time Relay Word bit 79DTL asserts

Active Circuit Breakers

Two Relay Word bits describe when Circuit Breaker 1 is active for the auto-reclose logic:

- NBK0, No Breaker Active in Reclose Scheme
- NBK1, One Breaker Active in Reclose Scheme

NBK1 equals logical 1 when Circuit Breaker 1 is closed and the auto-reclose logic is reset, or if the auto-reclose logic is in an auto-reclose cycle (79CY3). NBK0 equals logical 1 when Circuit Breaker 1 is open and not in an auto-reclose cycle (79CY3), or if the auto-reclose logic is locked out (BK1LO).

Enable Auto-Reclose Logic for One Circuit Breaker

The initial settings necessary to enable auto-reclose for a single circuit breaker are shown in *Table 2.2*.

Table 2.2 One-Circuit-Breaker Auto-Reclose Initial Settings

Setting	Description	Entry
General Global Settings (Global)		
NUMBK	Number of Breakers in Scheme	1
Breaker 1 Inputs (Breaker Monitor)		
52AA1	N/O Contact Input—BK1 (SELOGIC® control equation)	IN101
Relay Configuration (Group)		
E79	Enable Auto-Reclosing	Y

For additional settings to set specific operating parameters for the recloser, refer to *Auto-Reclose and Synchronism Check Example on page A.1.25*.

Recloser Mode Enable

The SELOGIC control equation E3PR1 enables the SEL-451 auto-reclose function (see *Table 2.3*).

Table 2.3 One Circuit Breaker Modes of Operation

E3PR1	Result
0	Auto-reclose disabled
1	Auto-reclose enabled

You can assign this setting to a control input. When E3PR1 equals logical 1, the relay can attempt an auto-reclose cycle for Circuit Breaker 1. If E3PR1 equals logical 0, the relay goes to lockout for Circuit Breaker 1.

Two-Circuit-Breaker Auto-Reclosing

Operation

NOTE: In the following discussion, n is 1 or 2 for Circuit Breaker BK1 or BK2.

Relay settings E3PR*n* (Three-Pole Reclose Enable—BK*n*) determine the auto-reclose mode (see *Recloser Mode Enables on page R.2.17*). This setting is an input to the recloser initiation Relay Word bit 3PARC (Three-Pole Reclose Initiate Qualified); see *Figure 2.8*. Relay Word bit 3PARC asserts when all necessary conditions to begin an auto-reclose cycle are satisfied (E3PR*n*, for example) and the recloser receives a reclose initiation 3PRI.

Other recloser settings include the initial recloser settings (see *Enable Auto-Reclose Logic for Two Circuit Breakers on page R.2.17*).

Figure 2.10 and *Figure 2.11* show the two circuit breaker auto-reclose cycle 79CY3 when E79 := Y AND E79 := Y1, respectively. The cycle starts when Relay Word bit 3PARC asserts. The recloser freezes calculation of the number of breakers, the leader circuit breaker, and the follower circuit breaker. Depending on the calculation, the recloser asserts the appropriate Relay Word bits NBK0, NBK1, NBK2, LEADBK0, LEADBK1, LEADBK2, FOLBK0, FOLBK1, and FOLBK2. The recloser checks SELOGIC control equation 79SKP at this point to determine whether to increment the shot counter.

The recloser waits indefinately for 3POLINE to assert:

- if E79 := Y, 3POLINE asserts when both breakers (leader *and* follower) open (see *Figure 2.6*)
- if E79 := Y1, 3POLINE asserts when at least one breaker (leader *or* follower) opens (see *Figure 2.7*)

If 3POLINE asserts, the recloser proceeds to timing 3POID1 (Three-Pole Open Interval 1 Delay). In applications where 3POLINE may not reliably assert while in the 79CY3 state, we recommend forcing the auto-reclose cycle into a drive-to-lockout state (79DTL = 1) after a fixed time delay. You can do this by using the entry into the cycle state (79CY3 = 1) as an input to a conditioning timer. The conditioning timer applies a pickup delay, and the relay 79DTL setting includes the conditioning timer output. The time delay should be long enough to allow normal breaker operation to occur, while preventing the auto-reclose logic from stalling while waiting indefinitely for 3POLINE to assert. If SELOGIC control equation 3PFARC (Three-Pole Fast Auto-Reclose Enable) is asserted, the recloser times the open interval time from setting 3PFOID (Three-Pole Fast Open Interval Delay). The 3PFOID is an alternative path allowing a faster open-interval delay. Once this delay is expired, the reclosing function continues in a manner identical to that which is used if 3PFARC is not asserted. When E79 := Y1, a Three-Pole Open Interval Supervision Condition(3POISC) must be satisfied before the recloser can proceed to timing 3POID1. If the supervisory condition is not met within the duration of timer 3POISD (Three-Pole Open Interval Supervision Delay), the recloser goes to lockout.

After three-pole open interval time 3POID or 3PFOID expires:

- and E79 := Y, the recloser attempts to close the leader breaker, as discussed below (first checking the supervisory condition 3P*n*CLS)
- and E79 := Y1, the recloser checks if the leader breaker is open. If open, it attempts to close the leader breaker, as discussed below (first checking the supervisory condition 3P*n*CLS). If the leader breaker is closed (it never opened at the outset), the recloser skips the leader breaker close logic and attempts to close the follower breaker, as discussed further below (first checking for two active breakers and an open follower breaker, before starting timer TBBKD [Time Between Breakers for ARC])

The recloser closes the leader (asserts appropriate BK*n*CL Relay Word bit) if supervisory condition 3P*n*CLS (Three-Pole BK*n* Reclose Supervision) is satisfied within the duration of timer BK*n*CLSD (BK*n* Reclose Supervision Delay).

At the leader close command, the recloser increments the shot counter and starts timer BKCFD (Breaker Close Failure Delay). If the leader fails to close, the recloser sends the leader to lockout BK*n*LO after timer BKCFD expires. If the leader closes within the BKCFD time, the recloser goes to 3PRCD (Three-Pole Reclaim Time Delay) reclaim timing if NBK1 is asserted, or prepares to close the follower circuit breaker if NBK2 is asserted.

To close the follower circuit breaker, the recloser checks for two active circuit breakers in the scheme. If NBK2 is asserted, the recloser checks for a three-pole open on the follower and starts timer TBBKD (Time Between Breakers For ARC). When TBBKD expires, the recloser closes the follower breaker if FBKCEN (Follower Breaker Closing Enable) is asserted and supervisory condition 3P*n*CLS is satisfied within the duration of timer BK*n*CLSD. At the

follower close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the follower fails to close, the recloser sends the follower to lockout after timer BKCFD expires. If the leader circuit breaker is not in lockout, the recloser begins timing 3PRCD reclaim time for the leader.

If the follower breaker closes successfully, the recloser starts the 3PRCD (Three-Pole Reclaim Time Delay) timer if 79BRCT (Block Reclaim Timer) is not asserted.

3PRCD Reclaim Timing

The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit 3PLSHT (Three-Pole Reclose Last Shot).

3PLSHT Deasserted (Three-Pole Shot Remains)

The recloser exhibits two possible state transitions when 3PLSHT is not asserted:

- If no further trip conditions occur and timer 3PRCD expires, the recloser returns to the reset states BK*n*RS.
- If a fault occurs while the 3PRCD reclaim timer is timing, the recloser asserts 3PARC if all auto-reclose initiate conditions are satisfied and goes to the beginning of the 79CY3 cycle. The recloser then recalculates and freezes the number of active circuit breakers, the leader, and the follower.

3PLSHT Asserted (Last Shot)

The recloser exits the 79CY3 state via two methods while 3PLSHT is asserted:

- If no further trip conditions occur and timer 3PRCD expires, the recloser returns to the reset states BK*n*RS.
- If a fault occurs during the 3PRCD reclaim time and 3PLSHT is asserted, then the recloser goes to lockout BK*n*LO.

Lockout State from 79CY3

The recloser goes to lockout (BK*n*LO):

- when the number of trips exceeds the maximum number of shots (N3PSHOT)
- when supervision condition 3P*n*CLS fails to assert in BK1CLSD time
- when Relay Word bit 3POLINE asserts for a circuit breaker manual opening (no qualified auto-reclose initiation 3PARC)
- when the circuit breaker fails to close within BKCFD time
- any time SELOGIC equation 79DTL asserts

Active Circuit Breakers

The following three Relay Word bits describe when Circuit Breaker BK1 and Circuit Breaker BK2 are active for the auto-reclose logic:

- NBK0, No Breaker Active in Reclose Scheme
- NBK1, One Breaker Active in Reclose Scheme
- NBK2, Two Breakers Active in Reclose Scheme

Leader and Follower Circuit Breakers

One circuit breaker is the leader and the other is the follower for circuit breaker-and-a-half and ring-bus arrangements. *Figure 2.2* illustrates a multiple circuit breaker arrangement. The leader recloses first. If the leader recloses successfully, the follower also typically recloses.

Figure 2.2 Multiple Circuit Breaker Arrangement

Choose Circuit Breaker BK1 as the leader and Circuit Breaker BK2 as the follower. If Circuit Breaker BK1 is out of service (for maintenance, for example), the SEL-451 can automatically make Circuit Breaker BK2 the leader.

The relay freezes the leader, follower, and number of active circuit breaker designations during an auto-reclose cycle. If the logic receives another reclose initiation, the relay reevaluates the leader, follower, and number of active circuit breaker designations. The logic considers a circuit breaker out of service if the circuit breaker goes to lockout, and declares a circuit breaker to be in service as soon as the circuit breaker closes and is no longer in lockout.

Leader Logic

Relay settings SLBK1 (Leader Breaker = Breaker 1) and SLBK2 (Leader Breaker = Breaker 2) SELOGIC control equations determine the criteria for relay selection of the active leader. Set SLBK1 := 1 to select Circuit Breaker 1 as the leader; set SLBK2 := 1 to select Circuit Breaker 2 as the leader. SLBK1 has priority over SLBK2; if you set both settings to 1 or both to 0, Circuit Breaker 1 is the leader.

Circuit Breaker BK1 is the leader for the following conditions:

- BK1 is the only circuit breaker in service
- BK1 and BK2 are in service and BK1 is selected as the leader (SLBK1 := 1)
- BK1 and BK2 are in service and the setting combination SLBK := 0 and SLBK2 := 1 is not in effect

Circuit Breaker BK2 is the leader for the following conditions:

- BK2 is the only circuit breaker in service
- BK1 and BK2 are in service and BK2 is selected as the leader (SLKBK1 := 0 and SLBK2 := 1)

If neither circuit breaker is in service, there is no leader.

The following three Relay Word bits describe which circuit breaker is the leader:

- LEADBK0, No Breaker In Service
- LEADBK1, Leader Breaker = Breaker 1
- LEADBK2, Leader Breaker = Breaker 2

The SEL-451 loads the corresponding circuit breaker settings into the leader Relay Word bits (LEADBK0, LEADBK1, and LEADBK2). If there is no leader (no circuit breaker is active), the relay loads a logical 0 into LEADBK1 and LEADBK2, and a logical 1 into LEADBK0.

Follower Logic

The FBKCEN SELOGIC control equation, Follower Breaker Closing Enable, defines the conditions necessary for the follower breaker to reclose.

The SEL-451 selects the follower as follows:

- If Circuit Breaker BK1 is the leader and Circuit Breaker BK2 is not locked out, then Circuit Breaker BK2 is the follower.
- If Circuit Breaker BK2 is the leader and Circuit Breaker BK1 is not locked out, then Circuit Breaker BK1 is the follower.

If fewer than two circuit breakers are in service (NBK0 or NBK1 is asserted), then there is no follower.

The following three Relay Word bits describe which circuit breaker is the follower:

- FOLBK0, No Follower Breaker
- FOLBK1, Follower Breaker = Breaker 1
- FOLBK2, Follower Breaker = Breaker 2

If there is no follower (in the case of only one circuit breaker, for example), the relay loads a logical 0 into the follower Relay Word bit FBKCEN.

Dynamic Selection of Leader and Follower Circuit Breakers

The SEL-451 dynamically selects the leader and follower circuit breakers during the reclose cycle. The relay calculates the leader in the ready (reset) state. At the start of the reclose cycle, the relay freezes this calculation and sets circuit breaker designations. The leader/follower designation can dynamically change in the cycle if the leader circuit breaker goes to lockout and FBKCEN is asserted.

Set the initial leader/follower designation and follower close conditions with settings SLBK1 (Lead Breaker = Breaker 1), SLBK2 (Lead Breaker = Breaker 2), and FBKCEN (Follower Breaker Closing Enable). *Table 2.4* shows the permutations of these settings.

Table 2.4 Dynamic Leader/Follower Settings

SLBK1	SLBK2	FBKCEN	Comments
0	0	0	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will not close as the follower upon successful close of leader BK1.
0	0	1	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will close as the follower if BK1 → LO after BKCFD. BK2 will close as the follower upon successful close of the leader BK1.
0	1	0	BK2 is the leader; BK1 is the leader only if BK2→ LO and BK1 is closed. BK1 will not close as the follower upon successful close of leader BK2.
0	1	1	BK2 is the leader; BK1 is the leader only if BK2→ LO. BK1 will close if BK2 → LO after BKCFD. BK1 will close as the follower, after TBBKD time, upon successful close of the leader BK2.
1	0	0	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will not close as the follower upon successful close of leader BK1.
1	0	1	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will close as the follower if BK1 → LO after BKCFD. BK2 will close as the follower, after TBBKD time, upon successful close of the leader BK1.
1	1	0	Same as 1/0/0.
1	1	1	Same as 1/0/1.
1	0	52AA1	BK1 is the leader; BK2 to LO if BK1→ LO. BK2 will close as the follower after TBBKD upon successful close of the leader BK1.

Circuit Breaker BK1 is always the leader if SLBK1 is asserted and BK1 is not locked out. Circuit Breaker BK2 is the leader if SLBK2 is asserted, BK2 is not locked out, and SLBK1 is not asserted. The second circuit breaker can become the leader when the leader is locked out.

Setting FBKCEN does not pick the follower, but decides when the second circuit breaker can reclose. If the leader goes to lockout, then the follower goes to lockout if FBKCEN := 0. If, however, the leader is manually opened, the follower breaker can become the leader (after being manually closed) and can close via a reclose cycle if FBKCEN := 1. If you want the follower breaker to close only for specific conditions, use the enable settings to force this close requirement. For example, Circuit Breaker BK2 can dynamically become the leader if BK1 is locked out and BK2 is closed. If you do not want BK2 to become the leader, set FBKCEN := 52AA1. Also see *Example One: No Follower on page R.2.12* for another method to prevent BK2 from becoming the leader.

The following examples help illustrate how the SEL-451 auto-reclose logic dynamically determines the leader and follower circuit breakers. These examples describe a two circuit breaker scheme (such as used in a circuit breaker-and-a-half arrangement) as shown in *Figure 2.3*.

Example One: No Follower

This example describes recloser states when Circuit Breaker BK1 fails to reclose following the first open interval delay. Set the FBKCEN SELOGIC control equation to prevent Circuit Breaker BK2 from closing as the follower. The leader and follower selection settings are shown in *Table 2.5*.

Figure 2.3 Multiple Circuit Breaker Arrangement

Table 2.5 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	0

Reset State and 79CY3 Cycle State

Prior to receiving initiation for a fault, the auto-reclose logic resets for both circuit breakers. *Table 2.6* defines the logical state of the auto-reclose logic for this example prior to the initiation of an auto-reclose cycle.

Table 2.6 Example One: Reset and 79CY3 States

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

Lockout State

In our example, Circuit Breaker BK1 fails to close when the first open interval expires, forcing BK1 to lockout. Circuit Breaker BK2 automatically goes to lockout because setting FBKCEN := 0. *Table 2.7* defines the logical state of the auto-reclose logic at this point.

Table 2.7 Example One: Lockout State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	1
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	1
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Reset State After Reclaim Time

Circuit Breaker BK2 is manually closed and now becomes active as the leader after 3PMRCD (Manual Close Reclaim Time Delay). Subsequent reclosing occurs with BK2. *Table 2.8* defines the logical state of the auto-reclose logic at this point.

Table 2.8 Example One: Reset State After Reclaim Time

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Block Reclosing with Enable Settings

If we want to block breaker BK2 from automatically reclosing under this condition, set E3PR2 := NBK2. With this enable setting, BK2 is never allowed to reclose unless both breakers are in service.

Example Two: BK2 as Successful Follower and Dynamic Leader

Another example is similar to the first with SLBK1/SLBK2/FBKCEN at 1/0/1 (see *Table 2.9*).

Table 2.9 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	1

Reset State

Prior to receiving initiation for a fault, the auto-reclose logic resets for both circuit breakers. At the start of the reclose cycle, Relay Word bits LEADBK1, FOLBK2, and NBK2 are asserted (see *Table 2.10*).

Table 2.10 Example Two: Initial Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

When BK1 successfully recloses, BK2 closes as the follower after timer TBBKD (Time Between Breakers for ARC).

If BK1 fails to close, causing it to go to lockout during a reclose cycle (after BKCFD time), BK2 will close as the follower. Upon successful reclose, timer 3PRCD (Three-Pole Reclaim Time Delay) times out and the recloser enters the reset state for BK2 (BK2RS). The recloser dynamically recalculates the leader and follower circuit breakers. BK2 becomes the leader with Relay Word bits LEADBK2, FOLBK0, and NBK1 asserted (see *Table 2.11*).

Table 2.11 Example Two: Final Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Example Three: BK2 as Conditional Follower

One method to program BK2 for closing only after a successful BK1 close is to set SLBK1/SLBK2/FBKCEN as in *Table 2.12*.

Table 2.12 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	52AA1

Reset State

Prior to receiving initiation for a fault, the auto-reclose logic resets for both circuit breakers. *Table 2.13* defines the logical state of the auto-reclose logic for this example prior to the initiation of an auto-reclose cycle.

Table 2.13 Example Three: Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

79CY3 Cycle State

The SEL-451 auto-reclose logic receives an auto-reclose initiation. *Table 2.14* defines the logical state of the auto-reclose logic for this example during the auto-reclose cycle.

Table 2.14 Example Three: Auto-Reclose Cycle State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

BK2 closes as the follower when BK1 successfully closes (after timer TBBKD).

Lockout State

Circuit Breaker BK1 must close before Circuit Breaker BK2. If Circuit Breaker BK1 fails to close and goes to lockout, then Circuit Breaker BK2 goes to lockout as well because BK2 cannot close as the follower and cannot dynamically become the leader. *Table 2.15* defines the logical state of the auto-reclose logic for this example following the unsuccessful reclose attempt.

Table 2.15 Example Three: Lockout State, BK1

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	1
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	1
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Example Four: Input Selection of Leader

Figure 2.4 illustrates a double breaker configuration for this particular example. The leader and follower selection settings are shown in *Table 2.16* Circuit Breaker BK1 is out of service for maintenance and Disconnect Switch 1 is open.

Table 2.16 Leader/Follower Selection

Setting Label	Setting
SLBK1	IN106 (Disconnect 1 a contacts)
SLBK2	IN107 (Disconnect 2 a contacts)
FBKCEN	0

Figure 2.4 Leader/Follower Selection by Relay Input

Table 2.17 defines the logical state of the auto-reclose logic for this example prior to the initiation of an auto-reclose cycle. These conditions are frozen during an auto-reclose cycle. The SEL-451 auto-reclose logic can unfreeze these conditions if the relay receives another initiation.

Table 2.17 Two Circuit Breakers: Circuit Breaker BK1 Out of Service

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Enable Auto-Reclose Logic for Two Circuit Breakers

The initial settings necessary to enable auto-reclose for two circuit breakers are shown in *Table 2.18*.

Table 2.18 Two-Circuit-Breaker Auto-Reclose Initial Settings

Setting	Description	Entry
NUMBK	Number of Breakers in Scheme	2
Breaker 1 Inputs (Breaker Monitor)		
52AA1	N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Breaker 2 Inputs (Breaker Monitor)		
52AA2	N/O Contact Input—BK2 (SELOGIC Equation)	IN102
Relay Configuration (Group)		
E79	Reclosing	Y or Y1

For additional settings to set specific operating parameters for the recloser, refer to *Auto-Reclose and Synchronism Check Example on page A.1.25*.

Recloser Mode Enables

The SELOGIC control equation E3PR*n* enables the SEL-451 to reclose. *Table 2.19* and *Table 2.20* illustrate how to enable the auto-reclose modes per circuit breaker.

Table 2.19 Circuit Breaker BK1 Modes of Operation

E3PR1	Result
0	Auto-reclose disabled
1	Auto-reclose enabled

E3PR1 is the SELOGIC control equation that enables auto-reclosing for Circuit Breaker BK1. You can assign this setting to a control input.

When E3PR1 equals logical 1, the relay can attempt an auto-reclose cycle for Circuit Breaker BK1. If E3PR1 equals logical 0, the relay goes to lockout for Circuit Breaker BK1 and the corresponding leader logic transfers automatically to Circuit Breaker BK2.

Table 2.20 Circuit Breaker BK2 Modes of Operation

E3PR2	Result
0	Auto-reclose disabled
1	Auto-reclose enabled

E3PR2 is the SELOGIC control equation that enables auto-reclosing for Circuit Breaker BK2. You can assign this setting to a control input.

When E3PR2 equals logical 1, the relay can attempt an auto-reclose cycle for Circuit Breaker BK2. If E3PR2 equals logical 0, the relay goes to lockout for Circuit Breaker BK2.

Assert one or both SELOGIC control equations E3PR1, E3PR2 according to your reclosing requirements.

Auto-Reclose Logic Diagrams

Figure 2.5 Circuit Breaker Pole-Open Logic Diagrams

Figure 2.6 Line-Open Logic Diagram When E79 := Y

Figure 2.7 Line-Open Logic Diagram When E79 := Y1

Figure 2.8 Qualified Auto-Reclose Initiation

Note:
If 3POLINE does not assert (three-pole breaker does not open), the auto-reclose cycle state will remain in the check for the 3POLINE = 1 condition indefinitely, or until the 79DTL logic (Drive to Lockout) Relay Word bit asserts. In applications where the 3POLINE Relay Word bit may not reliably assert at this point, we recommend using logic in the 79DTL setting to bypass this stall condition after a fixed time delay.

Figure 2.9 One Circuit Breaker Three-Pole Cycle State (79CY3)

Figure 2.10 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y

Figure 2.10 **Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y** (continued)

Figure 2.10 **Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y** (continued)

Figure 2.11 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1

Figure 2.11 **Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1** (continued)

Figure 2.11 **Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1** (continued)

Manual Closing

Manual closing is available via the relay to issue a close to the circuit breaker(s) via the same close logic outputs used in auto-reclosing (Relay Word bits BK1CL and BK2CL for up to two circuit breakers). The manual close logic can be user-configured in most any manner with SELOGIC settings BK1MCL and BK2MCL. *Figure 2.12* is a flowchart of the manual close logic. This logic is enabled with Manual Closing enable setting EMANCL := Y.

Figure 2.12 only details the manual close logic for one circuit breaker (breaker BK1). The manual close logic for a second circuit breaker (breaker BK2), if enabled (global setting NUMBK := 2), is similar. The only difference between the breaker BK1 and breaker BK2 manual close logic in *Figure 2.12* is the substitution of settings and logic outputs (BK2MCL for BK1MCL, ULCL2 for ULCL1, etc.). A manual close is issued for breaker BK1 if:

- A new manual close signal for breaker BK1 is detected (rising edge assertion of SELOGIC setting BK1MCL),
- No unlatch close conditions are present (SELOGIC setting ULCL1 deasserted),
- And no close is presently in progress for breaker BK1 (Relay Word bit output BK1CL is deasserted).

If a manual close is successfully issued for breaker BK1, then:

- Close logic output BK1CL asserts
- And the close failure timer starts timing

If breaker BK1 closes successfully, then:

- The unlatch close condition asserts (indicating breaker closure)
- And close logic output BK1CL deasserts

If breaker BK1 does not close successfully, then:

- The close failure timer times out (Relay Word bit BK1CFT asserts momentarily)
- And close logic output BK1CL deasserts

Note in *Figure 2.12* that if breaker BK1 manual close logic is actively operating (as described in the preceding steps), then the breaker BK2 manual close logic can't be actively operating. The breaker BK2 manual close logic only has a chance to operate if the breaker BK1 manual close logic is not actively operating and two breakers are enabled for the scheme (global setting NUMBK := 2). Thus, manually closing can only be attempted for one breaker at a time.

Figure 2.12 Manual Close Logic

Voltage Checks for Auto-Reclosing and Manual Closing

Voltage elements are available for a final check of line and bus voltages before an auto-reclose or manual close is issued. These voltage elements and corresponding pickup settings are enabled with Reclosing Voltage Check enable setting EVCK := Y. *Figure 2.13* shows the application of these voltage elements and *Figure 2.14* shows their implementation. Check voltages for arrangements of up to two circuit breakers (global setting NUMBK := 2), as shown in *Figure 2.13*. If the SEL-451 is only connected to a single breaker (global setting NUMBK := 1), then settings 27BK2P and 59BK2P and their associated elements (LLDB2, DLDB2, and DLLB2) are not available.

Voltages V_P, V_{S1}, and V_{S2} in *Figure 2.13* and *Figure 2.14* come from corresponding voltage source selection settings SYNCP, SYNCS1, and SYNCS2 in the *Synchronism Check* subsection (see *Figure 2.18*). *Figure 2.20*, *Figure 2.21*, *Figure 2.22*, and accompanying text in *Synchronism Check on page R.2.35* explain an example where:

SYNCP = **VAY** (V_P is the voltage from voltage input VAY, referred to as the line voltage)

SYNCS1 = **VAZ** (V_{S1} is the normalized voltage from voltage input VAZ, referred to as the bus 1 voltage)

SYNCS2 = **VBZ** (V_{S2} is the normalized voltage from voltage input VBZ, referred to as the bus 1 voltage)

Figure 2.21, *Figure 2.22*, and accompanying text in *Synchronism Check on page R.2.35* explain the origin and normalization of voltages V_{S1} and V_{S2} to the V_P voltage base. This normalization example concerns both voltage angle and magnitude. The pickup settings in *Figure 2.14* are made on the V_P voltage base. V_P is the voltage reference for voltage angle and magnitude. Only voltage magnitude is of concern for the settings in *Figure 2.14*, not voltage angle.

Figure 2.13 implies that three-phase voltage is available from the line PTs. But, resultant voltage V_P corresponds to only one phase of this three-phase voltage (e.g., setting SYNCP = VAY; V_P is the normalized voltage from voltage input VAY). All the voltage elements in *Figure 2.14* are single-phase voltage elements—detecting live or dead voltage on the bus side with a single-phase voltage element and likewise on the line side.

Whether or not synchronism check logic is used, it still has to be enabled for the respective breaker (E25BK1 := Y and E25BK2 := Y) in order that the corresponding voltage source selection settings (SYNCP, SYNCS1, and SYNCS2) can be made.

Live Line/Live Bus

Note in *Figure 2.13* that live line/live bus is not available for either circuit breaker. Voltage elements 59VP, 59VS1, and 59VS2 in *Synchronism Check on page R.2.35* (see *Figure 2.19* and *Figure 2.23*) are available for such a function (e.g., 59VP AND 59VS1 for live line/live bus 1).

Supervising Circuit Breaker Closing with Voltage Checks

Supervising Auto-Reclosing

For a fault on the line in *Figure 2.13*, both breakers trip open and the lead breaker recloses first. For example, presume the lead breaker closes only if its respective bus is live and the line is dead (dead line/live bus; see *Figure 2.13*). Then, after successful reclose of the lead breaker, the follower breaker closes on synchronism check (see *Figure 2.19*). Such reclose supervision logic is realized as follows for respective breakers BK1 and BK2:

3P1CLS := **LEADBK1 AND DLLB1 OR FOLBK1 AND 25A1BK1 OR ...**

3P2CLS := **LEADBK2 AND DLLB2 OR FOLBK2 AND 25A1BK2 OR ...**

Note that the lead breaker and follower breaker supervision (Relay Word bits LEADBK*n* and FOLBK*n*, respectively) provides dynamic control for reclose supervision. One, but not both of the breakers can reclose for a dead line/live bus condition (lead breaker), while the other then closes for a synchronism check condition (follower breaker).

Supervising Manual Closing

Voltage checks can also be used to supervise manual closing. For example, presume that manual closing of breaker BK1 (*Figure 2.13*) should ***not*** be allowed if the respective bus is dead (dead line/dead bus or live line/dead bus condition):

BK1MCL := **NOT(DLDB1 OR AND LLDB1) AND (...)**

Figure 2.13 Voltage Check Element Applications

Figure 2.14 Voltage Check Element Logic

Settings and Relay Word Bits for Auto-Reclosing and Manual Closing

Table 2.21 shows the auto-reclose logic settings. *Table 2.22* provides all of the Relay Word bits for auto-reclosing.

Table 2.21 Auto-Reclosing and Manual Closing Settings (Sheet 1 of 2)[a]

Label	Prompt	Default Value
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	1
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	PLT02 and PLT04
E3PR2	Three-Pole Reclose Enable—BK2 (SELOGIC Equation)	PLT02 and PLT04
TBBKD	Time Between Breakers for Automatic Reclose (1–99999 cycles)	300
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	300
SLBK1	Lead Breaker = Breaker 1 (SELOGIC Equation)	1
SLBK2	Lead Breaker = Breaker 2 (SELOGIC Equation)	NA
FBKCEN	Follower Breaker Closing Enable (SELOGIC Equation)	1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 OR TRIP
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2 OR TRIP

Table 2.21 Auto-Reclosing and Manual Closing Settings (Sheet 2 of 2)[a]

Label	Prompt	Default Value
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	NOT (PLT02 AND PLT04) AND (3PT OR NOT 52AA1)
79BRCT	Block Reclaim Timer (SELOGIC Equation)	3PT
BK1MCL	Breaker 1 Manual Close (SELOGIC Equation)	(CC1 OR PB7_PUL) AND PLT04
BK2MCL	Breaker 2 Manual Close (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	300
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	60
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)	60
3POISC	Three-Pole Open Interval Supervision (SELOGIC Equation)[b]	1
3POISD	Three-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1
3POID1	Three-Pole Open Interval 1 Delay (1–99999 cycles)	300
3POID2	Three-Pole Open Interval 2 Delay (1–99999 cycles)	300
3POID3	Three-Pole Open Interval 3 Delay (1–99999 cycles)	300
3POID4	Three-Pole Open Interval 4 Delay (1–99999 cycles)	300
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA
3PFOID	Three-Pole Fast Open Interval Delay (1–99999 cycles)	60
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT AND NOT SOTFT
3PRIH	Three-Pole Line Open Failure Delay (OFF, 1–99999)	15
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3P1CLS	Three Pole BK 1 Reclose Supervision (SELOGIC Equation)[b]	PLT02
3P2CLS	Three Pole BK 2 Reclose Supervision (SELOGIC Equation)[b]	PLT02
Voltage Elements		
EVCK	Reclosing Voltage Check (Y, N)	N
27LP	Dead Line Voltage (1.0–200 V secondary)	14
59LP	Live Line Voltage (1.0–200 V secondary)	53
27BK1P	Breaker 1 Dead Busbar Voltage[c] (1.0–200 V secondary)	14
59BK1P	Breaker 1 Live Busbar Voltage[c] (1.0–200 V secondary)	53
27BK2P	Breaker 2 Dead Busbar Voltage[c] (1.0–200 V secondary)	14
59BK2P	Breaker 2 Live Busbar Voltage[c] (1.0–200 V secondary)	53

[a] Adjust all timers in 1-cycle steps.
[b] These settings cannot be set to NA or to logical 0.
[c] These settings must be made on the normalized voltage scale if setting KS1M ≠ 1.00 or KS2M ≠ 1.00; see Voltage Magnitude and Angle Compensation on page R.2.40.

Table 2.22 Auto-Reclosing Logic Relay Word Bits (Sheet 1 of 2)

Name	Description
3PARC	Qualified Three-Pole Reclose Initiate
3POISC	Three-Pole Open Interval Supervision Condition
Auto-Reclosing States	
79STRT	Relay in Start State
BK1RS	Breaker 1 in Reset State
BK2RS	Breaker 2 in Reset State
79CY3	Relay in Three-Pole Reclose Cycle State
BK1LO	Breaker 1 in Lockout State
BK2LO	Breaker 2 in Lockout State
Shot Counter	
3PSHOT0	Three-Pole Shot Counter = 0
3PSHOT1	Three-Pole Shot Counter = 1
3PSHOT2	Three-Pole Shot Counter = 2
3PSHOT3	Three-Pole Shot Counter = 3
3PSHOT4	Three-Pole Shot Counter = 4
3PLSHT	Three-Pole Reclose Last Shot
Pole-Open Status/Timing	
3POBK1	Three-Pole Open Breaker 1
3POBK2	Three-Pole Open Breaker 2
3POLINE	Three-Pole Open Line
3POI	Three-Pole Open Interval Timing (in reclose cycle state)
Breaker Close Logic Outputs	
BK1CLSS	Breaker 1 Close Supervision Delay Timing
BK2CLSS	Breaker 2 Close Supervision Delay Timing
BK1CLST	Breaker 1 Close Supervision Delay Timed Out
BK2CLST	Breaker 2 Close Supervision Delay Timed Out
BK1CL	Breaker 1 Close Command
BK2CL	Breaker 2 Close Command
BK1CFT	Breaker 1 Close Failure Delay Timed Out
BK2CFT	Breaker 2 Close Failure Delay Timed Out
BK1EXT	Breaker 1 Closed Externally
BK2EXT	Breaker 2 Closed Externally
Reclaim/Reset Timing	
BK1RCIP	Breaker 1 Reclaim in Progress (in lockout state)
BK2RCIP	Breaker 2 Reclaim in Progress (in lockout state)
3PRCIP	Three-Pole Reclaim In-Progress (in reclose cycle state)
Lead and Follower Breakers	
TBBK	Time Between Breakers Timing
LEADBK0	No Leader Breaker
LEADBK1	Leader Breaker = Breaker 1
LEADBK2	Leader Breaker = Breaker 2

Table 2.22 Auto-Reclosing Logic Relay Word Bits (Sheet 2 of 2)

Name	Description
FOLBK0	No Follower Breaker
FOLBK1	Follower Breaker = Breaker 1
FOLBK2	Follower Breaker = Breaker 2
NBK0	No Breaker Active in Reclose Scheme
NBK1	One Breaker Active in Reclose Scheme
NBK2	Two Breakers Active in Reclose Scheme
Voltage Checks	
LLDB1	Live Line/Dead Bus 1
DLLB1	Dead Line/Live Bus 1
DLDB1	Dead Line/Dead Bus 1
LLDB2	Live Line/Dead Bus 2
DLLB2	Dead Line/Live Bus 2
DLDB2	Dead Line/Dead Bus 2

Synchronism Check

Synchronism-check elements prevent circuit breakers from closing if the corresponding phases across the open circuit breaker are excessively out of phase, magnitude, or frequency. The SEL-451 synchronism-check elements selectively close circuit breaker poles under the following criteria:

- The systems on both sides of the open circuit breaker are in phase (within a settable voltage angle difference).
- The voltages on both sides of the open circuit breaker are healthy (within a settable voltage magnitude window).

You can use synchronism-check elements to program the relay to supervise circuit breaker closing; include the synchronism-check element outputs in the close SELOGIC control equations. These element outputs are Relay Word bits 25W1BK1, 25A1BK1, 25W2BK1, 25A2BK1, 25W1BK2, 25A1BK2, 25W2BK2, and 25A2BK2 (see *Synchronism-Check Logic Outputs on page R.2.38* and *Angle Checks and Synchronism-Check Element Outputs on page R.2.44*).

An example best demonstrates the synchronism-check capability in the SEL-451. This subsection presents a typical synchronism-check system.

Generalized System

The generalized system single-line drawing in *Figure 2.15* shows a partial circuit breaker-and-a-half or ring-bus substation arrangement. Presuming that both Circuit Breakers BK1 and BK2 are open, the system is split into three sections: Bus 1, Bus 2, and Line.

Figure 2.15 Partial Breaker-and-a-Half or Partial Ring-Bus Breaker Arrangement

Paralleled and Asynchronous Systems

Figure 2.15 shows remote sources for each section. Often, a portion of the power system is paralleled beyond the open Circuit Breakers BK1 and BK2; the remote sources are really the same aggregate source. If the aggregate source is much closer to one side of the open circuit breaker than the other, there is a noticeable voltage angle difference across the system (it is not simply zero degrees). The corresponding angular separation results from load flow and the impedance of the parallel system.

Here is a simple method to calculate the voltage angle across the circuit breaker if a load flow study is not readily available. Be aware that the angle resulting from load flow is typically larger than the angle calculated in *Equation 2.1* and shown in *Figure 2.16*.

Voltage Angle Difference Estimate

The propagation of the electric signal at nearly the speed of light causes a voltage angle to appear across the open circuit breaker. *Figure 2.16* illustrates the angle difference. Note that the aggregate source is near one end of the open circuit breaker, but is 80 kilometers away from the other end. The angle difference is calculated in *Equation 2.1*:

$$80\ \text{km} \bullet \frac{\text{s}}{300 \bullet 10^3\,\text{km}} \bullet \frac{60\ \text{cyc}}{\text{s}} \bullet \frac{360°}{\text{cyc}} \approx 6°$$

Equation 2.1

Therefore, even though this system is paralleled beyond the open circuit breaker, a 6-degree voltage angle difference results across the circuit breaker (even with no load flow through the parallel path).

You must consider this angle difference when setting the synchronism-check element for a paralleled system. In this example, do not set the voltage angle difference setting to less than 15–20 degrees nominal. A paralleled system does not imply a zero degree voltage angle difference at every measuring point.

Figure 2.16 Voltage Angle Difference in a Paralleled System

Alternatively, if the remote sources in each section of the example system shown in *Figure 2.15* are not paralleled beyond the open circuit breakers, the systems are asynchronous. The corresponding phase voltages of two such systems are only in phase at infrequent times—when one of the systems slips by the other. At all other times, the corresponding phase voltages of two such systems are out of phase (sometimes as much as 180 degrees out of phase) as the systems continue to slip by each other.

Single-Phase Voltage Inputs

Figure 2.17 shows single-phase voltage transformers (1 PT) on Bus 1 and Bus 2. Use these single-phase voltage sources to perform a synchronism check across the two circuit breakers.

Figure 2.17 Synchronism-Check Voltages for Two Circuit Breakers

Synchronism check occurs on a single-phase voltage basis—see the single-phase potential transformers (1 PT) shown on each bus in *Figure 2.17*. The assumption is that, if the monitored single-phase voltage inputs are in phase (within a settable voltage angle difference) and are healthy (within a settable voltage magnitude window), the other phase-to-neutral voltages are likewise in phase and healthy. The line voltage source is three-phase, but you only need a single-phase bus voltage to perform a synchronism check across the corresponding circuit breaker. The relay uses the three-phase voltage from the line for other functions such as fault location and metering.

Synchronism-Check Settings

This example uses a two-circuit breaker arrangement (see *Figure 2.17*). Set the synchronism-check enable settings:

E25BK1 := **Y** Synchronism Check for Circuit Breaker BK1 (Y, N)

E25BK2 := **Y** Synchronism Check for Circuit Breaker BK2 (Y, N)

If you are using the SEL-451 on a single circuit breaker, enable synchronism check for only one circuit breaker (E25BK1 := Y and E25BK2 := N).

Figure 2.18 shows the correspondence between the synchronism-check settings and the two-circuit breaker application example. All of these settings are listed in *Section 10: Settings*. The following subsections explain these settings and include an explanation of Alternative Synchronism-Check Voltage Source 2 settings (see *Figure 2.28*).

Figure 2.18 Synchronism-Check Settings

Synchronism-Check Logic Outputs

Figure 2.19 shows the correspondence between synchronism-check logic outputs (Relay Word bits) and the two-circuit breaker arrangement. These Relay Word bits assert to logical 1 (e.g., 59VP equals logical 1) if true and deassert to logical 0 (e.g., 59VS1 equals logical 0) if false. *Table 2.23* lists these Relay Word bits.

Figure 2.19 Synchronism-Check Relay Word Bits

Table 2.23 Synchronism-Check Relay Word Bits

Relay Word Bit	Description
59VP	V_P within healthy voltage window
59VS1	V_{S1} within healthy voltage window
25ENBK1	Circuit Breaker BK1 synchronism-check element enabled
SFZBK1	Circuit Breaker BK1 slip frequency less than 0.005 Hz (“no slip” condition)
SFBK1	0.005 Hz ≤ Circuit Breaker BK1 slip frequency < 25SFBK1
25W1BK1	Voltage angle across Circuit Breaker BK1 < ANG1BK1
25W2BK1	Voltage angle across Circuit Breaker BK1 < ANG2BK1
25A1BK1	Same operation as 25W1BK1, except for the restrictive operation (0° closure attempt) when setting 25SFBK1 ≠ OFF and the system is slipping (see *Figure 2.27*)
25A2BK1	Same operation as 25W2BK1, except for the restrictive operation (0° closure attempt) when setting 25SFBK1 ≠ OFF and the system is slipping (see *Figure 2.27*)
FAST1	Bus 1 frequency greater than line frequency ($f_{S1} > f_P$)
SLOW1	Bus 1 frequency less than line frequency ($f_{S1} < f_P$)
59VS2	V_{S2} within healthy voltage window
25ENBK2	Circuit Breaker BK2 synchronism-check element enabled
SFZBK2	Circuit Breaker BK2 slip frequency less than 0.005 Hz (“no slip” condition)
SFBK2	0.005 Hz ≤ Circuit Breaker BK2 slip frequency < 25SFBK2
25W1BK2	Voltage angle across Circuit Breaker BK2 < ANG1BK2
25W2BK2	Voltage angle across Circuit Breaker BK2 < ANG2BK2
25A1BK2	Same operation as 25W1BK2, except for the restrictive operation (0° closure attempt) when setting 25SFBK2 ≠ OFF and the system is slipping (see *Figure 2.27*)
25A2BK2	Same operation as 25W2BK2, except for the restrictive operation (0° closure attempt) when setting 25SFBK2 ≠ OFF and the system is slipping (see *Figure 2.27*)
FAST2	Bus 2 frequency greater than line frequency ($f_{S2} > f_P$)
SLOW2	Bus 2 frequency less than line frequency ($f_{S2} < f_P$)

NOTE: If 25ENBK1 = 0 or 25SFBK1 = OFF, then SFZBK1 = 0 and SFBK1 = 0.

Supervising Circuit Breaker Closing via Synchronism Check

Use the synchronism-check element outputs to control circuit breaker closing. Some examples follow (the ellipsis indicates other elements that you can add to these SELOGIC control equations):

Supervising Auto-Reclosing of Circuit Breaker BK1

3P1CLS := **25A1BK1 OR ...** Three-Pole BK1 Reclose Supervision (SELOGIC Equation)

Manual Closing of Circuit Breaker BK1

BK1MCL := **25W2BK1 AND ...** Circuit Breaker BK1 Manual Close (SELOGIC Equation)

PT Connections

Figure 2.20 is an example of connecting PTs to the SEL-451 for two circuit breakers. The Bus 1 and Bus 2 single-phase voltages are connected to relay voltage inputs VAZ and VBZ, respectively. They could just as easily have been connected to any of the other voltage inputs. The voltage connected to voltage input VAZ (setting SYNCS1 := VAZ; see *Figure 2.20*) is not necessarily from A-phase on Bus 1. Likewise, the voltage connected to voltage input VBZ (setting SYNCS2 := VBZ; see *Figure 2.20*) is not necessarily from B-phase on Bus 2. The connection can be from any phase-to-neutral or phase-to-phase voltage (as long as you do not exceed the relay voltage input ratings). Settings in the SEL-451 compensate for any steady-state magnitude or angle difference with respect to a synchronism-check voltage reference, as discussed next in this example.

Three-phase line voltages are connected to relay voltage inputs VAY, VBY, and VCY (these voltage inputs are also used for fault location, loss-of-potential, load encroachment, and directionality). Only one of these single-phase voltage inputs is designated for use in synchronism check. In this example, this voltage input is also designated the synchronism-check voltage reference (setting SYNCP := VAY; see *Figure 2.20*). As the synchronism-check voltage reference, the relay makes all steady-state magnitude and angle adjustments for the Bus 1 and Bus 2 synchronism check voltages (connected to voltage inputs FAZ and FBZ, respectively, as discussed in the preceding paragraph) with respect to this designated reference line voltage, VAY, as discussed later in this example.

For a nominal single-circuit breaker application (global setting NUMBK := 1), you can use either bus-side potentials or line-side potentials for directional control; connect the three-phase voltage source to voltage inputs VAY, VBY, and VCY. If a single-phase voltage source is available on the other side of the circuit breaker for synchronism check, connect the source to voltage input VAZ, VBZ, or VCZ.

Figure 2.20 Example Synchronism-Check Voltage Connections to the SEL-451

Voltage Magnitude and Angle Compensation

The *Figure 2.20* example continues in *Figure 2.21*. The *Figure 2.21* example demonstrates possible voltage input connections (presuming ABC phase rotation). The synchronism-check voltage reference (V_P) is from the A-phase voltage (V_A) of the line (setting SYNCP := VAY). You can connect phase-to-

phase voltage V_{BC} originating from Bus 1, and connect phase-to-neutral voltage V_C from Bus 2. Thus, Bus 1 voltage V_{BC} lags synchronism-check voltage reference V_P by 90 degrees, and Bus 2 voltage V_C lags the synchronism-check voltage reference V_P by 240 degrees. To compensate for these steady-state angle differences, set KS1A for Bus 1 and KS2A for Bus 2.

KS1A := **90** Synchronism Source 1 Angle Shift (0, 30, …, 330 degrees)

KS2A := **240** Synchronism Source 2 Angle Shift (0, 30, …, 330 degrees)

Figure 2.21 Synchronism-Check Voltage Reference

For a given secondary base voltage, phase-to-phase voltages are a factor of 1.73 (√3) times the magnitude of the phase-to-neutral voltages. In reverse, phase-to-neutral voltages are a factor of 0.58 (1/√3) times the magnitude of the phase-to-phase voltages. Therefore, you must compensate the Bus 1 voltage V_{BC} magnitude with setting KS1M to reference it to the synchronism-check voltage reference V_P magnitude.

KS1M := **0.58** Synchronism Source 1 Ratio Factor (0.10–3)

You do not need special magnitude compensation for the Bus 2 voltage V_C to reference Synchronism Source 2 to the synchronism-check voltage reference V_P magnitude; these are both phase-to-neutral voltages with the same nominal rating (for example, 67 V secondary).

KS2M := **1.00** Synchronism Source 1 Ratio Factor (0.10–S3)

As another example of synchronism-source magnitude adjustment flexibility, suppose Bus 1 voltage V_{BC} is 201 V secondary (phase-to-phase), and the synchronism-check voltage reference V_P is 67 V secondary (phase-to-neutral). Then, the magnitude compensation setting would be as in *Equation 2.2*.

$$\mathrm{KS1M} = \frac{67\ \mathrm{V}}{201\ \mathrm{V}} := 0.33$$

Equation 2.2

Normalized Synchronism-Check Voltage Sources V_{S1} and V_{S2}

The *Figure 2.21* example continues in *Figure 2.22*. *Figure 2.22* graphically illustrates how the introduced settings adjust the Bus 1 and Bus 2 synchronism-check input voltages in angle and magnitude to reference to the synchronism-check voltage reference V_P. The resultant Bus 1 and Bus 2 voltages are the normalized synchronism-check voltage sources V_{S1} and V_{S2}, respectively.

Voltages V_P, V_{S1}, and V_{S2} are used in the logic in the balance of this section to check for healthy voltage and determine voltage phase angle for synchronism-check element operation.

Figure 2.22 Normalized Synchronism-Check Voltage Sources VS1 and VS2

Voltage Checks and Blocking Logic

Two conditions can cause the synchronism-check function in the SEL-451 to abort. These conditions are out-of-range synchronism-check input voltages and block synchronism check configurations that you specify in SELOGIC control equations.

Voltage Magnitude Checks

For synchronism check to proceed for a given circuit breaker (BK1 or BK2), the voltage magnitudes of the synchronism-check voltage reference V_P and the corresponding normalized synchronism-check voltage source on the other side of the circuit breaker (normalized voltage V_{S1} for Circuit Breaker BK1 and normalized voltage V_{S2} for Circuit Breaker BK2) must lie within a healthy voltage window, bounded by voltage threshold settings 25VH and 25VL (see *Figure 2.23*).

The relay asserts Relay Word bits 59VP, 59VS1, and 59VS2 to indicate healthy synchronism-check voltages V_P, V_{S1}, and V_{S2}, respectively (see *Figure 2.23*). If either of the voltage pairs (V_P and V_{S1} or V_P and V_{S2}) does not meet this healthy voltage criterion, synchronism check cannot proceed for the circuit breaker associated with the corresponding voltage pair.

Figure 2.23 Healthy Voltage Window and Indication

Block Synchronism Check

If the block synchronism check BSYNBK*n* SELOGIC control equation (where *n* = 1 or 2 for Circuit Breaker BK1 or Circuit Breaker BK2, respectively) asserts, synchronism check cannot proceed for the corresponding circuit breaker. Following is an example for Circuit Breaker BK1:

BSYNBK1 := **52AA1** Block Synchronism Check—BK1 (SELOGIC Equation)

If Circuit Breaker BK1 is closed, the indication back to the relay shows 52AA1 equals logical 1. Thus, BSYNBK1 equals logical 1, and synchronism check is blocked for Circuit Breaker BK1. There is no need to qualify or continue with the synchronism check for circuit breaker closing; the circuit breaker is already closed.

Synchronism-Check Enable Logic

The relay combines the voltage check elements and block synchronism check condition to create a synchronism-check enable condition for each circuit breaker, as shown in *Figure 2.24*.

Figure 2.24 Synchronism-Check Enable Logic

Angle Checks and Synchronism-Check Element Outputs

After the relay determines that voltage magnitudes are healthy and determines that no block synchronism check conditions exist, the relay must check voltage phase angles across the circuit breakers before a final synchronism-check element output can be available for supervising circuit breaker closing.

The following discussion/examples use Circuit Breaker BK1. Synchronism-check element output operation for Circuit Breaker BK2 is similar (replace BK2 for BK1 in associated settings and Relay Word bits).

Angle Difference Settings ANG1BK1 and ANG2BK1

Each circuit breaker has two angle difference windows. For Circuit Breaker BK1, the maximum angle difference settings are ANG1BK1 and ANG2BK1.

Often, a greater phase angle across the circuit breaker is tolerated for a manual close. Typically, you set angle setting ANG1BK1 for synchronism check in auto-reclosing Circuit Breaker BK1 (e.g., ANG1BK1 := 20 degrees), and you set angle setting ANG2BK1 for synchronism check when manually closing Circuit Breaker BK1 (e.g., ANG2BK1 := 35 degrees).

Synchronism-Check Element Outputs 25W1BK1 and 25A1BK1

Angle difference setting ANG1BK1 affects synchronism-check element outputs 25W1BK1 and 25A1BK1. *Figure 2.25*, *Figure 2.26*, and *Figure 2.27* illustrate the operation of synchronism-check element outputs 25W1BK1 and 25A1BK1.

These outputs operate for a voltage phase angle within and without the angle difference setting ANG1BK1 for the following three conditions:

- no slip
- slip—no compensation
- slip—with compensation

The operational differences between synchronism-check element outputs 25W1BK1 and 25A1BK1 are apparent in the “slip—with compensation” example (*Figure 2.27*).

The second angle difference setting (ANG2BK1) for Circuit Breaker BK1 operates similarly to affect synchronism-check element outputs 25W2BK1 and 25A2BK1.

"No Slip" Synchronism Check

Refer to the paralleled system beyond the open circuit breaker in *Figure 2.16*. For such a system, there is essentially no slip across the open circuit breaker (the monitored voltage phasors on each side are not moving with respect to one another). In a "no slip" system, any voltage angle difference across the open circuit breaker remains relatively constant.

The four drawings shown in *Figure 2.25* are separate, independent cases for a "no slip" paralleled system. If the phase angle between the synchronism-check voltage reference V_P and the normalized synchronism-check voltage source V_{S1} is less than angle setting ANG1BK1, synchronism-check element outputs 25W1BK1 and 25A1BK1 both assert to logical 1. The relay declares that the per-phase voltages across Circuit Breaker BK1 are in synchronism. Otherwise, if the phase angle is greater than or equal to angle setting ANG1BK1, element outputs 25W1BK1 and 25A1BK1 both deassert to logical 0; the relay declares that the per-phase voltages across Circuit Breaker BK1 are out-of-synchronism.

The out-of-synchronism phase angles in *Figure 2.25* appear dramatic for a "no slip" paralleled system. This is for illustrative purposes; these angles are not usually this large in actual systems.

Figure 2.25 "No Slip" System Synchronism-Check Element Output Response

Slip Frequency and SFZBK1

Relay Word bit SFZBK1 (BK1 Slip Frequency less than 0.005 Hz) also asserts to logical 1, indicating a "no slip" condition across Circuit Breaker BK1. In other words, the slip frequency is less than 0.005 Hz ($|f_{S1}–f_P| < 0.005$ Hz).

Synchronism-Check Element Output Effects

Note that element outputs 25W1BK1 and 25A1BK1 operate identically in all of the "no slip" cases in *Figure 2.25* (both assert to logical 1 or deassert to logical 0).

"Slip—No Compensation" Synchronism Check

The four cases [(a), (b), (c), and (d)] shown in *Figure 2.26* are "slip—no compensation" cases for asynchronous systems (not paralleled). The cases progress in time from top to bottom. The normalized synchronism-check voltage source V_{S1} slips with respect to synchronism-check voltage reference V_P. The indication of the rotation arrow on phasor V_{S1} (and the time progression down the page) shows that the system corresponding to V_{S1} has a

higher system frequency f_{S1} than the system corresponding to reference V_P with system frequency f_P. The slip frequency across Circuit Breaker BK1 is $f_{S1}–f_P$.

Figure 2.26 "Slip–No Compensation" Synchronism-Check Element Output Response

Positive Slip Frequency

If the slip frequency is positive, V_{S1} is slipping ahead of reference V_P (the system corresponding to V_{S1} has a higher system frequency than the system corresponding to V_P; $f_{S1} > f_P$). Positive slip frequency is the counter-clockwise rotation of V_{S1} with respect to reference V_P, as shown in *Figure 2.26*. Relay Word bit FAST1 asserts to logical 1 (and Relay Word bit SLOW1 deasserts to logical 0) to indicate this condition.

Negative Slip Frequency

If the slip frequency is negative, V_{S1} is slipping behind reference V_P (the system corresponding to V_{S1} has a lower system frequency than the system corresponding to V_P; $f_{S1} < f_P$). For such a case, V_{S1} rotates clockwise with respect to reference V_P. Relay Word bit SLOW1 asserts to logical 1 (and Relay Word bit FAST1 deasserts to logical 0) to indicate this condition.

"No-Slip" Condition

If the absolute value of the slip is less than 0.005 Hz ($|f_{S1}–f_P| < 0.005$ Hz; a "no-slip" condition), both Relay Word bits FAST1 and SLOW1 deassert to logical 0 and Relay Word bit SFZBK1 asserts to logical 1. A "no-slip" condition is confirmed when FAST1 and SLOW1 are deasserted, and SFZBK1 is asserted.

Synchronism-Check Element Output Effects

Compare the corresponding "slip—no compensation" cases in *Figure 2.26* to the previous "no-slip" cases in *Figure 2.25*. Note that synchronism-check element outputs 25W1BK1 and 25A1BK1 operate identically in all cases of the "slip—no compensation" examples in *Figure 2.26* (both assert to logical 1 or deassert to logical 0). The condition of "no slip" or "slip—no compensation" does not affect the operation of element outputs 25W1BK1 and 25A1BK1 in the scenarios depicted in *Figure 2.25* and *Figure 2.26*.

The similarity of element outputs 25W1BK1 and 25A1BK1 for the "no slip" condition (*Figure 2.25*) and the "slip—no compensation" (*Figure 2.26*) condition results from the maximum slip frequency setting 25SFBK1 := OFF. Setting 25SFBK1 has no effect in a "no slip" scenario (*Figure 2.25*), but the setting does affect the operation of synchronism-check element output 25A1BK1 (see the "slip—no compensation" scenario, *Figure 2.26*).

With setting 25SFBK1 := OFF, the relay does not compensate for the further angular travel of V_{S1} (with respect to reference V_P) during the Circuit Breaker BK1 close time setting TCLSBK1. The relay measures the phase angle directly with no compensation between reference V_P and V_{S1} for synchronism-check element output 25A1BK1.

The relay always measures the phase angle directly (without compensation) between reference V_P and V_{S1} for element output 25W1BK1. Setting 25SFBK1, time setting TCLSBK1, and whether system conditions are "no slip" (*Figure 2.25*) (see the "slip—no compensation" in *Figure 2.26*) have no effect on element output 25W1BK1.

"Slip—With Compensation" Synchronism Check

Figure 2.27 is derived from *Figure 2.26*, but with the maximum slip frequency setting 25SFBK1 set to some value other than OFF; thus the SEL-451 compensates for circuit breaker closing time with setting TCLSBK1. This results in a compensated normalized synchronism-check voltage source V'_{S1}

Synchronism-check element output 25W1BK1 in *Figure 2.27* operates the same as in *Figure 2.26*. Element output 25W1BK1 is unaffected by relay settings 25SFBK1 and TCLSBK1, and by whether system conditions are slipping. Element 25W1BK1 follows normalized synchronism-check voltage source V_{S1}.

Figure 2.27 "Slip–With Compensation" Synchronism-Check Element Output Response

Element 25A1BK1 follows V'_{S1}. With setting 25SFBK1 (maximum slip frequency) set to other than OFF, the relay calculates V'_{S1} derived from V_{S1}. Phasor V'_{S1} leads V_{S1} by an angle described by *Equation 2.3*:

$$\text{angle} = \frac{(f_{S1} - f_P)\ \text{slip cycle}}{\text{s} \bullet \dfrac{60\ \text{cyc}}{\text{s}}} \bullet \frac{360°}{\text{slip cycle}} \bullet \text{TCLSBK1 (cyc)}$$

Equation 2.3

From *Equation 2.3* note that the angle between V_{S1} and V'_{S1} increases for a greater slip between V_{S1} and V_P (f_{S1}–f_P), a greater Circuit Breaker BK1 close time setting TCLSBK1, or both in combination.

For any case [(a), (b), (c), or (d)] in *Figure 2.27*, the location of V'_{S1} is the location of V_{S1} a period later (this period is setting TCLSBK1, Circuit Breaker BK1 Close Time). Consider, for example, issuing a close command to

Circuit Breaker BK1. If case (b) in *Figure 2.27* represents the time at which the close command occurs, then V_{S1} is the normalized synchronism-check voltage source position at the instant the close is issued and V'_{S1} is the position of V_{S1} when Circuit Breaker BK1 actually closes.

Slip Frequency

If the slip frequency exceeds setting 25SFBK1, synchronism check cannot proceed via element output 25A1BK1. Synchronism check stops because element output 25A1BK1 deasserts to logical 0 for an out-of-range slip frequency condition, regardless of other synchronism-check conditions such as healthy voltage magnitudes.

Synchronism check remains possible (although not necessarily advantageous) if you use element output 25W1BK1 and the slip frequency exceeds setting 25SFBK1. Synchronism-check element 25W1BK1 does not measure slip. In this instance, synchronism check occurs (25W1BK1 is logical 1) when the phase angle difference between reference V_P and V_{S1} is less than angle setting ANG1BK1.

Synchronism-Check Element Output Effects

A contradiction seems to result from analysis of case (a) in *Figure 2.27*; it appears that element output 25A1BK1 should assert to logical 1 because V'_{S1} is within angle setting ANG1BK1. Note in this case, however, that V'_{S1} is approaching synchronism-check reference V_P. This is where element output 25A1BK1 behaves differently than element output 25W1BK1, for setting 25SFBK1 set to some value other than OFF. As V'_{S1} approaches V_P, 25A1BK1 remains deasserted (equals logical 0) until the phase angle difference between reference V_P and V'_{S1} equals zero degrees.

At this zero degrees difference between V_P and V'_{S1} point, element output 25A1BK1 asserts to logical 1. We know the systems will truly be in synchronism (0 degrees between reference V_P and V_{S1}) a period later (this period is setting TCLSBK1, Circuit Breaker BK1 Close Time). Thus, if a close command occurs right at the instant that element output 25A1BK1 asserts to logical 1, then there will be a zero degree phase angle difference across Circuit Breaker BK1 when Circuit Breaker BK1 actually closes. Closing Circuit Breaker BK1 at a phase angle difference of 0 degrees between reference V_P and V'_{S1} minimizes system shock when you bring two asynchronous systems together.

Element output 25A1BK1 remains asserted to logical 1 as V'_{S1} moves away from reference V_P. When the phase angle difference between reference V_P and V'_{S1} is again greater than angle setting ANG1BK1, element output 25A1BK1 deasserts to logical 0.

Alternative Synchronism-Check Source 2 Settings

You can program alternative input sources for the synchronism-check function in the SEL-451. Alternative inputs give you additional flexibility to synchronize other portions of your power system.

The SELOGIC control equation ALTS2 determines when the relay uses alternate Synchronism-Check Voltage Source 2 in place of regular Synchronism-Check Voltage Source 2. When ALTS2 is logical 1, the relay substitutes alternative Synchronism-Check Voltage Source 2 (ASYNCS2) and corresponding settings AKS2M and AKS2A for the regular Synchronism-Check Voltage Source 2 values SYNCS2, KS2M, and KS2A. The result is a normalized synchronism-check voltage source V_{S2} derived from the alternative source.

EXAMPLE 2.1 Setting Alternative Synchronism-Check Source 2

Figure 2.28 shows an extra circuit breaker (BK3) and a generator position added to the existing example system of Figure 2.17. You can monitor the voltage at the generator position by connecting a single-phase voltage to remaining voltage input VCZ (see Figure 2.20). Make setting ASYNCS2 := VCZ to designate this relay voltage input as the alternate synchronism-check voltage source.

ASYNCS2 := **VCZ** Alternative Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)

For this new synchronism source voltage connection, adjust the source-to-reference magnitude ratio with setting AKS2M and the source-to-reference angle compensation with setting AKS2A, considering the settings for Voltage Magnitude and Angle Compensation on page R.2.40.

Figure 2.28 Alternative Synchronism-Check Source 2 Example and Settings

For example, in Figure 2.28, the Bus 2 voltage is the regular Synchronism-Check Voltage Source 2 for synchronism check across Circuit Breaker BK2. However, if Circuit Breaker BK3 is open and the generator switch is closed, the Synchronism-Check Voltage Source 2 transfers to the alternative Synchronism-Check Voltage Source 2 the voltage from the generator position.

For circuit breaker status, make the following 52A auxiliary contact connections from the circuit breaker and switch to control inputs on the SEL-451:

- Circuit breaker BK3 to IN103
- Generator switch to IN104

These input connections are for this application example only; use relay inputs that are appropriate for your system.

Set the ALTS2 SELOGIC control equation to assert when Circuit Breaker BK3 is open and the generator switch is closed.

ALTS2 := **NOT IN103 AND IN104** Alternative Synchronism Source 2 (SELOGIC Equation)

Section 3

SELOGIC Control Equations

This section describes use of SELOGIC® control equations and programming to customize relay operation and automate substations. This section covers the following topics:

- *SELOGIC Control Equation History on page R.3.1*
- *Separation of Protection and Automation Areas on page R.3.2*
- *SELOGIC Control Equation Programming on page R.3.3*
- *SELOGIC Control Equation Setting Structure on page R.3.6*
- *Multiple Setting Groups on page R.3.8*
- *SELOGIC Control Equation Capacity on page R.3.10*
- *SELOGIC Control Equation Elements on page R.3.11*
- *SELOGIC Control Equation Operators on page R.3.25*
- *Effective Programming on page R.3.36*
- *SEL-311 and SEL-351 Series Users on page R.3.38*

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-451 Relay provide both protection application flexibility and a platform for substation automation.

SELOGIC control equation programming in the SEL-451 includes several features and capabilities not included in SEL-300 series relays. The new features with a brief description are listed in *Table 3.1*.

Table 3.1 Advanced SEL-451 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 timing and controlling noncontinuous operations
Counters	Incrementing and decrementing counters for increased sophistication in custom protection and automation programming
Aliases	Custom programming is more readable when you rename as many as 200 analog or digital quantities

Use SELOGIC control equations in the SEL-451 to customize protection operation, create custom protection elements, and automate substation operation. The SEL-451 introduces several advanced programming features, operators, and methods. *Table 3.2* is a summary that compares SELOGIC control equation programming in SEL-351 series relays and SEL-311 series relays with the SEL-451.

Table 3.2 SEL-451 SELOGIC Control Equation Programming Summary

Element	SEL-351 Series/ SEL-311 Series	SEL-451	
		Protection Free Form	Automation Free Form
SELOGIC control equation variables	16	64	256
SELOGIC math variables	0	64	256
Conditioning timers[a]	16	32	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-451 acts as a protective relay and as a smart 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 capacitor bank control system or 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-451 contains several separate programming areas discussed in *SELOGIC Control Equation Setting Structure on page R.3.6*. 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.

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 relay outputs to control substation equipment. Separation of protection and automation storage areas is illustrated in *Figure 3.1*.

Figure 3.1 Protection and Automation Separation

Figure 3.1 illustrates how the SEL-451 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-451 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 in which 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-451 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 3.1*.

EXAMPLE 3.1 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 the 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 program steps sequentially so that the relay will perform steps in the order that you specify. You can refer to storage locations multiple times and build up intermediate results in successive equations. You can also enter entire line comments 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 3.2*.

EXAMPLE 3.2 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 12kV

PMV01 := **VAFM * 0.8** # 80% of A-phase fundamental voltage

PSV04 := **PMV01 >= 12000** # 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.

There are two basic types of assignment statements that form SELOGIC control equations. In the first type, Boolean SELOGIC control equations, the SEL-451 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 * BK1IAFM to store the product of 5 and the Circuit Breaker 1 A-phase current in automation math variable 34. *Example 3.3* lists several examples of Boolean and math SELOGIC control equations.

EXAMPLE 3.3 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 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 * VAFM # Store the product of A-phase 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-451. You can use comments liberally; comments do not reduce SELOGIC control equation execution capacity.

SELOGIC Control Equation Setting Structure

The SEL-451 uses SELOGIC control equations in three major areas. First, you can customize protection operations with SELOGIC control equation settings and free-form programming. Second, there is a free-form programming area for more sophisticated automation SELOGIC control equation programming. Third, there is a fixed area for relay output programming. The SELOGIC control equation programming areas are shown in *Figure 3.2*. There are also a small number of fixed SELOGIC control equations in other settings areas including front-panel settings that allow you to customize relay features not directly related to protection or automation.

Figure 3.2 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 (for example TR) with fixed SELOGIC control equation programming. Use these settings to control protection operation and customize relay operation. The programming and operation 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 9: ASCII Command Reference*. You can also copy group settings and perform copy-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.

All of the SELOGIC control equation programming in the protection area executes at the same deterministic interval as the protection algorithms. Because of this type of programming execution, you can use protection free-form and fixed programming to extend and customize protection operation.

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.

The SEL-451 dedicates a minimum processing time when executing automation SELOGIC control equations. If the processing load is light, the relay uses more processing time for executing automation programming. This means that the overall execution time fluctuates. You can display the average and peak execution time with the **STATUS S ASCII** command. Use the **STATUS SC** command to reset the peak execution time.

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.

Perform time-critical tasks with protection free-form SELOGIC control equations. For example, if you require a SELOGIC control equation for TR (trip) that contains more than 15 elements, you must perform that calculation in several steps. Because detection of a TR condition is a time-critical activity, perform the calculation with protection free-form SELOGIC control equations and set TR to the protection 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-451 has six (6) independent setting groups, as shown in the left-hand side of *Figure 3.2*. Each setting group has complete relay settings (distance, directional, overcurrent, reclosing, etc.—see *SHO on page R.9.50*) and protection SELOGIC settings (see *SHO L on page R.9.52*). The active setting group can be:

- Shown or selected with the SEL ASCII serial port **GROUP** command—see *GROUP on page R.9.25*.
- Shown or selected with the `MAIN` menu `Set/Show` menu item and the `Active Group` submenu item as described in *Figure 5.35 on page U.5.32*.
- 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.5.8*.
- Shown with DNP3 Objects 20 and 22 as described in *Table 6.10* and selected with Objects 40 and 41.

Setting 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 3.3*.

Table 3.3 Definitions for Active Setting Group Indication Relay Word Bits SG1 Through SG6

Relay Word Bit	Definition
CHSG	Indication that a group switch timer 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 3.4*.

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 3.4 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 with 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 timer is picked-up and timing, and also when a setting group change has been initiated.

Active Setting Group Changes

The SEL-451 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. See *Table 5.4*.

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.

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-451 provides storage space for as many as 250 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 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. Only one protection settings group can be active. When a protection settings group is active, the relay executes SELOGIC control equations in the Global 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-451 provides storage space for 10 blocks of as many as 100 lines of automation free-form programming each. 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-451 and use the relay to automate substation operation. The elements that you can use in SELOGIC control equations are summarized in *Table 3.5*.

Table 3.5 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-451. Analog quantities are analog values within the relay including measured and calculated values. *Appendix B: Analog Quantities in the Reference Manual* contains a list of analog quantities available within the SEL-451.

Special Condition Bits

Several Relay Word bits are available for special conditions related to SELOGIC control equation programming in the SEL-451. 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 3.6*.

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 3.6*, *Table 3.7*, and *Table 3.8*. 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 3.6 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 3.7 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 3.8 First Execution Bit Operation on Protection Settings Change, Group Switch, and Source Selection

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, respectively, when you evaluate Boolean logic statements. The quantities of SELOGIC control equation variables available in the different programming areas are listed in *Table 3.9*.

Table 3.9 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 3.4* illustrates SELOGIC control equation variable usage. You can view the results of protection and automation math variables using the **METER** command. Use the **MET PMV** command to see the last 16 protection math variables (PMV49–PMV64). Use the **MET PMV A** command to see all of the protection math variable results (PMV01–PMV64). Likewise, use the **MET AMV** command to see the last 16 automation math variable results (AMV241–AMV256) and the **MET AMV A** command to see all 256 automation math variable results.

EXAMPLE 3.4 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-451 are shown in *Table 3.10*.

Table 3.10 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 3.5* illustrates SELOGIC control equation math variable usage.

EXAMPLE 3.5 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 + VAFM** # Store sum of 5 and A-phase 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

A-phase

AMV010 := **VAFIM/1000** # VA in kV

ASV010 := **AMV010 > 13** # Set if greater than 13 kV

B-phase

AMV010 := **VBFIM/1000** # VB in kV

ASV011 := **AMV010 > 13** # Set if greater than 13 kV
C-phase
AMV010 := **VCFIM/1000** # VC 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 3.11*. Latch bits have two input parameters, Reset and Set, and one Latched Value, as shown in *Table 3.12*.

Table 3.11 Latch Bit Quantities

Type	Quantity	Name Range
Protection free-form latch bits	32	PLT01–PLT32
Automation latch bits	32	ALT01–ALT32

Table 3.12 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-451. 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. You can view the status of individual latch bits in the Relay Word using the **TARGET** command. Use the **TAR PLT*nn*** command or the **TAR ALT*nn*** command to view the Relay Word row containing the protection or automation latch bit specified by the two-digit number *nn*. You can also view the status of latch bits through the SEL-451 LCD front-panel display by selecting `RELAY ELEMENTS` from the Main Menu and scrolling through the rows of Relay Word bits.

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 settings group. 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 on IN107 when Protection Settings Group 1 is active and program the latch to set on IN106 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 3.6* illustrates protection latch bit usage.

EXAMPLE 3.6 Protection Latch Bits

This example studies the factory settings for the HOT LINE TAG operator control logic. Protection Latch Bit 4 (PLT04) is used as a close enable signal, which is deasserted during Hot Line Tag conditions. When the HOT LINE TAG operator control is pressed, Relay Word bit PB5_PUL pulses for one processing interval, and one of two actions will occur, depending on the previous state of PLT04:

- If PLT04 was previously asserted, the PB5_PUL is ANDed with PLT04 in the PLT04R SELogic equation, causing PLT04 to deassert. In this state, closing is blocked.
- If PLT04 was previously deasserted, the PB5_PUL is ANDed with NOT PLT04 in the PLT04S SELogic equation, causing PLT04 to assert. In this state, closing is permitted.

The settings below are duplicated in the Protection SELogic control equation free-form programming areas corresponding to each of 6 setting groups:

```
# Store HOT LINE TAG state in PLT04, controlled by front panel pushbutton
#
PLT04S := PB5_PUL AND NOT PLT04
PLT04R := PB5_PUL AND PLT04 # HOT LINE TAG (WHEN PLT04 DEASSERTED)
#
# PLT04 defeats the RECLOSE ENABLED operator control function
PLT02R := PB2_PUL AND PLT02 OR NOT PLT04 # HOT LINE TAG DISABLES RECLOSE
```

In the factory settings for PLT04S and PLT04R, rising edge operators are not required because Relay Word bit PB5_PUL only asserts for one processing interval. If the application required control input IN103 to set or clear the Hot Line Tag function in addition to the operator control pushbutton, the settings would look like this:

PLT04S := (PB5_PUL OR R_TRIG IN103) AND NOT PLT04

PLT04R := (PB5_PUL OR R_TRIG IN103) AND PLT04 # HOT LINE TAG (WHEN PLT04 DEASSERTED)

If the R_TRIG operators were not present, Protection Latch Bit 4 (PLT04) would oscillate whenever IN103 was asserted, and the final state after IN103 deasserts would be indeterminate. To prevent contact bounce sensed by Control Input IN103 from triggering multiple rising edges, make appropriate debounce time settings—see Control Input Assignment on page U.4.67 for debounce timer information and an example.

Protection Latch Bit 4 (PLT04) appears in the factory settings for several SELOGIC control equations in the SEL-451:

- In the Protection SELogic control equation free-form programming area, PLT04 defeats the RECLOSE ENABLED operator control function

  PLT02R := PB2_PUL AND PLT02 OR **NOT PLT04** # HOT LINE TAG DISABLES RECLOSE

- In the front-panel settings, PB5_LED follows the inverted state of PLT04:

  PB5_LED := **NOT PLT04** #HOT LINE TAG

- In group settings, PLT04 supervises close and reclose conditions:
  - Auto-reclose enable

    E3PR1 := PLT02 **AND PLT04**
  - Auto-reclose drive-to-lockout

    79DTL := NOT (PLT02 **AND PLT04**) AND (3PT OR NOT 52AA1)
  - Manual close

    BK1MCL := (CC1 OR PB7_PUL) **AND PLT04**

The above settings allow the **HOT LINE TAG** operator control pushbutton to enable or disable close operations in the SEL-451. Any changes to these factory settings should be carefully designed and tested to ensure proper operation.

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 automation free-form area dominates, and the relay uses this equation to evaluate the latch.

Conditioning Timers

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 3.13*. Conditioning timers have the three input parameters and one output shown in *Table 3.14*.

Table 3.13 Conditioning Timer Quantities

Type	Quantity	Name Range
Protection free-form conditioning timers	32	PCT01–PCT32

Table 3.14 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 3.3*. 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 3.3 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 3.4*. If the input reasserts again, one or more processing cycles later, the conditioning timer pickup timer begins timing again from zero.

Figure 3.4 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 3.5*. 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. If the input reasserts before the dropout time expires, the dropout timer resets so it begins timing again from zero when the input drops out again.

Figure 3.5 Conditioning Timer With Dropout and No Pickup Timing Diagram

Combining the features shown above, *Figure 3.6* 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 3.6 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-451, the protection processing interval is 1/8 cycle (or 0.125 cycles). Actual settings, programming, and operation are illustrated in *Example 3.7*.

EXAMPLE 3.7 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 3.7. Because the pickup setting is an uneven number of protection processing intervals (1/8 cycle), the pickup occurs on the first 1/8th cycle after the Pickup Time of 5.3 cycles expires.

Figure 3.7 Conditioning Timer Timing Diagram for Example 3.7

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 3.7*. You can view the status of the protection conditioning timer output Relay Word bits using the **TAR PCT*nn*Q** command, where *nn* is the number of the protection conditioning timer. You can also view the status of these timer elements through the SEL-451 front-panel LCD display by selecting `RELAY ELEMENTS` from the Main Menu and scrolling through the rows of Relay Word bits.

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 3.15*. Sequencing timers have three input parameters and two outputs listed in *Table 3.16*.

Table 3.15 Sequencing Timer Quantities

Type	Quantity	Name Range
Protection free-form sequencing timers	32	PST01–PST32
Automation free-form sequencing timers	32	AST01–AST32

Table 3.16 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 3.8 is a timing diagram for typical sequencing timer operation.

Figure 3.8 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 1/8 cycle, so the relay effectively rounds up all operation to the nearest 0.125 cycles. 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 accuracy of the timer in stopping and starting when the input of the timer turns on averages half an automation execution cycle. If you change automation free-form programming, you must also check the new automation average execution cycle to verify that you will obtain satisfactory accuracy for your application. *Example 3.8* describes typical timer programming and describes the resulting operation.

EXAMPLE 3.8 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 3.8*. You can view the current state of the timer by assigning the elapsed time output of the sequencing timer to a math variable. *Example 3.8* shows how you would assign the elapsed time output for automation sequence timer AST01 to automation math variable AMV256. To see the elapsed time value, issue the **MET AMV** command to display the values of the last 16 automation math variables. Likewise, you can assign the elapsed time output of a protection sequence timer to a protection math variable.

The elapsed time output is stored in volatile memory. Elapsed time resets to zero for both protection and automation sequential timers when relay power cycles, you change settings or settings groups, or you perform any function that reboots the relay.

Counters

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 3.17*. Counters have three input parameters, Input, Preset Value, and Reset; and two outputs, Current Value and Output as listed in *Table 3.18*.

Table 3.17 Counter Quantities

Type	Quantity	Name Range
Protection counters	32	PCN01–PCN32
Automation counters	32	ACN01–ACN32

Table 3.18 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 3.9*. You can view the current value of the counter by assigning the protection counter current value, PCV*nn*CV, to a protection math variable or by assigning the automation counter current value, ACV*nn*CV, to an automation math variable. View the math variable values by issuing the appropriate **MET PMV** or **MET AMV** commands.

The current value count is stored in volatile memory. Elapsed time resets to zero for both protection and automation sequential timers when relay power cycles, you change settings or settings groups, or you perform any function that reboots the relay.

EXAMPLE 3.9 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 52AA1 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 52AA1 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 a circuit breaker closes
# The counter automatically resets every 1,000 operations
PCN01PV := 1000
PCN01R := PCN01Q
PCN01IN := 52AA1
```

The SELOGIC control equations below provide multiple-change detection counting both close and open operations of the circuit breaker. The intermediate value PSV01 turns on for one processing interval each time the circuit breaker closes. The intermediate value PSV02 turns on for one processing interval each time the circuit breaker opens. The OR combination of PSV01 and PSV02 contains a rising edge for each circuit breaker operation, open or closed, that Protection Counter 1 counts.

```
# Example protection counter programming
#
# This example counts how many times a circuit breaker operates either
open or closed
#
# Detect OPEN and CLOSE and combine
PSV01 := R_TRIG 52AA1 # Pulse for each close
PSV02 := F_TRIG 52AA1 # Pulse for each open
PSV03 := PSV01 OR PSV02 # Pulse for each open or close
#
```

The counter automatically resets every 1,000 operations

PCN01PV := **1000**

PCN01R := **PCN01Q**

PCN01IN := **PSV03** # Count open and close operations

PSV04 := **PCN01CV >900** # PSV04 signals impending reset

Aliases

Although the SEL-451 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 3.10* provides examples of assigning aliases.

EXAMPLE 3.10 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 as many as 200 alias names to any Relay Word bit or analog quantity, 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 or analog quantity 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 or analog quantity. 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 (52AA1, 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-451 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 3.19*.

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 3.20* contains a summary of Boolean operators available in the SEL-451.

Table 3.19 Operator Precedence From Highest to Lowest

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
<, >, <=, >=	Comparison
=	Equality
<>	Inequality
AND	Boolean AND
OR	Boolean OR

Table 3.20 Boolean Operator Summary

Operator	Description
( )	Parentheses
NOT	Logical inverse
AND	Logical AND
OR	Logical OR
R_TRIG	Rising-edge trigger
F_TRIG	Falling-edge trigger
>, <, =, <=, >=, <>	Comparison of values

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 3.21* is a truth table for an example operation that illustrates how parentheses can affect equation evaluation.

Table 3.21 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

NOT

Use NOT to calculate the inverse of a Boolean value according to the truth table shown in *Table 3.22*.

Table 3.22 NOT Operator Truth Table

Value A	NOT A
0	1
1	0

AND

Use AND to combine two Boolean values according to the truth table shown in *Table 3.23*.

Table 3.23 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

OR

Use OR to combine two Boolean values according to the truth table shown in *Table 3.24*.

Table 3.24 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	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 3.9*. Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only once when the value changes. The R_TRIG output is a pulse of one protection processing cycle duration (1/8th cycle). This rising-edge pulse output asserts one processing interval after the monitored element asserts.

Pulse outputs should not be used in automation logic because the short duration of the pulse may be missed during the longer automation processing interval.

Figure 3.9 R_TRIG Timing Diagram

The argument of an R_TRIG statement must be a single bit within the SEL-451. An example of the relay detecting a rising edge of a calculated quantity is shown in *Example 3.11*.

EXAMPLE 3.11 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 *Example 3.11*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state. The F_TRIG output is a pulse of one protection processing cycle duration (1/8th cycle). This pulse output asserts one processing interval after the monitored element deasserts.

Pulse outputs should not be used in automation logic because the short duration of the pulse may be missed during the longer automation processing interval.

Figure 3.10 F_TRIG Timing Diagram

The argument of an F_TRIG statement must be a single bit within the SEL-451. An example of the relay detecting a falling edge of a calculated quantity is shown in *Example 3.12*.

EXAMPLE 3.12 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

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 3.25*.

Table 3.25 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 and provide a numerical base 10 result. *Table 3.26* summarizes the operators available for math SELOGIC control equations.

Table 3.26 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. Include as many as 14 levels of nested parentheses in your math SELOGIC control equation. *Example 3.13* shows how parentheses affect the operation and evaluation of math operations.

EXAMPLE 3.13 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-451 turns on the math error bit, MATHERR, in the Relay Word. A settings change or the **STATUS SC** command resets 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 3.27 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 expression results in an error and prevents storage of 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-451 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 3.14* contains examples of arithmetic operations in use.

EXAMPLE 3.14 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.3.32*. *Example 3.15* shows examples of the SQRT operator in use.

EXAMPLE 3.15 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 on page R.3.32*. EXP calculates the value of e raised to the power of the argument. *Example 3.16* shows examples of expressions that use the LN, EXP, and LOG operators. Use parentheses to delimit the argument of a LN, EXP, or LOG operation.

EXAMPLE 3.16 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-451 uses to express metering quantities. *Example 3.17* shows examples of SIN and COS. Use parentheses to delimit the argument of a SIN or COS operation.

EXAMPLE 3.17 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 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 on page R.3.32*. *Example 3.18* shows examples of ASIN and ACOS. Use parentheses to delimit the argument of an ASIN or ACOS operation.

EXAMPLE 3.18 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 3.19* contains examples of the ABS operator in use.

EXAMPLE 3.19 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 positive infinity. Use parentheses to group a math expression as the argument of a CEIL operation. *Example 3.20* contains examples of the CEIL operator.

EXAMPLE 3.20 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 3.21* contains examples of the FLOOR operator.

EXAMPLE 3.21 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 3.22* contains examples of expressions that utilize the negation operator.

EXAMPLE 3.22 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-451 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 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-451. 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 3.23* shows how to use comments to divide and structure free-form SELOGIC control equation programming.

EXAMPLE 3.23 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. To see all of the values stored in the protection and automation math variables, use the **MET PMV A** and **MET AMV A** commands, respectively.

SEL-311 and SEL-351 Series Users

You can convert logic that you have used in SEL-311 and SEL-351 series relays to logic for the SEL-451. In the SEL-351 series relays, SELOGIC control equation programming is restricted to equations where the left side value, LVALUE, is fixed. The SEL-451 uses a combination of fixed and free-form programming. *Table 3.28* shows comparable features between the fixed logic settings of the SEL-351-5, -6, -7 series relays and the corresponding logic elements that can be programmed in the SEL-451 using free-form logic programming.

Table 3.28 SEL-351 Series Relays and SEL-451 SELOGIC Control Equation Programming Equivalent Functions

Feature	SEL-351 Series	SEL-451 Protection Free-Form Style
SELOGIC control equation variables	SV1–SV16	PSV01–PSV64
Timer Input	SV1–SV16	PCT01–PCT32
Timer Pickup settings	SV1PU–SV16PU	PCT01PU–PCT32PU
Timer Dropout settings	SV1DO–SV16DO	PCT01DO–PCT32DO
Timer Outputs	SV1T–SV16T	PCT01Q–PCT32Q
Latch Bit Set Control	SET1–SET16	PLT01S–PLT16S
Latch Bit Reset Control	RST1–RST16	PLT01R–PLT16R
Latch Bit	LT1–LT16	PLT01–PLT16

Table 3.29 shows the SEL-451 Boolean operators compared to the operators used in the SEL-351 series relays.

Table 3.29 SEL-351 Series Relays and SEL-451 SELOGIC Control Equation Boolean Operators

Feature	SEL-351 Series	SEL-451
Logical AND operator	*	AND
Logical OR operator	+	OR
Logical NOT operator	!	NOT
Parentheses	( )	( )
Rising, falling edge operators	/, \	R_TRIG, F_TRIG

In the SEL-351 series relays, SELOGIC control equation variables and timers are connected. Each SELOGIC control equation variable is the input to a timer. In the SEL-451, timers and SELOGIC control equation variables are independent.

The SELOGIC control equation Boolean operators in the SEL-451 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-451, you must convert the operators. *Example 3.24* and *Example 3.25* demonstrate conversion of several settings to the SEL-451 setting.

EXAMPLE 3.24 Converting SEL-351 Series Relay SELOGIC Control Equation Variables

If you have the following SELOGIC control equation in an SEL-351 series relay, convert it as shown below.

```
SV1 = IN101 + RB3 * LT4
```

In the SEL-451, use the line shown below.

PSV01 := **IN101 OR RB03 AND PLT04** # Free-form example .

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. In the protection group settings example, use the input of a timer, as shown in Table 3.25.

EXAMPLE 3.25 Converting SEL-351 Series Relay SELOGIC Control Equation Timers

If you have the following SELOGIC control equation timer in an SEL-351 series relay, convert it as shown below.

```
SV1 = IN101

SV1PU = 5.25

SV1DO = 3.50
OUT101 = SV1T
```

In the SEL-451, 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 3.26 Converting SEL-351 Series Relay Latch Bits

If you have the following SELOGIC control equation latch programming in an SEL-351 series relay, convert it as shown below.

```
SET1 = RB4

RST1 = RB5

OUT101 = LT1
```

In the SEL-451, 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 4

Communications Interfaces

This section provides information on communications interface options for the SEL-451 Relay. The following topics are discussed:

- *Communications Interfaces on page R.4.1*
- *Serial Communication on page R.4.2*
- *Communications Card on page R.4.4*

Communications Interfaces

The SEL-451 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 event reports. You must enter settings to configure the SEL-451 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-451 has three rear-panel serial ports and one front-panel serial port. These serial ports conform to the EIA/TIA-232 standard (often called RS-232). Several optional SEL devices are available to provide alternative physical interfaces, including EIA-485 and fiber-optic cable. The relay also has a communications card slot for additional optional communications interfaces 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-451, see the instruction manual sections listed in *Table 4.1*.

Table 4.1 SEL-451 Communications Protocols (Sheet 1 of 2)

Communications Protocol	Communications Interface	For More Information See
DNP3 (serial)	EIA-232[a]	*Section 6: DNP3 Communications*
DNP3 (Ethernet)	Ethernet card	*Section 6: DNP3 Communications*
Distributed Port Switch (LMD)	SEL-2885 EIA-232 to EIA-485 transceiver on an EIA-232 port	*Section 5: SEL Communications Protocols*
SEL Binary Protocols (Fast Meter, Fast Operate, Fast SER)	EIA-232[a] or Telnet using Ethernet card	*Section 5: SEL Communications Protocols*

NOTE: Fast SER is not supported over Ethernet in SEL-451 model relays with SEL-2701/SEL-2702 Ethernet cards.

Table 4.1 SEL-451 Communications Protocols (Sheet 2 of 2)

Communications Protocol	Communications Interface	For More Information See
SEL Fast Message RTD protocol	EIA-232[a]	*Section 5: SEL Communications Protocols*
MIRRORED BITS® communications	EIA-232[a]	*Section 5: SEL Communications Protocols*
Phasor Measurement Protocols (C37.118 and SEL Fast Message)	EIA-232[a] Ethernet card[b]	*Section 7: Synchrophasors*
ASCII Commands	EIA-232 or Telnet using Ethernet card	*Section 9: ASCII Command Reference*

[a] You can add converters to transform EIA-232 to other physical interfaces.
[b] Phasor Measurement over the ethernet card is only C37.118 protocol.

Section 6: SEL Communications Processor Applications in the Applications Handbook and *Section 7: Direct Network Communications in the Applications Handbook* include more information on communication topologies and protocols.

Serial Communication

Each SEL-451 has four serial ports that you can use for serial communication with other devices. While these ports are all EIA-232, you can add transceivers or converters to operate on different physical media including EIA-485 and fiber-optic cable.

EIA-232

The SEL-451 has four EIA-232 communications interfaces. The serial port locations for the 3U chassis are shown in *Figure 4.1* and *Figure 4.2*; other chassis sizes are similar. The port on the front panel is PORT F and the three rear-panel ports are PORT 1, PORT 2, and PORT 3.

Figure 4.1 SEL-451 3U Chassis Front-Panel Layout

Figure 4.2 SEL-451 3U Rear-Panel Layout

The EIA-232 ports are standard female 9-pin connectors with the pin numbering shown in *Figure 4.3*. The pin functions are listed in *Table 4.2*. See the manual section listed in *Table 4.1* 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.2.21* for more information on installing the jumper to provide voltage on Pin 1.

Figure 4.3 EIA-232 Connector Pin Numbers

Table 4.2 EIA-232 Pin Assignments

Pin	Signal Name	Description	Comments
1	5 Vdc	Modem or EIA-232 to EIA-485 transceiver power	Jumper selectable on PORT1–PORT 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 PORT F, PORT 2, and PORT 3.
5	GND	Signal ground	Also connected to chassis ground.
6	–IRIG-B	Time code signal negative	PORT 1 only. No connection on PORT F, PORT 2, and PORT 3.
7	RTS	Request to send	
8	CTS	Clear to send (input)	
8	TX/RX CLK (for SPEED := SYNC, only available when PROTO := MBA or MBB)	Transmit and receive clock (input)	Rear-panel serial ports only
9	GND	Chassis ground	

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. 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, please 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 the SEL cable C234A for relay configuration and programming with a terminal program or with the ACSELERATOR QuickSet® SEL-5030 Software. See *Figure 2.44 on page U.2.47* for the construction of SEL cable C234A.

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.

Use the SEL-2800 product family transceivers for multimode or single-mode fiber-optic communications. 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.

EIA-485

There is no EIA-485 port integral to the SEL-451. You can install an SEL-2885 or SEL-2886 transceiver to convert one of the rear-panel EIA-232 ports (**PORT 1**, **PORT 2**, or **PORT 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 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 5: SEL Communications Protocols in the Reference Manual*.

Communications Card

PORT 5 of the SEL-451 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-451. 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 *SEL Communications Processor Applications on page A.6.1*, *Direct Network Communications on page A.7.1*, *Section 6: DNP3 Communications in the Reference Manual*, and *Section 8: IEC 61850 Communications in the Reference Manual*.

Once installed in an SEL-451, 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-451 with the optional Ethernet card operates on an Ethernet network. These settings include IP addressing information, network port fail-over options, and network speeds.

Network Configuration

Use the network configuration settings shown in *Table 4.3* to configure the SEL-451 for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation.

Table 4.3 Ethernet Card Network Configuration Settings

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
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-451 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-451 uses the DEFRTR address setting to determine how to communicate with nodes on other local networks. The SEL-451 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-451 or the SEL-451 will reject the DEFRTR setting. You must also coordinate the default router with your general network implementation and administration plan. See *Table 4.4* for examples of how IPADDR and SUBNETM define the network and node and how these settings affect the DEFRTR setting.

Table 4.4 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	192.92a[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-451 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-451 does not transmit any TCP data within the interval specified by the KAIDLE setting, the SEL-451 sends a keep-alive packet to the remote computer. If the SEL-451 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-451 remote device is no longer available, so the SEL-451 can terminate the connection without waiting for the idle timer (TIDLE or FTPIDLE) to expire.

The SEL-451 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-451 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-451 Ethernet card can resolve 20 network host names to corresponding IP addresses. Settings for Network Address Resolution (NAR) are shown in *Table 4.5*. 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 4.5 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

Data Access Settings

Access data using either the standard TCP/IP Telnet and FTP interfaces or, optionally, through the DNP3 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-451 Ethernet card operates as an FTP server. It presents Ethernet card and host files to FTP clients. The SEL-451 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 4.6*.

Table 4.6 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 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-451
- 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-451 configuration information

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 4.7* 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 4.7 Ethernet Card 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 4.8*.

Table 4.8 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-451 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 4.10* 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 4.9* to control long transmissions like event reports and SER reports.

Table 4.9 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 4.10 summarizes the Ethernet card commands. Subsequent subsections provide full descriptions of each command in alphabetical order.

Table 4.10 Ethernet Card 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-451 is shown in *Table 4.11*.

Table 4.11 Ethernet Card 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 4.11*. 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 4.12*.

Table 4.12 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 time-out setting associated with connections to the Ethernet card and connections to the host through the Ethernet card. The time-out 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 time-out, the Ethernet card automatically closes the connection and changes to Access Level 0 when the time-out 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 4.13 illustrates how to use the **DATE** command to view or set the date.

Table 4.13 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 DNP 3.00. The output of the **DNPMAP** command documents the DNP 3.00 data map in the SEL-451 to help with the configuration of the DNP 3.00 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 DNP 3.00 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 DNP 3.00 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-451.

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-451 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 4.14*.

Table 4.14 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 4.15*.

Table 4.15 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-451_OtterTail)
- type: the IED type (e.g., SEL_451)
- configVersion: the CID file configuration version (e.g., ICD-451-R100-V0-Z001001-20060512)

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 4.16*.

Table 4.16 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.

STATUS command example (including CID parse error):

```
#>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 4.17*.

Table 4.17 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.

Ethernet Card Status and Alarm Bits

Status Information

The Ethernet card has its own processor and memory, separate from the main processor and memory of the SEL-451 host relay. The card's interface to the host relay can provide status information accessible to the user.

You can obtain status information on the Ethernet card directly from the card or through the host. If you TELNET directly to the card or use the **POR 5** command in a terminal session to the relay, the **STATUS** command will provide the card self-test report, link status, Ethernet media and speed, and Ethernet traffic sent and received.

CCALARM Bit

The SEL-451 CCALARM bit reflects the state of the Ethernet card alarm bit. Its state is automatically included in the SALARM bit. Conditions that activate an Ethernet card alarm also activate the relay alarm light and output contact. See *Table 4.18* for a list of conditions that assert the Ethernet card alarm bit. For example, the Ethernet card sets the alarm bit if you are unsuccessful when changing access levels with the **ACC** or **2AC** command. The **ACC** and **2AC** commands allow you three attempts to enter the password. If you enter an incorrect password on the third attempt, the Ethernet card automatically sets the access level to 0 and activates the alarm bit.

Table 4.18 Ethernet Card Alarm Bit Assertion

Condition	Assertion Type
Ethernet card diagnostic failure	Continuous
Telnet connection established to the Ethernet card user interface	Momentary
FTP connection established	Momentary
Successful Level 2 access to the Ethernet card user interface	Momentary
Access failure to Ethernet card	Momentary

Ethernet Card Status Bits (CCSTA01–CCSTA32)

The host relay monitors the card status and heartbeat and reports failures appropriately. It also maintains its own status and heartbeat for the card. The status register within the card is copied into the CCSTA01–CCSTA16 Relay Word bits every 10 seconds. The card self-test status register is also copied into the CCSTA17–CCSTA32 Relay Word bits every 10 seconds.

The Ethernet card status bits are listed in *Table 4.19* (CCSTA01–CCSTA32).

Table 4.19 Ethernet Card Status Bit Assertion (Sheet 1 of 3)

CC Status Bit	Type	Function	Indication When Set
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	

Table 4.19 Ethernet Card Status Bit Assertion (Sheet 2 of 3)

CC Status Bit	Type	Function	Indication When Set
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	Indicates a low resource condition
CCSTA10	Card Status Register Bit 6	Alarm bit	Indicates an alarm condition
CCSTA11	Card Status Register Bit 5	Settings selection	Cleared if operating on local settings; set if operating on settings passed from host
CCSTA12	Card Status Register Bit 4	Running in SELBOOT	
CCSTA13	Card Status Register Bit 3	Settings error	Settings are not valid
CCSTA14	Card Status Register Bit 2	Network port active	Set once port is initialized and active
CCSTA15	Card Status Register Bit 1	Self-test failure	Set if a self-test failure occurs
CCSTA16	Card Status Register Bit 0	Alive and initialized	Set once status and settings are initialized
CCSTA17	Self Test Failure Bit 15	Spare	
CCSTA18	Self Test Failure Bit 14	Spare	
CCSTA19	Self Test Failure Bit 13	SELBOOT Incompatible	SLBT Incompatible with current version of EXE
CCSTA20	Self Test Failure Bit 12	No Host Response to Interrupt	Host failed to respond to a Ethernet card interrupt in a timely fashion
CCSTA21	Self Test Failure Bit 11	Active Ethernet Port	0 = Operating on primary Ethernet port or the network ports are disabled by settings (NETPORT = 'D') 1 = Operating on backup Ethernet port
CCSTA22	Self Test Failure Bit 10	Host Access Counter Error	Host Access counter has stopped incrementing for at least 60 seconds
CCSTA23	Self Test Failure Bit 9	Host Access Counter Warning	Host Access counter has stopped incrementing for at least 10 seconds
CCSTA24	Self Test Failure Bit 8	Host Incompatible	Host is not compatible
CCSTA25	Self Test Failure Bit 7	Host Commanded Read/ Write Test Results	R/W Test Failed
CCSTA26	Self Test Failure Bit 6	Shared Memory Interface Failure	Interface R/W Test Failed

Table 4.19 Ethernet Card Status Bit Assertion (Sheet 3 of 3)

CC Status Bit	Type	Function	Indication When Set
CCSTA27	Self Test Failure Bit 5	Configuration	Configuration Checksum Failed
CCSTA28	Self Test Failure Bit 4	Executable Storage Block	Storage Block Failed
CCSTA29	Self Test Failure Bit 3	Settings Check	Settings Failed
CCSTA30	Self Test Failure Bit 2	SLBT Code Flash Check	SLBT Failed
CCSTA31	Self Test Failure Bit 1	EXE Code Flash Check	EXE Failed
CCSTA32	Self Test Failure Bit 0	RAM Check	RAM Failed

The CCSTA Ethernet card status bits may be used to monitor status of the Ethernet communications. For example, for a card that is enabled and communicating through its primary Ethernet port, you would see CCSTA14 and CCSTA16 set, and all other CCSTA bits cleared. If the card is communicating through its backup port, CCSTA21 will also be set.

Communications Card Database

The SEL-451 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 4.20*. Use the **MAP** and **VIEW** commands to display maps and contents of the database regions. See *Section 9: ASCII Command Reference in the Reference Manual* for more information.

Table 4.20 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
DEMAND	Demand and peak demand measurement data	15 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
BREAKER	Summary circuit breaker monitor data updated every 15 s	15 s
STATUS	Self-test diagnostic status data	5 s
ANALOGS	Protection and automation math variables	0.5 s
STATE	Elements defined as SER points	0.5 s of any new event

Data within the communications card regions are 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 4.21*.

Table 4.21 SEL-451 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[24]	Device part number, from factory settings
0088	CONFIG	char[8]	Device configuration string (as reported in **ID** command)
0090	SPECIAL	char[8]	Special device configuration string (as reported in **ID** command)
0098	DEVICE_ID	char[40]	Relay ID setting, from global settings
00C0	NODE_ID	char[40]	Station ID from global settings
00E8	GROUP	int	Active group
00E9	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 4.22* for the map.

Table 4.22 SEL-451 Communications Card Database Structure—METER Region (Sheet 1 of 3)

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 (0–86,400,00)
1004	FREQ	float	System frequency
1006	VDC1	float	Battery 1 voltage
1008	VDC2	float	Battery 2 voltage
100A, 100C	IA1	float[2]	Line phase A current magnitude and phase
100E, 1010	IB1	float[2]	Line phase B current magnitude and phase
1012, 1014	IC1	float[2]	Line phase C current magnitude and phase
1016, 1018	I0_1	float[2]	Line Terminal W 0-sequence current magnitude and phase
101A, 101C	I1_1	float[2]	Line 1-sequence current magnitude and phase
101E, 1020	I2_1	float[2]	Line 2-sequence current magnitude and phase
1022, 1024	IA2	float[2]	Breaker 1 phase A current magnitude and phase
1026, 1028	IB2	float[2]	Breaker 1 phase B current magnitude and phase

Table 4.22 SEL-451 Communications Card Database Structure—METER Region
(Sheet 2 of 3)

Address (Hex)	Name	Type	Description
102A, 102C	IC2	float[2]	Breaker 1 phase C current magnitude and phase
102E, 1030	IA3	float[2]	Breaker 2 phase A current magnitude and phase
1032, 1034	IB3	float[2]	Breaker 2 phase B current magnitude and phase
1036, 1038	IC3	float[2]	Breaker 2 phase C current magnitude and phase
103A, 103C	VA	float[2]	phase A voltage magnitude and phase
103E, 1040	VB	float[2]	phase B voltage magnitude and phase
1042, 1044	VC	float[2]	phase C voltage magnitude and phase
1046, 1048	V0	float[2]	0-sequence voltage magnitude and phase
104A, 104C	V1	float[2]	1-sequence voltage magnitude and phase
104E, 1050	V2	float[2]	2-sequence voltage magnitude and phase
1052	VP	float	Polarizing voltage magnitude
1054	VS1	float	Synchronizing voltage 1 magnitude
1056	VS2	float	Synchronizing voltage 2 magnitude
1058	ANG1_DIF	float	VS1 and VP angle difference, in degrees
105A	VS1_SLIP	float	VS1 frequency slip with respect to VP, in HZ
105C	ANG2_DIF	float	VS2 and VP angle difference, in degrees
105E	VS2_SLIP	float	VS2 frequency slip with respect to VP, in HZ
1060	PA	float	phase A real power
1062	PB	float	phase B real power
1064	PC	float	phase C real power
1066	P	float	total real power
1068	QA	float	phase A reactive power
106A	QB	float	phase B reactive power
106C	QC	float	phase C reactive power
106E	Q	float	total reactive power
1070	SA	float	phase A apparent power, if available
1072	SB	float	phase B apparent power, if available
1074	SC	float	phase C apparent power, if available
1076	S	float	total apparent power
1078	PFA	float	phase A power factor
107A	PFB	float	phase power factor
107C	PFC	float	phase power factor
107E	PF	float	3-phase power factor

Table 4.22 SEL-451 Communications Card Database Structure—METER Region (Sheet 3 of 3)

Address (Hex)	Name	Type	Description
1080	PEA	float	positive phase A energy in KWh
1082	PEB	float	positive phase B energy in KWh
1084	PEC	float	positive phase C energy in KWh
1086	PE	float	total positive energy in KWh
1088	NEA	float	negative phase A energy in KWh
108A	NEB	float	negative phase B energy in KWh
108C	NEC	float	negative phase C energy in KWh
108E	NE	float	total negative energy in KWh

The **DEMAND** region contains demand and peak demand information. This region is updated every 15 seconds. See *Table 4.23* for the map.

Table 4.23 SEL-451 Communications Card Database Structure—DEMAND Region

Address (Hex)	Name	Type	Description
2000	_YEAR	int	4-digit year when data was sampled
2001	DAY_OF_YEAR	int	1–366 day when data was sampled
2002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,00)
2004	IA	float	phase A demand current
2006	IB	float	phase B demand current
2008	IC	float	phase C demand current
200A	I0	float	0-sequence demand current
200C	I2	float	2-sequence demand current
200E	PA	float	phase A demand real power
2010	PB	float	phase B demand real power
2012	PC	float	phase C demand real power
2014	P	float	total demand real power
2016	SA	float	phase A demand apparent power
2018	SB	float	phase B demand apparent power
201A	SC	float	phase C demand apparent power
201C	S	float	total demand apparent power
201E	PK_IA	float	phase A demand current
2020	PK_IB	float	phase B demand current
2022	PK_IC	float	phase C demand current
2024	PK_I0	float	0-sequence demand current
2026	PK_I2	float	2-sequence demand current
2028	PK_PA	float	phase A demand real power
202A	PK_PB	float	phase B demand real power
202C	PK_PC	float	phase C demand real power
202E	PK_P	float	total demand real power

Table 4.23 SEL-451 Communications Card Database Structure—DEMAND Region

Address (Hex)	Name	Type	Description
2030	PK_SA	float	phase A demand apparent power
2032	PK_SB	float	phase B demand apparent power
2034	PK_SC	float	phase C demand apparent power
2036	PK_S	float	total demand apparent power

The TARGET region contains the entire relay word plus the rows specifically designated for the TARGET region. This region is updated every 0.5 seconds. See *Table 4.24* for the map. See *Appendix A: Relay Word Bits in the Reference Manual* for detailed information on the Relay Word bits.

Table 4.24 SEL-451 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[~240]	Entire relay word with 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 4.25* for the Map.

Table 4.25 SEL-451 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	FREQ	float[10]	System frequency at time of fault
40AE	TARGETS	char[160]	System targets from event

Table 4.25 SEL-451 Communications Card Database Structure—HISTORY Region

Address (Hex)	Name	Type	Description
414E	FAULT_LOC	float[10]	Fault location
4162	SHOT	int[10]	Recloser shot counter (sum of 1-pole and 3-pole)
416C	SHOT_1P	int[10]	Single-pole recloser counter
4176	SHOT_3P	int[10]	Three-pole recloser counter
4180	CURR	int[10]	Fault current in primary amps

The BREAKER region contains some of the information available in a summary Breaker report. This region is updated every 15 seconds. See *Table 4.26* for the map.

Table 4.26 SEL-451 Communications Card Database Structure—BREAKER Region

Address (Hex)	Name	Type	Description
5000	_YEAR	int	4-digit year when data was sampled
5001	DAY_OF_YEAR	int	1–366 day when data was sampled
5002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
5004	BCWA1	float	Breaker 1 phase A breaker wear (%)
5006	BCWB1	float	Breaker 1 phase B breaker wear (%)
5008	BCWC1	float	Breaker 1 phase C breaker wear (%)
500A	BCWA2	float	Breaker 2 phase A breaker wear (%)
500C	BCWB2	float	Breaker 2 phase B breaker wear (%)
500E	BCWC2	float	Breaker 2 phase C breaker wear (%)
5010	CURA1	float	Breaker 1 phase A accumulated current (kA)
5012	CURB1	float	Breaker 1 phase B accumulated current (kA)
5014	CURC1	float	Breaker 1 phase C accumulated current (kA)
5016	CURA2	float	Breaker 2 phase A accumulated current (kA)
5018	CURB2	float	Breaker 2 phase B accumulated current (kA)
501A	CURC2	float	Breaker 2 phase C accumulated current (kA)
501C	NOPA1	long int	Breaker 1 phase A number of operations
501E	NOPB1	long int	Breaker 1 phase B number of operations
5020	NOPC1	long int	Breaker 1 phase C number of operations
5022	NOPA2	long int	Breaker 2 phase A number of operations
5024	NOPB2	long int	Breaker 2 phase B number of operations
5026	NOPC2	long int	Breaker 2 phase C number of operations

The STATUS region contains complete relay status information. This region is updated every 5 seconds. See *Table 4.27* for the map.

Table 4.27 SEL-451 Communications Card Database Structure—STATUS Region

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(mV)	int	Channel 1 offset
6005	CH2(mV)	int	Channel 2 offset
6006	CH3(mV)	int	Channel 3 offset
6007	CH4(mV)	int	Channel 4 offset
6008	CH5(mV)	int	Channel 5 offset
6009	CH6(mV)	int	Channel 6 offset
600A	CH7(mV)	int	Channel 7 offset
600B	CH8(mV)	int	Channel 8 offset
600C	CH9(mV)	int	Channel 9 offset
600D	CH10(mV)	int	Channel 10 offset
600E	CH11(mV)	int	Channel 11 offset
600F	CH12(mV)	int	Channel 12 offset
6010	MOF(mV)	int	Master offset
6011	OFF_WARN	char[8]	Offset warning string
6019	OFF_FAIL	char[8]	Offset failure string
6021	PS3(V)	float	3.3 Volt power supply voltage
6023	PS5(V)	float	5 Volt power supply voltage
6025	PS_N5(V)	float	–5 Volt regulated voltage
6027	PS15(V)	float	15 Volt power supply voltage
6029	PS_N15(V)	float	–15 Volt power supply voltage
602B	PS_WARN	char[8]	Power supply warning string
6033	PS_FAIL	char[8]	Power supply failure string
603B	HW_FAIL	char[40]	Hardware failure strings
6063	CC_STA	char[40]	Comm. card status strings
608B	PORT_STA	char[160]	Serial port status strings
612B	TIME_SRC	char[10]	Time source
6135	LOG_ERR	char[40]	SELOGIC error strings
615D	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 4.28* for the map.

Table 4.28 SEL-451 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 (0–86400000)
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 4.29* for the map. See *DNP LAN/WAN Application Example on page R.6.53* for DNP LAN/WAN implementation details.

Table 4.29 SEL-451 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 (0–86,400,00)
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

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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 4.20*). An example of the **MAP** command is shown in *Figure 4.4*.

```
=>>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              int[2]
FREQ         1004h              float
VDC1         1006h              float
VDC2         1008h              float
IA1          100ah              float[2]
IB1          100eh              float[2]
IC1          1012h              float[2]
I0_1         1016h              float[2]
I1_1         101ah              float[2]
I2_1         101eh              float[2]
IA2          1022h              float[2]
IB2          1026h              float[2]
IC2          102ah              float[2]
IA3          102eh              float[2]
IB3          1032h              float[2]
IC3          1036h              float[2]
VA           103ah              float[2]
VB           103eh              float[2]
VC           1042h              float[2]
V0           1046h              float[2]
V1           104ah              float[2]
V2           104eh              float[2]
VP           1052h              float
VS1          1054h              float
VS2          1056h              float
ANG1_DIF     1058h              float
VS1_SLIP     105ah              float
ANG2_DIF     105ch              float
VS2_SLIP     105eh              float
PA           1060h              float
PB           1062h              float
PC           1064h              float
P            1066h              float
QA           1068h              float
QB           106ah              float
QC           106ch              float
Q            106eh              float
SA           1070h              float
SB           1072h              float
SC           1074h              float
S            1076h              float
PFA          1078h              float
PFB          107ah              float
PFC          107ch              float
PF           107eh              float
PEA          1080h              float
PEB          1082h              float
PEC          1084h              float
PE           1086h              float
NEA          1088h              float
NEB          108ah              float
NEC          108ch              float
NE           108eh              float
```

Figure 4.4 MAP 1:METER Command Example

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Section 5

SEL Communications Protocols

This section describes features of the SEL-451 Relay communications protocols and includes the following topics:

- *Serial Port Hardware Protocol on page R.5.1*
- *Software Protocol Selections on page R.5.2*
- *Protocol Active When Setting PROTO := SEL on page R.5.3*
- *Virtual File Interface on page R.5.11*
- *SEL MIRRORED BITS Communications on page R.5.15*
- *SEL Distributed Port Switch Protocol (LMD) on page R.5.21*
- *SEL-2600 Series RTD Module Operation on page R.5.23*

Serial Port Hardware Protocol

The serial ports comply with the EIA/TIA-232 Standard, commonly referred to as EIA-232 (formerly known as RS-232). The serial ports support RTS/CTS hardware flow control. See also *Software Flow Control on page R.5.7*.

Hardware Flow Control

Hardware handshaking is one form of flow control that two 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** command (or front-panel **SET** pushbutton sequence) to set RTSCTS := Y. Disable hardware handshaking by setting RTSCTS := N. *Table 5.1* shows actions the relay takes for the RTSCTS setting values and the conditions relevant to hardware flow control.

Table 5.1 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 is normally 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-451 supports the protocols and command sets shown in *Table 5.2*.

Table 5.2 Supported Serial Command Sets (Sheet 1 of 2)

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

Table 5.2 Supported Serial Command Sets (Sheet 2 of 2)

PROTO Setting Value	Command Set	Description
PMU	Phasor Measurement Unit	Binary synchrophasor protocol, as selected by Global Setting MFRMT. See *Synchrophasors on page R.7.1*.
PMU	SEL Fast Operate	Binary operation commands
RTD	SEL Fast Message protocol for Resistance Temperature Detector (RTD) data	Up to 12 analog temperature readings from the SEL-2600 Series
DNP	DNP3 Level 2 Slave	Binary commands and responses. See *Section 6: DNP3 Communications in the Reference Manual*

Virtual Serial Ports

Actual serial ports are described in *Serial Port Hardware Protocol on page R.5.1*. In addition to actual serial ports, the SEL-451 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-451 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 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 9: ASCII Command Reference in the Reference Manual*. *Table 5.3* shows the subset of the ASCII control characters used in this section.

Table 5.3 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> or **<command> <Enter> <CR>**

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:

```
<DIALOG LINE ><CR><LF>
```

The relay transmits messages 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 **<Ctrl>** 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 generally 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 CRLF. 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 5.4 lists the Compressed ASCII commands and contents of the command responses. The Compressed ASCII commands are described in *Section 9: ASCII Command Reference in the Reference Manual*.

Table 5.4 Compressed ASCII Commands

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
CBREAKER	Circuit breaker data	1
CEVENT	Event report	1
CHISTORY	List of events	1
CSER	Sequential Events Recorder report	1
CSTATUS	Self-diagnostic status	1
CSUMMARY	Summary of an event report	1
DNAME	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 Level 0 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. 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 require 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",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",.......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",.......,"ddd","yyyy"<CR><LF>
.
.
.
"COMMAND n",ll,"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:

- `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.
- `#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.

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-451 communicates with an SEL Communications Processor, such as the SEL-2032, SEL-2020, or the SEL-2030. The communications processor performs auto-configuration 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 binary data stream to connect transparently to the SEL-451 and use the ASCII data stream for commands and responses.

Automatic Messages

If you enable automatic messages, AUTO = Y, the SEL-451 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

NOTE: Starting with firmware revision R104, synchrophasor data in the SEL Fast Message format is no longer available when PROTO := SEL. See Section 7: Synchrophasors for details.

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 and unsolicited synchrophasor messages automatically. If the relay is connected to an SEL Communications Processor, these messages provide the mechanism that the communications processor uses for SCADA or DCS functions that occur simultaneously with ASCII interaction. Reference the section, *Interleaved ASCII and Binary Messages on page R.5.7* and *Section 6: SEL Communications Processor Applications in the Applications Handbook*.

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 using Fast Messages with the SEL-451. To support this type of development, you will also need to contact SEL for Fast Message protocol details.

Table 5.5 lists the two-byte Fast Commands and the actions the relay takes in response to each command.

Table 5.5 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.
A5C2h	Demand Fast Meter configuration block	Defines contents of demand Fast Meter data message.
A5C3h	Peak demand Fast Meter configuration block	Defines contents of peak demand Fast Meter data message.
A5CEh	Fast Operate configuration block	Defines available circuit breaker, remote bits, and associated commands.
A5D1h	Fast Meter data message	Defines present values of analog and digital data.
A5D2h	Demand Fast Meter data message	Defines values of most recently completed demand period.
A5D3h	Peak demand Fast Meter data message	Defines values for peak demands as of end of most recently completed demand periods.

Fast Operate commands use one of the two-byte command types shown in *Table 5.6*. Each Fast Operate command also includes additional bytes that specify a remote bit or circuit breaker bit.

Table 5.6 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 report information. The Fast SER messages include function codes to accomplish different tasks. *Table 5.7* lists the Fast SER function codes and the actions the relay takes in response to each command.

Table 5.7 Fast Message Command Function Codes Used With Fast SER (A546 Message) and Relay Response Descriptions

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 FSERx. Relay will transmit subsequent SER events (Unsolicited SER broadcast, Function Code 18).
02h	Disable unsolicited transfers	Relay sends Fast SER command acknowledged message (Function Code 82) and clears relay element bit FSERx. 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.

The SEL Fast Message Synchrophasor protocol is covered in *Section 7: Synchrophasors*.

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. SEL Communications Processors use the self-description messages to configure a database and name the elements in the database.

Table 5.8 lists commands and command usage in the recommended order of execution for automatic configuration.

Table 5.8 Commands in Recommended Sequence for Automatic Configuration (Sheet 1 of 2)

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, A5C2h, A5C3h	Fast Meter configuration blocks	Defines contents of Fast Meter data messages
BNAME	Binary names	ASCII names of status bits
DNAME	Digital I/O name	ASCII names of digital I/O points
SNS	SER names	ASCII names for SER data points

Table 5.8 Commands in Recommended Sequence for Automatic Configuration (Sheet 2 of 2)

Command ASCII or hexadecimal (h suffix)	Response	Usage
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

Virtual File Interface

You can retrieve and send data as files through the SEL-451 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-451 has a two-level file structure. There is one file at the root level and three subdirectories or folders. *Table 5.9* shows the directories and the contents of each directory.

Table 5.9 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, COMTRADE, HIF and history reports	1

System Data Format (SDF)

All files use the SDF (System Data Format) unless otherwise specified. 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 as follows:

"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.

For each settings class that you modify, the software sends a SET_*cn*.TXT file to the SEL-451.

Step 3. The PC software reads the ERR.TXT file.

If it is not empty, the relay detects errors in the SET_*cn*.TXT file.

Step 4. For any detected errors, modify the settings and send the settings until the relay accepts your settings.

Step 5. Repeat steps 2–4 for each settings class that you want to modify.

Step 6. 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 5.10* 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 5.10 Settings Directory Files

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
S	SET_S*n*.TXT	Group *n*; *n* in range 1–6	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	Report	1, B, P, A, O, 2	P, A, O, 2
P	SET_P*n*.TXT	Port; *n* in range 1, 2, 3, 5, F	1, B, P, A, O, 2	P, A, O, 2
D	SET_D1.TXT	DNP 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*n*.TXT	Automation; *n* in range 1–10	1, B, P, A, O, 2	A, 2
L	SET_L*n*.TXT	Protection logic; *n* in range 1–6	1, B, P, A, O, 2	P, 2
T	SET_T1.TXT	Alias settings	1, B, P, A, O, 2	P, A, O, 2
M	SET_SM.TXT	Circuit breaker monitor	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

REPORTS Directory

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 5.11*. 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 5.11 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
BRE_1.TXT	BRE 1 H report (Circuit Breaker 1)
BRE_2.TXT	BRE 2 H report (Circuit Breaker 2)
BRE_S1.TXT	BRE 1 report (Circuit Breaker 1)
BRE_S2.TXT	BRE 2 report (Circuit Breaker 2)
CBRE.TXT	Compressed ASCII CBR report for both circuit breakers
HISTORY.TXT	History file
CHISTORY.TXT	Compressed ASCII history file

EVENTS Directory

The relay provides history, event reports, and oscillography files in the EVENTS directory. Event reports are available in the following formats: SEL ASCII 4- or 8-samples/cycle reports and Compressed ASCII 4- or 8-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. Higher resolution

oscilligraphy is available in binary COMTRADE (IEEE C37.111-1999) format at the sample rate (SRATE) and length (LER) settings 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- and 8-samples/cycle report files (files with names that begin with E or C) are text files with the same format as the EVENT and CEVENT command responses. Event file names start with the prefix E4_, E8_, C4_, C8_, or HR_, 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 5.12*. Event oscillography in COMTRADE format consists of three files (.CFG, .DAT, and .HDR) that conform to the COMTRADE standard. For an example of retrieving these files see *Retrieving Event Report Data Files: Terminal on page U.4.51*.

Table 5.12 EVENTS Directory Files (for Event 10001)

File	Usage
HISTORY.TXT	History file; read-only
CHISTORY.TXT	Compressed ASCII History file; read-only
C4_10001.TXT	4-samples/cycle Compressed ASCII event report; read-only
C8_10001.TXT	8-samples/cycle Compressed ASCII event report; read-only
E4_10001.TXT	4-samples/cycle event report; read-only
E8_10001.TXT	8-samples/cycle event report; read-only
HR_10001.CFG	Sample/second COMTRADE configuration file; read-only
HR_10001.DAT	Sample/second COMTRADE binary data file; read-only
HR_10001.HDR	Sample/second COMTRADE header file; read-only

High-impedance fault oscillography files are stored in the EVENTS directory when the relay supports HIF detection. The size of the HIF event report file is determined by the HIFLER setting in effect at the time the HIF event is triggered. Oscillography is available at the rate of 1-sample/2cycles. HIF event file names start with the prefix HF_, followed by a unique HIF event serial number (separate from the event serial number). If an HIF event is triggered with serial number of "10001," the EVENTS directory contains the files shown in *Table 5.13*. HIF event oscillography in COMTRADE format consists of three files (.CFG, .DAT, and .HDR) that conform to the COMTRADE standard.

Table 5.13 EVENTS Directory Files (for HIF Event 10001)

File	Usage
HF_10001.CFG	1-sample/2cycles COMTRADE configuration file; read-only
HF_10001.DAT	1-sample/2cycles COMTRADE binary data file; read-only
HF_10001.HDR	1-sample/2cycles COMTRADE header file; read-only

Ethernet Card Subdirectory

If an Ethernet card with the DNP3 protocol is installed into an SEL-451 relay, the SEL-2702 settings subdirectory is accessible as a subdirectory of the SETTINGS directory.

Table 5.14 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

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, remote sensing, or communications-assisted protection schemes such as POTT and DCB.

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the SEL-451 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 5.15* summarizes MIRRORED BITS communications features.

Table 5.15 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-451 Relay 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 with which channel 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. See *Table A.41* for MIRRORED BITS Relay Word bit definitions. See *Operation on page R.5.16* for a functional description.

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 to less than 8, you can use the remaining channels (up to a total of eight) for the features listed below.
- 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.
  - 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.

The virtual terminal session uses channels differently than other data exchange mechanisms. There can be only 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

MB8

While the SEL-451 does not have a setting for the MB8 protocol implemented in some SEL products, you can configure the relay to communicate with devices set to MB8A or MB8B (such as the SEL-351S or SEL-2505). Set the SEL-451 protocol setting PROTO to MBA or MBB. Set the STOPBIT setting to 2. Set all other settings to match those in the other device.

Message Transmission

Depending on the settings, the SEL-451 transmits a MIRRORED BITS communications message every 1/8 to 1/2 of an electrical cycle (see *Table 5.18*). 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.
- Accumulates the analog data, and every 18th message, updates the received analog quantities.
- Accumulates the virtual terminal information, and every 18th message, makes the received character or characters available to the virtual terminal.

NOTE: c represents the MIRRORED BITS channel (A or B). n represents the MIRRORED BITS data channel data number (1–8).

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 RMBn 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-451 communicating with another SEL-451 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 5.18* for the message rates based on the 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-451 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 enable loopback testing. 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 on page R.5.17*)

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 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. Other relays may set RTS to a positive voltage at the EIA-232 connector to signify usage of the R6 version or the R version of MIRRORED BITS communications.

Settings

The SEL-451 Port settings associated with MIRRORED BITS communications are shown in *Table 5.16* and *Table 5.17*.

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 5.16 General Port Settings Used With MIRRORED BITS Communications

Name	Description	Range	Default
PROTO	Protocol.	None, SEL, DNP[a], MBA, MBB, RTD, PMU	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
STOPBIT	Stop bits. Hidden and set to 1 if MBT := Y.	1, 2	1
RTSCTS	Hardware handshaking enable.	Y, N	N

[a] Optional relay feature.

Setting SPEED := SYNC (available only on the rear-panel serial ports for which PROTO := MBA or MBB) places the serial port in synchronous (or externally-clocked) mode. The serial port hardware will synchronize transmit and receive data (TX/RX) to a clock signal applied to the Pin 8 input at any effective baud rate up to 64000. This setting choice will suit certain synchronous communications networks.

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-451 can send messages more quickly 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 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 5.18*.

Table 5.17 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	0–10000 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	LIAFM
MBANA2[c]	Selection for Analog Channel 2	Analog quantity label	LIBFM
MBANA3[c]	Selection for Analog Channel 3	Analog quantity label	LICFM
MBANA4[c]	Selection for Analog Channel 4	Analog quantity label	VAFM
MBANA5[c]	Selection for Analog Channel 5	Analog quantity label	VBFM
MBANA6[c]	Selection for Analog Channel 6	Analog quantity label	VCFM
MBANA7[c]	Selection for Analog Channel 7	Analog quantity label	VABRMS
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 5.18 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 5.19* lists the MIRRORED BITS communications ID settings for Relays X, Y, and Z.

Table 5.19 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-451 does not have built in LMD protocol, but you can connect an SEL-451 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 at 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 5.20 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

Table 5.20 SEL-2885 Initialization String [MODE PREFIX ADDR:SPEED]

Field	Optional or Required	Value	Description
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.

You must wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is warming up.

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.

SEL-2600 Series RTD Module Operation

The SEL-2600 Series RTD Module Protocol enables communication with an SEL-2600 series via an SEL-2800 (EIA-232 to Fiber-Optic) Transceiver.

Figure 5.1 SEL-2600 Series RTD Module and the SEL-451

This protocol supports data acquisition of up to 12 temperature channels and places the results directly into predefined analog quantities (RTD01–RTD12) inside the relay for use in free-form SELOGIC applications. For more information on the SEL-2600 series or SEL-2800, contact your local technical service center, the SEL factory, or visit the SEL website (www.selinc.com) for a copy of the SEL-2600 series and SEL-2800 product flyers.

Initialization

Perform the following steps to prepare the SEL-451 for communicating with an SEL-2600 series RTD module:

Step 1. Set the desired port to RTD protocol (PROTO := RTD).

Step 2. Set the port setting RTDNUM to the number of RTDs attached to the SEL-2600 series.

Step 3. Set the RTD type settings (RTD*nn*TY) to the appropriate RTD type.

Step 4. Connect the SEL-2600 series RTD module to the port via the SEL-2800 (EIA-232 to Fiber-Optic) Transceiver.

Operational Overview

The SEL-2600 series RTD module sends all temperature measurements to the relay every 0.5 seconds. The relay places the received temperature measurements into analog quantities RTD01 through RTD12 for use in free-form SELOGIC applications. The data range is from –50 to +250 °C.

NOTE: When a channel status bit is not asserted, the data in the respective analog quantity is the last valid temperature, not the current temperature.

If the relay stops receiving valid analog quantities from a certain channel, the temperature stored in the relay freezes at the last received value. Fifteen status bits help supervise decisions based on temperature measurements. *Table 5.21* describes how to interpret the status bits.

Table 5.21 RTD Status Bits

RTD Status Bit	Description
RTDFL	Asserts if the SEL-2600 series experiences an internal problem.
RTDCOMF	Asserts if the relay does not receive a valid measurement from the SEL-2600 series for 1.25 seconds.
RTD01ST–RTD12ST	Assert when an RTD is attached to a channel and the SEL-2600 series is able to read RTD.

To view the temperature measurements received from the SEL-2600 series, issue the **MET T** command, as depicted in *Figure 5.2*.

```
=>>MET T <Enter>

Relay 1                                    Date: 05/17/2003  Time: 13:42:13.220
Station A                                  Serial Number: 0000000000

RTD Input Temperature Data (deg. C)
RTD  1 = -48
RTD  2 = Channel Failure
RTD  3 =   0
RTD  4 =  24
RTD  5 = Channel Not Used
RTD  6 =  72
RTD  7 = Channel Failure
RTD  8 = 120
RTD  9 = Channel Not Used
RTD 10 = 168
RTD 11 = 192
RTD 12 = 216
```

Figure 5.2 MET T Command Response

The **MET T** command displays the following messages:

- `Channel Failure`: This message is displayed for each channel whose channel status bit is not asserted.
- `Channel Not Used`: This message is displayed for each channel whose channel type is set to NA.

When there is a status problem with the SEL-2600 series RTD module, the **MET T** command will respond with an informational message, as shown in *Figure 5.3*.

```
=>>MET T <Enter>

SEL-2600 Failure
```

Figure 5.3 MET T Command Response for Status Problem

The three possible messages for status problems, with their interpretation, are indicated in *Table 5.22*.

Table 5.22 MET T Command Status Messages

Message	Interpretation
SEL-2600 Failure	RTDFL status bit asserted
Communication Failure	RTDCOMF status bit asserted
No data available	Port Protocol not set to RTD
Channel Failure	RTDxxST status bit asserted

Section 6

DNP3 Communications

The SEL-451 Relay provides a DNP3 (Distributed Network Protocol 3) Level 2 Slave interface for direct serial and/or network connections to the relay. This section covers the following topics:

- *Introduction to DNP3 on page R.6.1*
- *DNP3 (Serial) in the SEL-451 on page R.6.5*
- *DNP3 (Serial) Documentation on page R.6.12*
- *DNP3 (Serial) Application Example on page R.6.30*
- *DNP LAN/WAN Communications on page R.6.35*
- *DNP LAN/WAN in the SEL-451 on page R.6.36*
- *DNP LAN/WAN Documentation on page R.6.45*
- *DNP LAN/WAN Application Example on page R.6.53*

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. DNP 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 DNP 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 web site (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 6.1*.

Table 6.1 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 6.2*.

Table 6.2 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 6.3*.

The access methods listed in *Table 6.3* 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 6.3 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 6.15* and *Table 6.16* describe control point operation for the SEL-451.

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-451 is certified as having passed DNP3 Level 2 Slave 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-451

The SEL-451 is a DNP3 Level 2 remote (slave) device. Additional implementation documentation describing DNP in the relay is in *DNP3 (Serial) Documentation on page R.6.12*.

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 6.4*. *Table 6.4* also lists the SEL-451 DNP3 settings. You must configure the DNP master for the data access method you select.

Table 6.4 DNP Access Methods

Access Method	Master Polling	SEL-451 Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to Off, UNSOL to No.
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLSSC, ECLASSA, 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, ECLASSA, 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, ECLASSA 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 6.4*, 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-451, 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 Confirm, 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 half-duplex medium 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-451 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-451 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 pre-delay 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 time-stamp information that the SEL-451 collects and stores in a buffer. You can configure the SEL-451 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-451.

For event data collection you must also consider and enter appropriate settings for dead band and scaling operation on analog points shown in *Table 6.6*. 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.6.10* for a discussion of how to set scaling and dead-band operation on a point-by-point basis.

The settings ANADBA, ANADBV, 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-451 has the buffer capacities listed in *Table 6.5*.

Table 6.5 SEL-451 Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	256
Counters	128

Binary Controls

The SEL-451 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 6.15* and *Table 6.16* list control points and control methods available in the SEL-451.

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.6.26*.

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 time 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.

TIMERQ can be set in one of three ways:

- A numeric setting of 1–32767 minutes, specifies the rate at which the SEL-451 shall request a time synchronization.
- A setting of M disables the SEL-451 from requesting a time synchronization, but still allows the SEL-451 to accept and apply time synchronization messages from the master.
- A setting of I disables the SEL-451 from requesting a time synchronization, and sets the SEL-451 to ignore time synchronization messages from the master.

Modem Support

The SEL-451 DNP implementation includes modem support. Your DNP master can dial-in to the SEL-451 and establish a DNP3 connection. The SEL-451 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-451 to other devices.

NOTE: RTS/CTS hardware flow control is not available for a DNP3 modem connection. You must set the port data speed slower than the effective data rate of the modem.

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 dial. The relay will automatically 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.

DNP3 Settings

The DNP3 protocol settings that become available when you select DNP3 on a serial port are shown in *Table 6.6*. The DNP3 protocol settings are in the port settings for the port that you select for the DNP3 protocol. You can use DNP3 on any of the serial ports, **PORT F** and **PORT 1** through **PORT 3**, but you can only enable DNP3 on one port at a time.

Table 6.6 SEL-451 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
ECLASSV	Class for virtual terminal data	OFF, 1–3	OFF
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

Table 6.6 SEL-451 Port DNP Protocol Settings (Sheet 2 of 2)

Name	Description	Range	Default
DTIMEO	Data link time-out; hidden if DRETY set to 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 set to Off	0.00–30.00 seconds	0.00
ANADBA	Analog reporting dead band for current; hidden if ECLASSA set to Off	0–32767	100
ANADBV	Analog reporting dead band for voltages; hidden if ECLASSA set to Off	0–32767	100
ANADBM	Analog reporting dead band; hidden if ECLASSC and ECLASSA set to Off	0–32767	100
EVELOCK	Event summary lock period	0–1,000 seconds	0
MINDIST[a]	Minimum fault location to capture	OFF, -10000–10000	OFF
MAXDIST[a]	Maximum fault location to capture	OFF, -10000–10000	OFF
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 set to Off	Y, N	N
PUNSOL	Enable unsolicited reporting at power up; hidden if UNSOL set to N	Y, N	N
REPADR	DNP address to which the relay reports unsolicited data; hidden if UNSOL set to N	0–65519	1
NUMEVE	Number of events on which the relay transmits unsolicited data; hidden if UNSOL set to N	1–200	10
AGEEVE	Age of oldest event on which the relay transmits unsolicited data; hidden if UNSOL set to N	0.0–60.0 seconds	2.0
MODEM	Modem connected to port	Y, N	N
MSTR	Modem startup string; hidden if MODEM set to N	Up to 30 characters	“E0X0& D0S0=4”
PH_NUM	Phone number for unsolicited reporting dial-out; hidden if MODEM set to N or UNSOL set to N	Up to 30 characters	“”
MDTIME	Time to attempt dial	5–300 seconds	60
MDRET	Time between dial-out attempts	5–3600 seconds	120

[a] MAXDIST must be greater than MINDIST.

Configurable Data Mapping

One of the most powerful features of the SEL-451 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-451 DNP Map settings shown in *Table 6.7*. The SEL-451 provides binary input information with one of two reference maps: binary or extended. When you are remapping points, the new index will be the row number minus one. For example, if you want to remap the power in MW, Object 30 Index 87, to the first, Index 0, set DNPAID to N and enter 87 in the setting for Row 1 of the custom analog map.

Table 6.7 SEL-451 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	
•			
•			
•			
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	
•			
•			
•			

Table 6.7 SEL-451 DNP Map Settings (Sheet 2 of 2)

Name	Description	Range	Default
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 6.7* that follow DNPAOD are entered in a line-based free-form format. An example of these settings is shown in the *DNP3 (Serial) Application Example on page R.6.30*. 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 87 in Row 1 of the custom analog map with no other parameters, the power in MW 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 (*Table 6.7*).

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-451 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-451. 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 6.8 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 6.8 SEL-451 DNP3 Device Profile

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-451 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
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 6.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-451. The list of supported objects conforms to the format laid out in the DNP3 specifications and includes both supported and unsupported objects. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table 6.9 SEL-451 DNP Object List (Sheet 1 of 5)

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
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				

Table 6.9 SEL-451 DNP Object List (Sheet 2 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
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
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				

Table 6.9 SEL-451 DNP Object List (Sheet 3 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
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		
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

Table 6.9 SEL-451 DNP Object List (Sheet 4 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
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
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	1, 2	7, 8 index=0	129	07, quanity=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, quanity=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				

Table 6.9 SEL-451 DNP Object List (Sheet 5 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
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	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 6.10 shows the SEL-451 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-451 to reduce the data map to the points that your application requires.

The SEL-451 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 time-stamp 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 report for indices 0–799 uses a slower, less accurate time-stamping 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.21*–*Table A.53 on page R.A.76*) 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 6.10 SEL-451 DNP3 Default Data Map (Sheet 1 of 5)

Object	Indices	Description
		MAPSEL = B
01, 02	000–799	Relay Word bits, *Table 6.11*
01, 02	800–1599	SER Points, add 800 to indices in *Table 6.11*
01, 02	1600–1615	Relay front panel targets in *Table 6.12*
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	TLED_17–TLED_24
01, 02	1632–1635	A-phase, B-phase, C-phase and three-phase power factor leading if this point is on, lagging or zero if off
01, 02	1636–1639	Reserved
		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	5–11	Reserved
01, 02	12–15	Power factor leading for A, B, C, and three-phase
01, 02	16–265	SER points 1–250
01, 02	266–271	Reserved
01, 02	272–	Entire visible Relay Word, starting from bit 0
		MAPSEL = B, MAPSEL = E
10, 12	0–15	Remote bits RB01–RB16
10, 12	16	Pulse Open Circuit Breaker 1 command
10, 12	17	Pulse Close Circuit Breaker 1 command
10, 12	18	Pulse Open Circuit Breaker 2 command
10, 12	19	Pulse Close Circuit Breaker 2 command

Table 6.10 SEL-451 DNP3 Default Data Map (Sheet 2 of 5)

Object	Indices	Description
10, 12	20–23	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	34–35	Reserved
10, 12	36	Reset demands
10, 12	37	Reset demand peaks
10, 12	38	Reset energies
10, 12	39	Reset breaker monitor
10, 12	40	Reset front panel targets
10, 12	41	Read next relay event
10, 12	42	Reset min/max metering
10, 12	43	Reserved
10, 12	44–59	Remote bits RB17–RB32
10, 12	60–67	Remote bit pairs RB17–RB32
10, 12	68, 70, 72, 74, 76[a]	Pulse Open Disconnect Switch 1–5 command
10, 12	69, 71, 73, 75, 77[a]	Pulse Close Disconnect Switch 1–5 command
10, 12	78–87[a]	Pulse Close Disconnect Switch 1–10 command
10, 12	88, 90, 92, 94, 96[a]	Pulse Open Disconnect Switch 6–10 command
10, 12	89, 91, 93, 95, 97[a]	Pulse Close Disconnect Switch 6–10 command
20, 22	00	Active settings group
20, 22	01	Reserved
20, 22	02	Reserved
20, 22	03	Number of unread event reports
20, 22	04	Number of breaker operations on Circuit Breaker 1 A-phase
20, 22	05	Number of breaker operations on Circuit Breaker 1 B-phase
20, 22	06	Number of breaker operations on Circuit Breaker 1 C-phase
20, 22	07	Number of breaker operations on Circuit Breaker 2 A-phase
20, 22	08	Number of breaker operations on Circuit Breaker 2 B-phase
20, 22	09	Number of breaker operations on Circuit Breaker 2 C-phase
30, 32	00, 01[b]	Line A-phase current magnitude (amps) and angle (LIAFM, LIAFA)[c]
30, 32	02, 03[b]	Line B-phase current magnitude (amps) and angle (LIBFM, LIBFA)[c]
30, 32	04, 05[b]	Line C-phase current magnitude (amps) and angle (LICFM, LICFA)[c]
30, 32	06, 07	Reserved
30, 32	08, 09[b]	Circuit Breaker 1 A-phase current magnitude (amps) and angle (B1IAFM, B1IAFA)[c]
30, 32	10, 11[b]	Circuit Breaker 1 B-phase current magnitude (amps) and angle (B1IBFM, B1IBFA)[c]
30, 32	12, 13[b]	Circuit Breaker 1 C-phase current magnitude (amps) and angle (B1ICFM, B1ICFA)[c]
30, 32	14, 15	Reserved

Table 6.10 SEL-451 DNP3 Default Data Map (Sheet 3 of 5)

Object	Indices	Description
30, 32	16, 17[b]	Circuit Breaker 2 A-phase current magnitude (amps) and angle (B2IAFM, B2IAFA)[c]
30, 32	18, 19[b]	Circuit Breaker 2 B-phase current magnitude (amps) and angle (B2IBFM, B2IBFA)[c]
30, 32	20, 21[b]	Circuit Breaker 2 C-phase current magnitude (amps) and angle (B2ICFM, B2ICFA)[c]
30, 32	22–35	Reserved
30, 32	36, 37[d]	Line A-phase voltage magnitude (kV) and angle (VAFM, VAFA)[c]
30, 32	38, 39[d]	Line B-phase voltage magnitude (kV) and angle (VBFM, VBFA)[c]
30, 32	40, 41[d]	Line C-phase voltage magnitude (kV) and angle (VCFM, VCFA)[c]
30, 32	42[d]	Polarizing voltage magnitude (volts) (VPM)[c]
30, 32	43	Reserved
30, 32	44[d]	Synchronizing voltage 1 magnitude (volts) (NVS1M)[c]
30, 32	45	Reserved
30, 32	46[d]	Synchronizing voltage 2 magnitude (volts) (NVS2M)[c]
30, 32	47	Reserved
30, 32	48, 49[b]	Line zero-sequence current magnitude (3I0) in amps and angle (LIGM, LIGA)[c]
30, 32	50, 51[b]	Line positive-sequence current magnitude in amps and angle (LI1M, LI1A)[c]
30, 32	52, 53[b]	Line negative-sequence current magnitude (3I2) in amps and angle (L3I2M, L3I2A)[c]
30, 32	54–71	Reserved
30, 32	72, 73[d]	Zero-sequence voltage magnitude (3V0) in kV and angle (3V0M, 3V0A)[c]
30, 32	74, 75[d]	Positive-sequence voltage magnitude (V1) in kV and angle (V1M, V1A)[c]
30, 32	76, 77[d]	Negative-sequence voltage magnitude (3V2) in kV and angle (3V2M, 3V2A)[c]
30, 32	78–83	Reserved
30, 32	84[e]	A-phase real power in MW (PA_f)[c]
30, 32	85[e]	B-phase real power in MW (PB_f)[c]
30, 32	86[e]	C-phase real power in MW (PC_f)[c]
30, 32	87[e]	Three-phase real power in MW (3P_f)[c]
30, 32	88[e]	A-phase reactive power in MVAr (QA_f)[c]
30, 32	89[e]	B-phase reactive power in MVAr (QB_f)[c]
30, 32	90[e]	C-phase reactive power in MVAr (QC_f)[c]
30, 32	91[e]	Three-phase reactive power in MVAr (3Q_f)[c]
30, 32	92[f]	A-phase power factor (DPFA)[c]
30, 32	93[f]	B-phase power factor (DPFB)[c]
30, 32	94[f]	C-phase power factor (DPFC)[c]
30, 32	95	Power factor (3DPF)[c]
30, 32	96–99	Reserved
30, 32	100[f]	DC Battery 1 voltage (V) (DC1)[c]
30, 32	101	Reserved
30, 32	102[f]	DC Battery 2 voltage (V) (DC2)[c]
30, 32	103	Reserved
30, 32	104[f]	Frequency (Hz) (FREQ)[c]
30, 32	105	Reserved
30, 32	106, 107[e]	A-phase total power in and out (MWh) (MWHAIN, MWHAOUT)[c]

Table 6.10 SEL-451 DNP3 Default Data Map (Sheet 4 of 5)

Object	Indices	Description
30, 32	108, 109[e]	B-phase total power in and out (MWh) (MWHBIN, MWHBOUT)[c]
30, 32	110, 111[e]	C-phase total power in and out (MWh) (MWHCIN, MWHCOUT)[c]
30, 32	112, 113[e]	Three-phase total power in and out (MWh) (3MWHIN, 3MWHOUT)[c]
30, 32	114, 115	Reserved
30, 32	116, 117	Reserved
30, 32	118, 119	Reserved
30, 32	120, 121	Reserved
30, 32	122[c]	A-phase demand current (amps) (IAD)[c]
30, 32	123[c]	B-phase demand current (amps) (IBD)[c]
30, 32	124[c]	C-phase demand current (amps) (ICD)[c]
30, 32	125[c]	Demand zero-sequence current (amps) (IGD)[c]
30, 32	126[c]	Demand negative-sequence current (amps) (3I2D)[c]
30, 32	127	Reserved
30, 32	128–131[e]	A-phase, B-phase, C-phase, and three-phase demand power (MW) (PAD, PBD, PCD, 3PD)[c]
30, 32	132–135	Reserved
30, 32	136–139	Reserved
30, 32	140–143	Reserved
30, 32	144[c]	Peak A-phase demand current (amps) (IAPKD)[c]
30, 32	145[c]	Peak B-phase demand current (amps) (IBPKD)[c]
30, 32	146[c]	Peak C-phase demand current (amps) (ICPKD)[c]
30, 32	147[c]	Peak zero-sequence demand current (amps) (IGPKD)[c]
30, 32	148[c]	Peak negative-sequence demand current (amps) (3I2PKD)[c]
30, 32	149	Reserved
30, 32	150–153[e]	A-phase, B-phase, C-phase and three-phase peak demand power (MW) (PAPKD, PBPKD, PCPKD, 3PPKD)c
30, 32	154–157	Reserved
30, 32	158–161	Reserved
30, 32	162–165	Reserved
30, 32	166–168	Circuit Breaker 1 contact wear percentage multiplied by 100 (B1BCWPA, B1BCWPB, B1BCWPC)[c]
30, 32	169–171	Circuit Breaker 2 contact wear percentage multiplied by 100 (B2BCWPA, B2BCWPB, B2BCWPC)[c]
30, 32	172–175	Reserved
30, 32[g]	176	Fault type (*Table 6.13* and *Table 6.14*)
30, 32[g]	177	Fault targets (Relay Word rows 0 and 1)
30, 32[g]	178[f]	Fault location
30, 32[g]	179[c]	Fault current
30, 32[g]	180[f]	Fault frequency (Hz)
30, 32[g]	181	Fault settings group
30, 32[g]	182	Fault targets (Relay Word row 308)
30, 32[g]	183	Reserved
30, 32[g]	184–186	Fault time in DNP format (high, middle, and low 16 bits)

Table 6.10 SEL-451 DNP3 Default Data Map (Sheet 5 of 5)

Object	Indices	Description
30, 32[g]	187	Reserved
30, 32[g]	188	Three-pole reclose count
30, 32[g]	189–195	Reserved
30, 32	196–227	First 32 automation math variables (AMV001–AMV032)
40, 41	0	Active settings group
40, 41	1	Time-error preload value (TECORR)[h]

[a] SEL-451-4 Relay indices.
[b] Default current scaling DECPLA on magnitudes and scale factor of 100 on angles. Dead band ANADBV on magnitudes and ANADBM on angles.
[c] Analog quantity labels.
[d] Default voltage scaling DECPLV on magnitudes and scale factor of 100 on angles. Dead band ANADBV on magnitudes and ANADBM on angles.
[e] Default miscellaneous scaling DECPLM and dead band ANADBM.
[f] Default scale factor of 100.
[g] Event data shall only be generated for the fault summary information if the relay is operating in single event mode.
[h] In milliseconds, −30000 ≤ time ≤ 30000. Relay Word bit PLDTE asserts for approximately 1.5 cycles after this value is written.

With the base reference map, the Relay Word bits mapped into Objects 1 and 2 are shown in *Table 6.11*. 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 6.11*. 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 smaller number in the range listed in the first column. For example, the index of TLED_4 is 12 (the bit number, 4, plus the smaller number in the range, 8).

Table 6.11 SEL-451 Object 1, 2 Relay Word Bit Mapping (Sheet 1 of 3)

Index Range	Relay Word Bits[a]							
	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	3POBK2	3POLINE	3PLSHT	BK1RS	BK2RS	*	79CY3	BK1LO
39-32	BK2LO	BK1CL	BK2CL	LEADBK0	LEADBK1	LEADBK2	FOLBK0	FOLBK1
47-40	B1OPHA	B1OPHB	B1OPHC	B2OPHA	B2OPHB	B2OPHC	LOPHA	LOPHB
55-48	LOPHC	*	*	*	*	3PO	27APO	27BPO
63-56	27CPO	*	*	*	*	*	*	*
71-64	52ACL1	*	*	52AAL1	*	*	52AA1	52AB1
79-72	52AC1	*	52ACL2	*	*	52AAL2	*	*
87-80	52AA2	52AB2	52AC2	*	*	*	*	*
95-88	*	*	*	*	*	*	*	*
103-96	*	*	*	*	*	*	*	*
111-104	*	*	*	*	*	*	*	*
119-112	*	*	*	*	*	*	*	*
127-120	BM1TRPA	BM1TRPB	BM1TRPC	BM1CLSA	BM1CLSB	BM1CLSC	B1BCWAL	*
135-128	*	B1MSOAL	B1ESOAL	B1PSAL	B1PDAL	B1BITAL	B1MRTAL	B1MRTIN
143-136	BM2TRPA	BM2TRPB	BM2TRPC	BM2CLSA	BM2CLSB	BM2CLSC	B2BCWAL	*

Table 6.11 SEL-451 Object 1, 2 Relay Word Bit Mapping (Sheet 2 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
151-144	*	B2MSOAL	B2ESOAL	B2PSAL	B2PDAL	B2BITAL	B2MRTAL	B2MRTIN
159-152	RTD08ST	RTD07ST	RTD06ST	RTD05ST	RTD04ST	RTD03ST	RTD02ST	RTD01ST
167-160	RTDIN	RTDCOMF	RTDFL	*	RTD12ST	RTD11ST	RTD10ST	RTD09ST
175-168	DC1F	DC1W	DC1G	DC1R	DC2F	DC2W	DC2G	DC2R
183-176	PDEM	QDEM	GDEM	*	*	*	*	*
191-184	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
199-192	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
207-200	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
215-208	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
223-216	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
231-224	*	IN107	1N106	IN105	IN104	IN103	IN102	IN101
239-232	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
247-240	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
255-248	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
263-256	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
271-264	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
279-272	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
287-280	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
295-288	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
303-296	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
311-304	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
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	ASV001
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	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
423-416	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
431-424	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
439-432	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
447-440	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
455-448	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
463-456	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*

Table 6.11 SEL-451 Object 1, 2 Relay Word Bit Mapping (Sheet 3 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
471-464	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
479-472	SALARM	HALARM	BADPASS	CCALARM	CCOK	*	*	*
487-480	*	*	*	*	*	*	*	*
495-488	*	*	*	*	*	*	*	*
503-496	*	*	TIRIG	TUPDH	TSYNCA	TSOK	PMDOK	FREQOK
511-504	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
519-512	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
527-520	OUT216	OUT215	OUT214	OUT213	OUT212	OUT211	OUT210	OUT209
535-528	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
543-536	OUT316	OUT315	OUT314	OUT313	OUT312	OUT311	OUT310	OUT309
551-544	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
559-552	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
567-560	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
575-568	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
583-576	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
591-584	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*
599-592	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
607-600	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
615-608	CCIN25	CCIN26	CCIN27	CCIN28	CCIN29	CCIN30	CCIN31	CCIN32
623-616	CCIN17	CCIN18	CCIN19	CCIN20	CCIN21	CCIN22	CCIN23	CCIN24
631-624	CCIN09	CCIN10	CCIN11	CCIN12	CCIN13	CCIN14	CCIN15	CCIN16
639-632	CCIN01	CCIN02	CCIN03	CCIN04	CCIN05	CCIN06	CCIN07	CCIN08
647-640	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
655-648	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
663-656	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
671-664	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
679-672	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
687-680	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
695-688	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
703-696	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
711-704	FSERP1	FSERP2	FSERP3	FSERP4	*	*	*	*
719-712	ALTI	ALTV	ALTS2	DELAY	*	*	*	*
727-720[b]	89AL	*	89AL1	89OIP1	89OPN1	89CL1	89BM1	89AM1
735-728[b]	89OIP	*	89AL2	89OIP2	89OPN2	89CL2	89BM2	89AM2
743-736[b]	LOCAL	*	89AL3	89OIP3	89OPN3	89CL3	89BM3	89AM3
751-744[b]	*	*	89AL4	89OIP4	89OPN4	89CL4	89BM4	89AM4
759-752[b]	*	*	89AL5	89OIP5	89OPN5	89CL5	89BM5	89AM5

[a] An * denotes reserved for future use.
[b] SEL-451-4 relay indices.

Object 1, 2 indices 1600–1615 represent the front-panel target Relay Word bits as listed in *Table 6.12*.

Table 6.12 Object 1, 2 Indices 1600–1615 Front-Panel Targets

Index	Relay Word Bit	Description
1600	TLED_8	Front-panel target 8
1601	TLED_7	Front-panel target 7
1602	TLED_6	Front-panel target 6
1603	TLED_5	Front-panel target 5
1604	TLED_4	Front-panel target 4
1605	TLED_3	Front-panel target 3
1606	TLED_2	Front-panel target 2
1607	TLED_1	Front-panel target 1
1608	TLED_16	Front-panel target 16
1609	TLED_15	Front-panel target 15
1610	TLED_14	Front-panel target 14
1611	TLED_13	Front-panel target 13
1612	TLED_12	Front-panel target 12
1613	TLED_11	Front-panel target 11
1614	TLED_10	Front-panel target 10
1615	TLED_9	Front-panel target 9

Object 30, Index 176 is a 16-bit composite value, where the upper byte value indicates an event cause as shown in *Table 6.13* and a fault type shown in *Table 6.15*.

Reading Relay Event Data

The SEL-451 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 (not ER and not TRIG) occurs with a the fault location in the range of MINDIST to MAXDIST, this data shall be made available in the DNP fault summary area, generating appropriate DNP events. (If MINDIST is set OFF, then there is no minimum. Similarly, if MAXDIST is set OFF, there is no maximum.) The relay shall than 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 6.10) or point 3 (MAPSEL := E; see *Table 6.10*), 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 6.15*). This will load the relay event summary analogs (points 176 through 181 *Table 6.10*) 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.

Table 6.13 Object 30, 32, Index 176 Upper Byte—Event Cause

Byte Value	Description
1	Trigger command
4	Trip element
8	Event report element

Table 6.14 Object 30, 32, Index 176 Lower Byte—Fault Type

Bit	Description
0	Indeterminate
1	A-phase
2	B-phase
4	C-phase
8	Ground

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 6.15*. Pulse operations provide a pulse with a duration of one protection processing interval.

Table 6.15 SEL-451 Object 12 Trip/Close Pair Operation (Sheet 1 of 2)

Indices	Close	Trip
0–15	Set remote bits RB1–RB16	Clear remote bits RB1–RB16
16	Open Circuit Breaker 1	No action
17	Close Circuit Breaker 1	No action
18	Open Circuit Breaker 2	No action
19	Close Circuit Breaker 2	No action
20–23	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	Pulse CC1, Circuit Breaker 1 close command bit	Pulse OC1, Circuit Breaker 1 open command bit
33	Pulse CC2, Circuit Breaker 2 close command bit	Pulse OC2, Circuit Breaker 2 open command bit
34–35	Reserved	Reserved

Table 6.15 SEL-451 Object 12 Trip/Close Pair Operation (Sheet 2 of 2)

Indices	Close	Trip
36	Reset demands	Reset demands
37	Reset demand peaks	Reset demand peaks
38	Reset energy metering	Reset energy metering
39	Reset breaker monitor	Reset breaker monitor
40	Reset front panel targets	Reset front panel targets
41	Read next relay event	Read next relay event
42	Reset min/max metering	Reset min/max metering
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
65	Pulse RB28	Pulse RB27
66	Pulse RB30	Pulse RB29
67	Pulse RB32	Pulse RB31
68, 70, 72, 74, 76[a]	Open Disconnect Switch 1–5	No action
69, 70, 71, 73, 75, 77[a]	Close Disconnect Switch 1–5	No action
78–87[a]	Pulse 89CC*n*, Disconnect Switch *n* (*n* = 1–10) close bit	Pulse 89OC*n*, Disconnect Switch *n* open bit (*n* = 1–10)
88, 90, 92, 94, 96[a]	Open Disconnect Switch 6–10	No action
89, 91, 93, 95, 97[a]	Close Disconnect Switch 6–10	No action

[a] SEL-451-4 relay indices.

The SEL-451 assigns some special operations to the code portion of the control relay output block command. The special operations are shown in *Table 6.16*. Pulse operations provide a pulse duration of one protection-processing interval.

Table 6.16 SEL-451 Object 12 Code Selection Operation (Sheet 1 of 3)

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 OC1, Circuit Breaker 1 open bit	No action	Pulse OC1, Circuit Breaker 1 open bit	No action
17	Pulse CC1, Circuit Breaker 1 close bit	No action	Pulse CC1, Circuit Breaker 1 close bit	No action
18	Pulse OC2, Circuit Breaker 2 open bit	No action	Pulse OC2, Circuit Breaker 2 open bit	No action

Table 6.16 SEL-451 Object 12 Code Selection Operation (Sheet 2 of 3)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
19	Pulse CC2, Circuit Breaker 2 close bit	No action	Pulse CC2 Circuit Breaker 2 close bit	No action
20–23	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
32	Pulse CC1, Circuit Breaker 1 close bit	Pulse OC1, Circuit Breaker 1 open bit	Pulse CC1, Circuit Breaker 1 close bit	Pulse OC1, Circuit Breaker 1 open bit
33	Pulse CC2, Circuit Breaker 2 close bit	Pulse OC2, Circuit Breaker 2 open bit	Pulse CC2, Circuit Breaker 2 close bit	Pulse OC2, Circuit Breaker 2 open bit
34–35	Reserved	Reserved	Reserved	Reserved
36	Reset demands	No action	Reset demands	No action
37	Reset demand peaks	No action	Reset demand peaks	No action
38	Reset energy metering	No action	Reset energy metering	No action
39	Reset breaker monitor	No action	Reset breaker monitor	No action
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	Reset min/max metering	No action	Reset min/max metering	No action
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

Table 6.16 SEL-451 Object 12 Code Selection Operation (Sheet 3 of 3)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
68, 70, 72, 74, 76[a]	Pulse 89OC*n*, Disconnect Switch *n* (*n* = 1–5) open bit	No action	Pulse 89OC*n*, Disconnect Switch *n* (*n* = 1–5) open bit	No action
69, 71, 73, 75, 77[a]	Pulse 89CC*n*, Disconnect Switch *n* (*n* = 1–5) close bit	No action	Pulse 89CC*n*, Disconnect Switch *n* (*n* = 1–5) close bit	No action
78–87[a]	Pulse 89CC*n*, Disconnect Switch *n* (*n* = 1–10) close bit	Pulse 89OC*n*, Disconnect Switch *n* (*n* = 1–10) open bit	Pulse 89CC*n*, Disconnect Switch *n* (*n* = 1–10) close bit	Pulse 89OC*n*, Disconnect Switch *n* (*n* = 1–10) open bit
88, 90, 92, 94, 96[a]	Pulse 89OC*n*, Disconnect Switch *n* (*n* = 6–10) open bit	No action	Pulse 89OC*n*, Disconnect Switch *n* (*n* = 6–10) open bit	No action
89, 91, 93, 95, 97[a]	Pulse 89CC*n*, Disconnect Switch *n* (*n* = 6–10) close bit	No action	Pulse 89CC*n*, Disconnect Switch *n* (*n* = 6–10) close bit	No action

[a] SEL-451-4 relay indices.

DNP3 (Serial) Application Example

Application

This example uses an SEL-451 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 6.3*.

Figure 6.1 DNP Application Network Diagram

The metering and status data that the RTU collects from the relay are listed in *Table 6.26*.

Table 6.17 DNP3 Application Example Data Map (Sheet 1 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
EN	1, 2	7	1	Relay enabled
TRIPLED	1, 2	6	2	Circuit Breaker tripped
IN101	1, 2	1024	3	Relay Discrete Input 1
IN102	1, 2	1025	4	Relay Discrete Input 2
IN103	1, 2	1026	5	Relay Discrete Input 3
IN104	1, 2	1027	6	Relay Discrete Input 4
SALARM	1, 2	479	7	Relay software alarm
HALARM	1, 2	478	8	Relay hardware alarm
TESTDNP	1, 2	607	9	DNP test mode enabled
RB01	10, 12	0	1	General use Control Point 1
RB02	10, 12	1	2	General use Control Point 2
RB03	10, 12	2	3	General use Control Point 3
RB04	10, 12	3	4	General use Control Point 4
RB05	10, 12	4	5	General use Control Point 5
RB06	10, 12	5	6	General use Control Point 5
CC1, OC1	10, 12	32	7	Circuit Breaker manual trip/close

Table 6.17 DNP3 Application Example Data Map (Sheet 2 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
LIAFM[a], LIAFA[b]	30	0, 1	1, 2	IA magnitude and angle
LIBFM[a], LIBFA[b]	30	2, 3	3, 4	IB magnitude and angle
LICFM[a], LICFA[b]	30	4, 5	5, 6	IC magnitude and angle
VAFM[c], VAFA[b]	30	36, 37	7, 8	VAY magnitude and angle
VBFM[c], VBFA[b]	30	38, 39	9, 10	VBY magnitude and angle
VCFM[c], VCFA[b]	30	40, 41	11, 12	VCY magnitude and angle
3P_f[d]	30	87	6	Three-phase real power in MW
3Q_f[d]	30	91	7	Three-phase reactive power in MVAr
DC1[e]	30	100	8	DC1 voltage multiplied by 100
ACTGRP	40	0	0	Active settings group

[a] Assume the largest expected current is 2000 A, scale the analog value by the 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 MW for change event reporting.
[d] For a maximum load of 800 MW (or 800 mVar), scale the power by a factor of 40 to provide a resolution of 0.025 MW, and a maximum value of 819.175 MW. Report 1 MW for change event reporting.
[e] VDC1 is scaled by a factor of 1/100 for a volt. Report change events on a change of 2 V.

Settings

Figure 6.2 shows how to enter the new map into the relay. Use the **SET D** command and enter N at the prompts shown in *Figure 6.2* 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 10 of the Binary Input Map to advance to the Binary Output Map.

```
A=>SET D <Enter>
DNP

DNP Reference Map Selection

Reference Map Selection (B,E)                        MAPSEL  := B      ? <Enter>

DNP Object Default Map Enables

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)
?   7 <Enter>
2:
?   6 <Enter>
3:
?   1024 <Enter>
4:
?   1025 <Enter>
5:
?   1026 <Enter>
6:
?   1027 <Enter>
7:
?   479 <Enter>
8:
?   478 <Enter>
9:
?   607 <Enter>
10:
?    <Enter>

Binary Output Map
(Index Number)

1:
?   0 <Enter>
2:
?   1 <Enter>
3:
?   2 <Enter>
4:
?   3 <Enter>
5:
?   4 <Enter>
6:
?   5 <Enter>
7:
?   32 <Enter>
8:
?    <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:
?   36 <Enter>
8:
?   37,1,200 <Enter>
9:
?   38 <Enter>
10:
?   39,1,200 <Enter>
11:
?   40 <Enter>
12:
?   41,1,200 <Enter>
13:
?   87,40,40<Enter>
```

(Continued on next page)

(Continued from previous page)

```
14:
?  91,40,40 <Enter>
15:
?  100,,200 <Enter>
16:
?   <Enter>

Analog Output Map
(Index Number)

1:
?  0 <Enter>
2:
?   <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: 6
3: 1024
4: 1025
5: 1026
6: 1027
7: 479
8: 478
9: 607


Binary Output Map
(Index Number)

1: 0
2: 1
3: 2
4: 3
5: 4
6: 5
7: 32


Analog Input Map
(Index Number, Scale Factor, Deadband)

1: 0
2: 1, 1.000, 200
3: 2
4: 3, 1.000, 200
5: 4
6: 5, 1.000, 200
7: 36
8: 37, 1.000, 200
9: 38
10: 39, 1.000, 200
11: 40
12: 41, 1.000, 200
13: 87, 40.000, 40
14: 91, 40.000, 40
15: 100, , 200


Analog Output Map
(Index Number)

1: 0

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

A=>
```

Figure 6.2 SEL-451 Example DNP Map Settings

Table 6.18 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 6.18 SEL-451 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
RTSCTS	N	Hardware handshaking enable
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, tenths, and hundredths of a kilovolt.
DECPLM	2	Scale miscellaneous analog data, multiplying by 100 to send whole numbers and hundredths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master.
STIMEO	10.0	Select/operate time-out
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
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	100	Miscellaneous analog value dead band, based on DECPLM scaling factor
EVELOCK	0	Event summary lock period (0–1,000 seconds)
MINDIST[a]	OFF	Minimum fault location to capture (OFF, -10000–10000)
MAXDIST[a]	OFF	Maximum fault location to capture (OFF, -10000–10000)
ETIMEO	10	Event data confirmation time-out in seconds
UNSOL	N	Unsolicited reporting disabled because polling is polled report-by-exception
MODEM	N	No modem connected to port

[a] MAXDIST must be greater than MINDIST.

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-451 Relay provides a DNP3 Level 2 Slave interface for direct Ethernet network connections to the relay.

Because of the benefits that local- and wide-area networks 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 DNP3 over Ethernet networks.

The specification contains several key recommendations about DNP3 operation over LAN and Wide Area Network (WAN) links. The most significant recommendations are listed below:

- DNP3 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 DNP, are specifically not allowed for DNP3 over Ethernet. 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-451

See *Introduction to DNP3 on page R.6.1* for an introduction to DNP3.

Ethernet Card

Installation of the Ethernet card in an SEL-451 relay provides a high-performance network interface that enables the use of industry-standard SCADA network protocols, including DNP3 Level 2 slave functionality. DNP3 over the SEL-451 Ethernet port 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 DNP3 over Ethernet interface is completely independent of the Serial DNP3 interface, but is just as integrated. In this section, DNP3 over Ethernet is discussed as a function of the SEL-451, with the implication that this refers to the operation of an Ethernet card (with the DNP3 option) installed in an SEL-451.

Data Access

The data access methods listed for Serial DNP3 in Table 6.4 are also available for DNP3 over Ethernet, with the exception of Virtual Terminal classes. *Table 6.19* lists the appropriate settings for DNP3 over Ethernet. The DNP3 master session must be configured for one of the data access methods below.

Table 6.19 DNP3 Over Ethernet Access Methods

Access Method	Master Polling	SEL-451 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 6.19*, you must make a selection for the session's PUNSLnn setting. This setting enables or disables unsolicited data reporting at power up for this session. If your master can send the DNP message to enable unsolicited reporting from the SEL-451, you should set the session's PUNSL*nn* to No.

Please see *DNP3 Settings on page R.6.8* for more information on configuring DNP3 over Ethernet sessions.

Event Data

The same serial DNP event data objects are available for DNP3 over an Ethernet network. However, configuration is slightly different. You can still configure the SEL-451 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, and ECLASSA, you can set the event class for binary, counter, and analog information. Virtual terminal information is not supported for DNP3 over Ethernet 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.

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-451.

For event data collection, you must also consider and enter appropriate settings for dead band and scaling operations on analog points shown in *Table 6.20*. 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.6.41* 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 Ethernet DNP3 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-451 uses the same buffer capacities with DNP3 over Ethernet as through the serial connection, listed in *Table 6.6*.

Time Synchronization

Time synchronization is not supported for DNP3 over the Ethernet port. However, the relay will accept messages that contain a Record Current Time (Function Code 24) request and return a Null Response.

DNP3 Settings

The DNP3 protocol settings that become available for DNP3 on the SEL-451 Ethernet port are shown in *Table 6.20*. The DNP3 protocol settings are for the port assigned to the SEL-451: Port 5. Please keep in mind that any settings for the SEL-451 DNP3 Ethernet port 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 DNP3 over Ethernet:

- 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 the SEL-2032, SEL-2030, or SEL-2020 Communications Processor applications. With the SEL-451, 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, and
- enable or disable controls

Please note that although 10 masters are supported by the SEL-451, 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 SEL-451 settings subdirectory and are associated with the DNPMP*nn* setting of DNP3 Master *nn*, where *nn* is the master's number of the from 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-451 and DNP3 Master 01 will employ the custom mapping file named SET_DNP3.TXT. Mapping files may be used by a single session, multiple sessions, or not at all.

Please see *Custom Data Mapping on page R.6.41* for a discussion of how to configure custom DNP3 maps.

Table 6.20 SEL-451 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

Table 6.20 SEL-451 Ethernet Port DNP3 Protocol Settings (Sheet 2 of 4)

Name	Description	Range	Default
DNPIP01	IP Address for Master 1 (www.xxx.yyy.zzz)	20 Char String	“”
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	“”
…			

Table 6.20 SEL-451 Ethernet Port DNP3 Protocol Settings (Sheet 3 of 4)

Name	Description	Range	Default
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	“”
…			
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

Table 6.20 SEL-451 Ethernet Port DNP3 Protocol Settings (Sheet 4 of 4)

Name	Description	Range	Default
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
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-451 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-451 relay's DNP3 over Ethernet interface also maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations. Please see *Table 6.25* for a list of control points and control methods available in the SEL-451.

When the Ethernet port has been configured to use custom DNP3 maps, the SEL-451 will obtain these maps from the relay's Settings 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 6.21* below 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 ACSELERATOR QuickSet.

Table 6.21 SEL-451 DNP LAN/WAN Map Settings

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 6.25*)	OFF	These settings correlate specific control operations from *Table 6.25* to binary output indexes. A value of OFF indicates no object at that index.
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 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.
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.6.53*).

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

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-451, which has 128 CCIN*x* points, 32 Remote Bits, 16 Remote Bit pairs, controls for 2 Circuit Breakers, and (for the SEL-451-4) 5 Disconnect Switches, are given in *Table 6.22*. 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 BOM000 = 160, BOM001 = 130 to set the first DNP BO point to the remote bit pair RB02/RB01 and the second to RB03.

Table 6.22 SEL-451 Binary Output CPId Values

CPId	Description
0–127	CCIN01–CCIN128
128–159	Remote Bits RB01–RB32
160–175	Remote Bit Pairs RB02/RB01–RB32/RB31
176	Open/Close Pair for Circuit Breaker 1 (OC1/CC1)
177	Open/Close Pair for Circuit Breaker 2 (OC2/CC2)
178–187[a]	Open/Close Pair for Disconnect Switch (*n* = 1–10) (89OC*n*/89CC*n*)

[a] SEL-451-4 devices only.

Analog Outputs

Any of the 256 Analog Output Quantities in the D1 Region, RA001–RA256, can be included in a custom data map. Up to 64 Analog Outputs can be assigned to a custom map. Please note that you must subtract 1 from the Analog Quantity number to get the correct index. For example, if you want to specify RA064, use index 63.

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.

If the DNPMAP setting is set to CUSTOM, then you can specify an additional integer parameter corresponding to a DNPMAP number (1–5) to view each custom DNP3 data map. 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-451 FTP interface. The individual file names associated with the detailed custom map settings follow the DNPMAP*nn*.TXT naming convention.

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 any of the 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.9.33*). You must be familiar with the relay database structure to use the **TEST DB** command effectively; see *Communications Card Database on page R.4.21* for more information.

DNP LAN/WAN Documentation

The following section contains information specific to the DNP LAN/WAN implementation.

Device Profile

Table 6.23 contains the standard DNP3 over Ethernet device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table 6.23 SEL-451 DNP LAN/WAN Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-451 Relay with Ethernet card
Highest DNP request level	Level 2
Highest DNP 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	No
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 6.23 SEL-451 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 6.24* lists the supported objects for DNP LAN/WAN. Note the added support of object 34, and removed support of objects 112 and 113.

Table 6.24 SEL-451 DNP3 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 6.24 SEL-451 DNP3 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 6.24 SEL-451 DNP3 Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	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 6.24 SEL-451 DNP3 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]
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 6.24 SEL-451 DNP3 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 6.24 SEL-451 DNP3 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 6.25*. 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 6.25 SEL-451 DNP LAN/WAN Object 12 Control Point Operation

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
...							
143	RB16	SET remote bit RB16	CLEAR remote bit RB16	SET remote bit RB16	CLEAR remote bit RB16	SET remote bit RB16	CLEAR remote bit RB16
144	RB17	SET remote bit RB17	CLEAR remote bit RB17	SET remote bit RB17	CLEAR remote bit RB17	SET remote bit RB17	CLEAR remote bit RB17
...							
159	RB32	SET remote bit RB32	CLEAR remote bit RB32	SET remote bit RB32	CLEAR remote bit RB32	SET remote bit RB32	CLEAR remote bit RB32
160	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
161	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
162	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
...							
167	RB16/RB15	PULSE remote bit RB16	PULSE remote bit RB15	PULSE remote bit RB16	PULSE remote bit RB15	PULSE remote bit RB16	PULSE remote bit RB15
168	RB18/RB17	PULSE remote bit RB18	PULSE remote bit RB17	PULSE remote bit RB18	PULSE remote bit RB17	PULSE remote bit RB18	PULSE remote bit RB17
...							
175	RB32/RB31	PULSE remote bit RB32	PULSE remote bit RB31	PULSE remote bit RB32	PULSE remote bit RB31	PULSE remote bit RB32	PULSE remote bit RB31
176	CB1	PULSE CC1, Circuit Breaker 1 close bit	PULSE OC1, Circuit Breaker 1 open bit	PULSE OC1, Circuit Breaker 1 open bit	PULSE CC1, Circuit Breaker 1 close bit	PULSE OC1, Circuit Breaker 1 open bit	PULSE CC1, Circuit Breaker 1 close bit
177	CB2	PULSE CC2, Circuit Breaker 2 close bit	PULSE OC2, Circuit Breaker 2 open bit	PULSE OC2, Circuit Breaker 2 open bit	PULSE CC2, Circuit Breaker 2 close bit	PULSE OC2, Circuit Breaker 2 open bit	PULSE CC2, Circuit Breaker 2 close bit
178–187[a]	Dis*n*	PULSE 89CC*n*, Disconnect Switch *n* (*n* = 1–10) close bit	PULSE 89OC*n*, Disconnect Switch *n* (*n* = 1–10) open bit	PULSE 89OC*n*, Disconnect Switch *n* (*n* = 1–10) open bit	PULSE 89CC*n*, Disconnect Switch *n* (*n* = 1–10) close bit	PULSE 89OC*n*, Disconnect Switch *n* (*n* = 1–10) open bit	PULSE 89CC*n*, Disconnect Switch *n* (*n* = 1–10) close bit

[a] SEL-451-4 devices only

DNP LAN/WAN Application Example

Application

This example uses an SEL-451 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 6.3*.

Figure 6.3 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-451 slave, has an IP address of 192.9.0.1 and a DNP3 address of 12. The SEL-451 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 6.26*.

Table 6.26 DNP LAN/WAN Application Example Custom Data Map (Sheet 1 of 2)

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	DNP 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

Table 6.26 DNP LAN/WAN Application Example Custom Data Map
(Sheet 2 of 2)

Name	Object Type	Custom Map Index	Description
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) 5
OC1/ CC1	Binary Output	6	Circuit Breaker 1 trip/close
IA1[a,b]	Analog Input	0, 1	Line phase A current magnitude and phase angle
IB1[a,b]	Analog Input	2, 3	Line phase B current magnitude and phase angle
IC1[a,b]	Analog Input	4, 5	Line phase C current magnitude and phase angle
VA[c,b]	Analog Input	6, 7	Phase A current magnitude and phase angle
VB[c,b]	Analog Input	8, 9	Phase B current magnitude and phase angle
VC[c,b]	Analog Input	10, 11	Phase C current magnitude and phase angle
P[d]	Analog Input	12	Total real power in MW
Q[d]	Analog Input	13	Total reactive power in MVAr
VDC1[e]	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] For a maximum load of 800 MW (or 800 mVar), scale the power by a factor of 40 to provide a resolution of 0.025 MW, and a maximum value of 8193.175 MW. Report 1 MW for change event reporting.
[e] VDC1 is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

Settings

Use the ACSELERATOR QuickSet SEL-5030 software to enter the DNP3 protocol settings and new data map into the relay.

Table 6.27 DNP LAN/WAN Application Example Protocol Settings
(Sheet 1 of 2)

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

Table 6.27 DNP LAN/WAN Application Example Protocol Settings
(Sheet 2 of 2)

Setting Name	Setting	Description
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. (102=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

To meet the requirement for SOE-quality timestamps, enter all binary inputs into the SER report. See *Figure 6.4* for a screenshot of the process.

Figure 6.4 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 6.28*.

Table 6.28 DNP LAN/WAN Application Example Binary Input 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 6.29 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	176	Custom BO map position for Circuit Breaker 1 trip/close control

Table 6.30 DNP LAN/WAN Application Example Analog Input Map

Setting Name	Point	Scale Factor	Deadband	Description
AIM0000 Database Address	1:METER:IA1 (Meter Region > IA1)	1	50	Custom map position for IA1 magnitude, scale by 10 and report 5 amp change events
AIM0001 Database Address	1:100Ch			Custom map position for IA1 angle[a], scale by 100 and report 2 degree change events
AIM0002 Database Address	1:METER:IB1 (Meter Region > IB1)	1	50	Custom map position for IB1 magnitude[a], scale by 10 and report 5 amp change events
AIM0003 Database Address	1:1010h			Custom map position for IB1 angle[a], scale by 100 and report 2 degree change events
AIM0004 Database Address	1:METER:IC1 (Meter Region > IC1)	1	50	Custom map position for IC1 magnitude[a], scale by 10 and report 5 amp change events
AIM0005 Database Address	1:1014h			Custom map position for IC1 angle[a], scale by 100 and report 2 degree change events
AIM0006 Database Address	1:METER:VA (Meter Region > VA)	1	10000	Custom map position for VA magnitude, scale by 10 and report 1 kv change events
AIM0007 Database Address	1:103Ch			Custom map position for VA angle[a], scale by 100 and report 2 degree change events
AIM0008 Database Address	1:METER:VB (Meter Region > VB)	1	10000	Custom map position for VB magnitude, scale by 10 and report 1 kv change events
AIM0009 Database Address	1:1040h			Custom map position for VB angle[a], scale by 100 and report 2 degree change events
AIM0010 Database Address	1:METER:VC (Meter Region > VC)	1	10000	Custom map position for VC magnitude, scale by 10 and report 1 kv change events
AIM0011 Database Address	1:1044h			Custom map position for VC angle[a], scale by 100 and report 2 degree change events
AIM0012 Database Address	1:METER:P (Meter Region > P)	3	500	Custom map position for three-phase real power in MW scaled by 1000 with an event dead band of 0.5 MW
AIM0013 Database Address	1:METER:Q (Meter Region > Q)	3	500	Custom map position for three-phase real power in MW scaled by 1000 with an event dead band of 0.5 MW
AIM0014 Database Address	1:METER:VDC1 (Meter Region > VDC1)			DC1 voltage[a] multiplied by 100, with a dead band of 2 volts

[a] Uses default scaling and dead band

Table 6.31 DNP LAN/WAN Application Example Analog Output Map

Setting Name	Setting	Description
AOM0000 Database Address	0	Active Settings Group

Section 7

Synchrophasors

The SEL-451 provides Phasor Measurement Unit (PMU) capabilities when connected to a suitable IRIG-B time source. Synchrophasor is used as a general term that can refer to data or protocols.

This section covers:

- *Introduction on page R.7.1*
- *Synchrophasor Measurement on page R.7.3*
- *Settings for Synchrophasors on page R.7.6*
- *Synchrophasor Relay Word Bits on page R.7.14*
- *Synchrophasor Analog Quantities on page R.7.14*
- *View Synchrophasors by Using the MET PM Command on page R.7.16*
- *C37.118 Synchrophasor Protocol on page R.7.18*
- *SEL Fast Message Synchrophasor Protocol on page R.7.24*
- *Synchrophasor Protocols and SEL Fast Operate Commands on page R.7.30*

See *Configuring High-Accuracy Timekeeping on page U.4.73* for the requirements of the IRIG-B time source. Synchrophasors are still measured if the high-accuracy time source is not connected, however, the data is not time-synchronized to any external reference, as indicated by Relay Word bit TSOK = logical 0.

Introduction

The word synchrophasor is derived from two words: synchronized phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as a number of SEL-451 relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other off-line analysis functions, which are described in *Section 4: Time-Synchronized Measurements in the Applications Handbook*.

The SEL-451 Global settings class contains the synchrophasor settings, including the choice of synchrophasor protocol and the synchrophasor data set the relay will transmit. The Port settings class selects which serial port(s) are reserved for synchrophasor protocol use. See *Settings for Synchrophasors on page R.7.6*.

The SEL-451 High-Accuracy Timekeeping function generates status Relay Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELOGIC variables, and programmable digital trigger information (C37.118 protocol only) is also added to the Relay Word bits for synchrophasors—see *Synchrophasor Relay Word Bits on page R.7.14*.

When synchrophasor measurement is enabled, the SEL-451 creates the synchrophasor data set at a rate of either 50 or 60 times per second, depending on the nominal system frequency (Global setting NFREQ). This data set, including time-of-sample, is available in analog quantities in the SEL-451. See *Synchrophasor Analog Quantities on page R.7.14*. You can view synchrophasor data over a serial port set to PROTO := SEL, see *View Synchrophasors by Using the MET PM Command on page R.7.16*.

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. Two synchrophasor protocols are available in the SEL-451 that allow for a centralized device to collect data efficiently from several phasor measurement units (PMUs). Some possible uses of a system-wide synchrophasor system include the following:

- Power-system state measurement
- Wide-area network protection and control schemes
- Small-signal analysis
- Power-system disturbance analysis

The SEL-3306 Synchrophasor Processor is a PC-based communications processor specifically designed to interface with PMUs. The SEL-3306 has two primary functions. The first is to collect and correlate synchrophasor data from multiple PMUs. The second is to then compact and transmit synchrophasor data either to a data historian for post-analysis or to visualization software for real-time viewing of a power system.

Previous SEL-451 relays (firmware version R102 and R103) provided the SEL Fast Message synchrophasor protocol. SEL-451 relays, beginning with firmware version R104, still support this protocol, although the required settings are in a different settings class, and a few message rates are no longer supported—see *SEL-451 Fast Message Synchrophasor Settings on page R.7.25*.

Beginning with firmware version R104, the SEL-451 also supports IEEE C37.118, Standard for Synchrophasors for Power Systems. In the SEL-451, this protocol is referred to simply as C37.118. See *Settings Affect Message Contents on page R.7.18*.

In any installation, the SEL-451 can use only one of the synchrophasor protocols, SEL Fast Message Synchrophasor, or C37.118, as selected by Global setting MFRMT. However, the chosen protocol is available on multiple serial ports when port setting(s) PROTO := PMU.

With either the SEL Fast Message or C37.118 synchrophasor protocol, the SEL-451 can receive control operation commands over the same channel used for synchrophasor data transmission. These commands are SEL Fast Operate messages, which are described in *SEL Fast Meter, Fast Operate, and Fast SER Messages on page R.5.8*.

Synchrophasor Measurement

NOTE: The synchrophasor data stream is separate from the other protection and metering functions, as shown in Figure 3.1 on page A.3.3.

The phasor measurement unit in the SEL-451 measures three voltages and six currents on a constant-time basis. These samples are synchronized to the high-accuracy IRIG time source, and occur at a fixed frequency of either 60 Hz or 50 Hz, depending on Global setting NFREQ. The relay then filters the measurement samples according to Global setting PMAPP := F or N—see *PMAPP on page R.7.6*. The phase angle is measured relative to an absolute time reference, which is represented by a cosine function in *Figure 7.1*. The time-of-day is shown for the two time marks.

Figure 7.1 High Accuracy Clock Controls Reference Signal (60 Hz System)

The instrumentation transformers (pts or cts) and the interconnecting cables may introduce a time shift in the measured signal. Global settings VCOMP, IWCOMP, and IXCOMP, entered in degrees, are added to the measured phasor angles to create the corrected phasor angles, as shown in *Figure 7.2*, *Figure 7.3*, and *Equation 7.1*. The VCOMP, IWCOMP, and IXCOMP settings may be positive or negative values.

Figure 7.2 Waveform at Relay Terminals May Have a Phase Shift

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{freq_{nominal}}\right)} \bullet 360° = \Delta t_{pt} \bullet freq_{nominal} \bullet 360°$$

Equation 7.1

If the time shift on the pt measurement path $\Delta t_{pt} = 0.784$ ms and the nominal frequency, $freq_{nominal} = 60$Hz, use *Equation 7.2* to obtain the correction angle:

$$0.784 \bullet 10^{-3}s \bullet 60s^{-1} \bullet 360° = 16.934°$$

Equation 7.2

Figure 7.3 Correction of Measured Phase Angle

For a sinusoidal signal, the phasor magnitude is calculated as shown in *Equation 7.3*. The phasors are rms values scaled in primary units, as determined by Group settings PTRY or PTRZ (for the presently selected line voltage source, VY or VZ, respectively), CTRW, and CTRX (for the IW and IX current sources). The SEL-451 then creates the summation quantities IS = IW + IX phase currents, and calculates the positive-sequence voltage V1LPM_ and currents I1WPM_, I1XPM_, and I1SPM_.

$$\text{Magnitude M} = \frac{V_{pk}}{\sqrt{2}} \bullet PTR_{setting}$$

Equation 7.3

With PTRY = 2000, and the signal in *Figure 7.2* (with peak voltage V_{pk} = 94.851 V), use *Equation 7.4* to obtain the magnitude, VALPMM:

$$\begin{aligned} VALPMM &= \frac{94.851}{\sqrt{2}} \bullet 2000 \\ &= 134140 \text{ V} \\ &= 134.140 \text{ kV} \end{aligned}$$

Equation 7.4

Finally, the magnitude and angle pair for each synchrophasor is converted to a real and imaginary pair using *Equation 7.5* and *Equation 7.6*. For example, analog quantities VALPMM and VALPMA are converted to VALPMR and VALPMI. An example phasor with an angle measurement of 104.400° is shown in *Figure 7.4*. *Table 7.11* lists all of the synchrophasor analog quantities available in the SEL-451.

Figure 7.4 Example Calculation of Real and Imaginary Components of Synchrophasor

$$\text{Real part} = M \bullet \cos(\text{angle})$$ **Equation 7.5**

$$\text{Imaginary part} = M \bullet \sin(\text{angle})$$ **Equation 7.6**

Using the magnitude M from *Equation 7.5*, the real part is given in *Equation 7.7*.

$$\begin{aligned} VALPMR &= 134.140\ \text{kV} \bullet \cos 104.400° \\ &= -33.359\ \text{kV} \end{aligned}$$ **Equation 7.7**

Similarly, the imaginary part is calculated in *Equation 7.8*

$$\begin{aligned} VALPMI &= 134.140\ \text{kV} \bullet \sin 104.400° \\ &= 129.926\ \text{kV} \end{aligned}$$ **Equation 7.8**

Because the sampling reference is based on the GPS clock (IRIG-B signal) and not synchronized to the power system, an examination of successive synchrophasor data sets will almost always show some angular change between samples of the same signal. This is not a malfunction of the relay or the power system, but is merely a result of viewing data from one system with an instrument with an independent time base. In other words, a power system has a nominal frequency of either 50 or 60 Hz, but on closer examination, it is usually running a little faster or slower than nominal.

Accuracy

The listed SEL-451 phasor measurement accuracy is valid when frequency-based phasor compensation is enabled (Global setting PHCOMP := Y), and when the phasor measurement application setting is in the narrow bandwidth mode (Global setting PMAPP := N).

See IEEE C37.118 for an explanation of total vector error and for accuracy definitions and conditions.

The SEL-451 synchrophasor measurement accuracy is:

NOTE: When the SEL-451 is in the fast response mode (Global setting PMAPP := F), the TVE is within specified limits only when the out of band interfering signals influence quantity is not included.

TVE (total vector error) ≤ 1% for one or more of the following influence quantities:

- Signal Frequency Range: ±5 Hz of nominal (50Hz or 60Hz)
- Voltage Magnitude Range: 30 V to150 V
- Current Magnitude Range: (0.1–2) • I_{nom}, (I_{nom} = 1A or 5A)
- Phase Angle Range: –179.99 to 180°
- Harmonic distortion ≤10% (any harmonic)
- Out of band interfering signals ≤ 10%

The out of band interfering signal frequency (f_i) must satisfy:

$$| f_i - NFREQ | > MRATE/2,$$

where NFREQ is nominal system frequency and MRATE is the message rate, as defined in IEEE C37.118.

Settings for Synchrophasors

The phasor measurement unit (PMU) settings are listed in *Table 7.1*. Make these settings when you want to use the C37.118 synchrophasor protocol, or if you want to use synchrophasor analog quantities.

The Global enable setting EPMU must be set to Y before the remaining SEL-451 synchrophasor settings are available. No synchrophasor data collection can take place when EPMU := N.

You must make the serial port settings in *Table 7.3* to transmit data with a synchrophasor protocol. It is possible to set EPMU := Y without using any serial ports for synchrophasor protocols. For example, the serial port **MET PM** ASCII command can still be used.

The global settings for the SEL Fast Message synchrophasor protocol are a subset of the *Table 7.1* settings, and are listed separately, see *SEL Fast Message Synchrophasor Protocol on page R.7.24*.

Table 7.1 PMU Settings in the SEL-451 for C37.118 Protocol in Global Settings (Sheet 1 of 2)

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b]	C37.118
MRATE	Messages per Second {1, 2, 5, 10, 25, or 50 when NFREQ := 50} {1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ := 60}	2
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	STATION A
PMID	PMU Hardware ID (1–65534)	1
PHDATAV	Phasor Data Set, Voltages (V1, ALL, NA)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI	Phasor Data Set, Currents (I1, ALL, NA)	NA
PHCURR[c]	Current Source (IW, IX, BOTH, COMB)	IW
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	0.00
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHNR[d]	Phasor Numeric Representation (I = Integer, F = Floating point)	I
PHFMT[d]	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMANA	Number of Analog Values (0–8)	0
NUMDSW	Number of 16-bit Digital Status Words (0, 1, 2)	1
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)	NA

Table 7.1 PMU Settings in the SEL-451 for C37.118 Protocol in Global Settings (Sheet 2 of 2)

Setting	Description	Default
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)	NA
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)	NA
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)	NA
PMTRIG	Trigger (SELOGIC Equation)	NA

[a] Set EPMU := Y to access the remaining settings
[b] C37.118 = IEEE C37.118 Standard; FM := SEL Fast Message—see Table 7.17.
[c] Setting hidden when PHDATAI := NA
[d] Setting hidden when PHDATAV := NA and PHDATAI := NA

Table 7.2 Time and Date Management

Label	Prompt	Default Value
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When MFRMT := C37.118, IRIGC is forced to C37.118.

Certain settings in *Table 7.1* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the PHCURR setting is hidden to limit the number of settings for your synchrophasor application.

The Port settings for PROTO := PMU, shown in *Table 7.3*, do not include the settings DATABIT and PARITY; these two settings are internally fixed as DATABIT := 8, PARITY := N (None). See *Data Frame on page R.5.2* for descriptions of these functions.

Table 7.3 SEL-451 Serial Port Settings for Synchrophasors

Setting	Description	Default
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)[a, b]	SEL[c]
SPEED	Data Speed (300 to 57600)	9600
STOPBIT	Stop Bits (1, 2)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Enable Fast Operate Messages (Y, N)	N

[a] Some of the other PROTO setting choices may not be available.
[b] Setting choice PMU is not available on PORT 5.
[c] Set PROTO := PMU to enable (on this port) the synchrophasor protocol selected by Global setting MFRMT.

PROTO := PMU Does Not Allow Commands on That Serial Port

The PROTO := PMU settings choice in *Table 7.3* can be made even when Global setting EPMU := N. However, in this situation, the serial port will not respond to any commands or requests. Either enable synchrophasors by making the *Table 7.1* settings, or change the port PROTO setting to SEL.

If you use a computer terminal session or ACSELERATOR QuickSet® SEL-5030 Software connected to a serial port, and then set that same serial port PROTO setting to PMU, you will lose the ability to communicate with the relay through ASCII commands or virtual file interface commands. If this happens, either connect via another serial port (that has PROTO := SEL) or use the front-panel HMI SET/SHOW screen to change the disabled port PROTO setting back to SEL.

Table 7.4 SEL-451 Ethernet Port Settings for Synchrophasors

Setting	Description	Default
EPMIP	Enable PMU Processing (Y,N)	N
PMOTS1	PMU Output 1 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMOIPA1	PMU Output 1 Client IP (Remote) Address (www.xxx.yyy.zzz)	OFF
PMOTCP1	PMU Output 1TCP/IP (Local) Port Number (1–65534)	4712
PMOUDP1	PMU Output 1 UDP/IP Data (Remote) Port Number (1–65534)	4713
PMOTS2	PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMOIPA2	PMU Output 2 Client IP (Remote) Address (www.xxx.yyy.zzz)	OFF
PMOTCP2	PMU Output 2 TCP/IP (Local) Port Number (1–65534)	4722
PMOUDP2	PMU Output 2 UDP/IP Data (Remote) Port Number (1–65534)	4713

Descriptions of Synchrophasor Settings

Definitions for some of the settings in *Table 7.1* are as follows:

MFRMT

Selects the message format for synchrophasor data streaming on serial ports.

SEL recommends the use of MFRMT := C37.118 for any new PMU applications because of increased setting flexibility and the expected availability of software for synchrophasor processors. The SEL-451 still includes the MFRMT := FM setting choice to maintain compatibility in any systems presently using SEL Fast Message synchrophasors.

MRATE

Selects the message rate in messages per second for synchrophasor data streaming on serial ports.

Choose the MRATE setting that suits the needs of your PMU application. This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page R.7.18* for detailed information.

PMAPP

Selects the type of digital filters used in the synchrophasor algorithm:

- The Narrow Bandwidth setting (N) represents filters with a cutoff frequency approximately ¼ of MRATE. The response in the frequency domain is narrower, and response in the time domain is slower. This method results in synchrophasor data that are free of aliasing signals and well suited for post-disturbance analysis.

- The Fast Response setting (F) represents filters with a higher cutoff frequency. The response in frequency domain is wider and the response in the time domain is faster. This method results in synchrophasor data that can be used in synchrophasor applications requiring more speed in tracing system parameters.

PHCOMP

Enables or disables frequency-based compensation for synchrophasors.

For most applications, set PHCOMP := Y to activate the algorithm that compensates for the magnitude and angle errors of synchrophasors for frequencies that are off nominal. Use PHCOMP := N if you are concentrating the SEL-451 synchrophasor data with other PMU data that do not employ frequency compensation.

PMSTN and PMID

Defines the name and number of the PMU.

NOTE: The PMSTN setting is not the same as the SEL-451 Global setting SID (Station Identifier), even though they share the same factory default value.

The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHDATAV and VCOMP

PHDATAV selects which voltage synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.18* for detailed information.

- PHDATAV := V1 will transmit only positive-sequence voltage, V_1
- PHDATAV := ALL will transmit V_1, V_A, V_B, and V_C
- PHDATAV := NA will not transmit any voltages

Table 7.5 describes the order of synchrophasors inside the data packet.

NOTE: The SEL-451 only provides one VCOMP setting, which is applied to both the main or alternate voltage sources VY or VZ; respectively. See Voltage Source Switching and Uses on page R.1.6.

The VCOMP setting allows correction for any steady-state voltage phase errors (from the potential transformers or wiring characteristics). See *Synchrophasor Measurement on page R.7.3* for details on this setting.

PHDATAI, PHCURR, IWCOMP, and IXCOMP

PHDATAI and PHCURR select which current synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. These settings are two of the eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.18* for detailed information.

- PHDATAI := I1 will transmit only positive-sequence current, I_1
- PHDATAI := ALL will transmit I_1, I_A, I_B, and I_C
- PHDATAI := NA will not transmit any currents

PHCURR selects the source current(s) for the synchrophasor data selected by PHDATAI.

- PHCURR := IW uses the currents measured on the IAW, IBW, and ICW inputs
- PHCURR := IX uses the currents measured on the IAX, IBX, and ICX inputs
- PHCURR := COMB uses the summation of the currents measured on the inputs: IAS = IAW + IAX, IBS = IBW + IBX, and ICS = ICW + ICX
- PHCURR:= BOTH uses the currents measured on both the I_W inputs and I_X inputs

Table 7.5 describes the order of synchrophasors inside the data packet.

The IWCOMP and IXCOMP settings allow correction for any steady-state phase errors (from the current transformers or wiring characteristics). See *Synchrophasor Measurement on page R.7.3* for details on these settings.

Table 7.5 Synchrophasor Order in Data Stream (Voltages and Currents)

Synchrophasors[a] (Analog Quantity Names)				Included When Global Settings are as follows:
Polar[b]		Rectangular[c]		
Magnitude	Angle	Real	Imaginary	
V1LPMM	V1LPMA	V1LPMR	V1LPMI	PHDATAV := V1 or ALL
VALPMM	VALPMA	VALPMR	VALPMI	PHDATAV := ALL
VBLPMM	VBLPMA	VBLPMR	VBLPMI	
VCLPMM	VCLPMA	VCLPMR	VCLPMI	
I1WPMM	I1WPMA	I1WPMR	I1WPMI	PHDATAI := I1 or ALL **AND** (PHCURR := IW or BOTH)
IAWPMM	IAWPMA	IAWPMR	IAWPMI	PHDATAI := ALL **AND** (PHCURR := IW or BOTH)
IBWPMM	IBWPMA	IBWPMR	IBWPMI	
ICWPMM	ICWPMA	ICWPMR	ICWPMI	
I1XPMM	I1XPMA	I1XPMR	I1XPMI	(PHDATAI := I1 or ALL) **AND** (PHCURR := IX or BOTH)
IAXPMM	IAXPMA	IAXPMR	IAXPMI	PHDATAI := ALL **AND** (PHCURR := IX or BOTH)
IBXPMM	IBXPMA	IBXPMR	IBXPMI	
ICXPMM	ICXPMA	ICXPMR	ICXPMI	
I1SPMM	I1SPMA	I1SPMR	I1SPMI	(PHDATAI := I1 or ALL) **AND** PHCURR := COMB
IASPMM	IASPMA	IASPMR	IASPMI	PHDATAI := ALL **AND** PHCURR := COMB
IBSPMM	IBSPMA	IBSPMR	IBSPMI	
ICSPMM	ICSPMA	ICSPMR	ICSPMI	

[a] Synchrophasors are included in the order shown (i.e., voltages, if selected, will always precede currents).
[b] Polar coordinate values are sent when PHFMT := P.
[c] Rectangular (real and imaginary) values are sent when PHFMT := R.

PHNR

Selects the numeric representation of voltage and current phasor data in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.18* for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHNR := I sends each voltage and/or current synchrophasor as 2 two-byte integer values. In this representation, synchrophasor current measurements have an upper limit of $7 \bullet I_{nom}$, where I_{nom} = 1 A or 5 A, depending on the current input rating—see *Secondary Circuits on page U.2.5*.

Setting PHNR := F sends each voltage and/or current synchrophasor as 2 four-byte floating-point values.

The PHFMT setting determines the format of the data.

PHFMT

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHFMT := R (rectangular) sends each voltage and/or current synchrophasor as a pair of signed real and imaginary values.

Setting PHFMT := P (polar) sends each voltage and/or current synchrophasor as a magnitude and angle pair. The angle is in radians when PHNR := F, and in radians $\bullet 10^4$ when PHNR := I. The range is as follows:

$$-\pi < \text{angle} <= \pi.$$

In both the rectangular and polar representations, the values are scaled in rms (root mean square) units. For example, a synchrophasor with a magnitude of 1.0 at an angle of –30 degrees will have a real component of 0.866, and an imaginary component of –0.500. See *Synchrophasor Measurement on page R.7.3* for a sample conversion between polar and rectangular coordinates.

FNR

Selects the numeric representation of the two frequency values in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.18* for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting FNR := I sends the frequency data as a difference from nominal frequency, NFREQ, with the following formula:

$$(FREQ_{measured} - NFREQ) \bullet 1000,$$

represented as a signed, two-byte value.

Setting FNR := I also sends the rate-of-change of frequency data with scaling.

$DFDT_{measured} \bullet 100$,

represented as a signed, two-byte value.

Setting FNR := F sends the measured frequency data and rate-of-change-of-frequency as two four-byte, floating point values.

NUMANA

Selects the number of user-definable analog values to be included in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.18* for detailed information.

The choices for this setting depend on the synchrophasor system design.

Setting NUMANA := 0 sends no user-definable analog values.

Setting NUMANA := 1–8 sends the user-definable analog values, as listed in *Table 7.6*.

The format of the user-defined analog data is always floating point, and each value occupies four bytes.

Table 7.6 User-Defined Analog Values Selected by the NUMANA Setting

NUMANA Setting	Analog Quantities Sent	Total Number of Bytes Used for Analog Values
0	None	0
1	PMV64	4
2	Above, plus PMV63	8
3	Above, plus PMV62	12
4	Above, plus PMV61	16
5	Above, plus PMV60	20
6	Above, plus PMV59	24
7	Above, plus PMV58	28
8	Above, plus PMV57	32

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.18* for detailed information.

The choices for this setting depend on the synchrophasor system design. The inclusion of binary data can help indicate breaker status or other operational data to the synchrophasor processor. See *PMU Setting Example on page R.7.20* for a suggested use of the digital status word fields.

Setting NUMDSW := 0 sends no user-definable binary status words.

Setting NUMDSW := 1 or 2 sends the user-definable binary status words, as listed in *Table 7.7*.

Table 7.7 User-Defined Digital Status Words Selected by the NUMDSW Setting

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
0	None	0
1	[PSV64, PSV63.....PSV49]	2
2	[PSV64, PSV63.....PSV49] [PSV48, PSV47.....PSV33]	4

TREA1, TREA2, TREA3, TREA4, and PMTRIG

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations in the Global settings class. The SEL-451 evaluates these equations and places the results in Relay Word bits with the same names: TREA1–TREA4, and PMTRIG.

NOTE: The PM Trigger function is not associated with the SEL-451 Event Report Trigger ER, a SELOGIC control equation in the Group settings class.

The trigger reason equations represent the Trigger Reason bits in the STAT field of the data packet. After the trigger reason bits are set to convey a message, the PMTRIG Equation should be asserted for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The IEEE C37.118 standard defines the first eight of 16 binary combinations of these trigger reason bits (bits 0–3).

The remaining eight binary combinations are available for user definition.

Table 7.8 PM Trigger Reason Bits—IEEE C37.118 Assignments

TREA4	TREA3	TREA2	TREA1		Meaning[a]
(bit 3)	(bit 2)	(bit 1)	(bit 0)	Hexadecimal	
0	0	0	0	0x00	Manual
0	0	0	1	0x01	Magnitude Low
0	0	1	0	0x02	Magnitude High
0	0	1	1	0x03	Phase Angle Diff.
0	1	0	0	0x04	Frequency High/Low
0	1	0	1	0x05	df/dt High
0	1	1	0	0x06	Reserved
0	1	1	1	0x07	Digital
1	0	0	0	0x08	User
1	0	0	1	0x09	User
1	0	1	0	0x0A	User
1	0	1	1	0x0B	User
1	1	0	0	0x0C	User
1	1	0	1	0x0D	User
1	1	1	0	0x0E	User
1	1	1	1	0x0F	User

[a] When PMTRIG is asserted. The terminology comes from IEEE C37.118.

The SEL-451 does not automatically set the TREA1–TREA4 or PMTRIG Relay Word bits—these bits must be programmed.

These bits may be used to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The SEL-451 synchrophasor processing and protocol transmission are not affected by the status of these bits.

Synchrophasor Relay Word Bits

Table 7.9 and *Table 7.10* list the SEL-451 Relay Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Relay Word bits in *Table 7.9* follow the state of the SELOGIC control equations of the same name, listed at the bottom of *Table 7.1*. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table 7.7* for standard definitions for these settings.

Table 7.9 Synchrophasor Trigger Relay Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC Equation).
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)

The Time Synchronization Relay Word bits in *Table 7.10* indicate the present status of the high-accuracy timekeeping function of the SEL-451. See *Configuring High-Accuracy Timekeeping on page U.4.73*.

Table 7.10 Time Synchronization Relay Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
TSOK	Time Synchronization OK. Asserts while time is based on high-accuracy IRIG-B time source (HIRIG mode) of sufficient accuracy for synchrophasor measurement.
PMDOK	Phasor Measurement Data OK. Asserts when the SEL-451 is enabled and synchrophasors are enabled (Global setting EPMU := Y).

Synchrophasor Analog Quantities

Table 7.11 lists the synchrophasor analog quantities in the SEL-451 relay.

See *Frequency Estimation on page R.1.14* for more information.

The synchrophasor measurements in *Table 7.11* are available whenever Global setting EPMU := Y. When EPMU := N, these analog quantities are set to 0.0000.

It is important to note that the synchrophasors are only valid when the relay is in HIRIG timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the SEL-451 timekeeping is synchronized to the high-accuracy IRIG-B signal, and the synchrophasor data is precisely time-stamped.

Table 7.11 Synchrophasor Analog Quantities (Sheet 1 of 2)

Name	Description	Units
Frequency		
FREQ_PM	Measured system frequency[a]	Hz
DFDT	Rate-of-change of frequency, df/dt[a]	Hz/s
Synchrophasor Measurements		
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude (I_W terminals)	A[b]
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle (I_W terminals)	degrees
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current, real component (I_W terminals)	A[b]
IAWPMI, IBWPMI, ICWPMI	Synchrophasor current, imaginary component (I_W terminals)	A[b]
IAXPMM, IBXPMM, ICXPMM	Synchrophasor current magnitude (I_X terminals)	A[b]
IAXPMA, IBXPMA, ICXPMA	Synchrophasor current angle (I_X terminals)	degrees
IAXPMR, IBXPMR, ICXPMR	Synchrophasor current, real component (I_X terminals)	A[b]
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current, imaginary component (I_X terminals)	A[b]
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude (I_W + I_X terminals)	A[b]
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMR, IBSPMR, ICSPMR	Synchrophasor current, real component (I_W + I_X terminals)	A[b]
IASPMI, IBSPMI, ICSPMI	Synchrophasor current, imaginary component (I_W + I_X terminals)	A[b]
I1WPMM	Synchrophasor positive-sequence current magnitude (I_W terminals)	A[b]
I1WPMA	Synchrophasor positive-sequence current angle (I_W terminals)	degrees
I1WPMR	Synchrophasor positive-sequence current, real component (I_W terminals)	A[b]
I1WPMI	Synchrophasor positive-sequence current, imaginary component (I_W terminals)	A[b]
I1XPMM	Synchrophasor positive-sequence current magnitude (I_X terminals)	A[b]
I1XPMA	Synchrophasor positive-sequence current angle (I_X terminals)	degrees
I1XPMR	Synchrophasor positive-sequence current, real component (I_X terminals)	A[b]

Table 7.11 Synchrophasor Analog Quantities (Sheet 2 of 2)

Name	Description	Units
I1XPMI	Synchrophasor positive-sequence current, imaginary component (I_X terminals)	A[b]
I1SPMM	Synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[b]
I1SPMA	Synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMR	Synchrophasor positive-sequence current, real component (I_W + I_X terminals)	A[b]
I1SPMI	Synchrophasor positive-sequence current, imaginary component (I_W + I_X terminals)	A[b]
VALPMM, VBLPMM, VCLPMM	Synchrophasor voltage magnitude	kV[b]
VALPMA, VBLPMA, VCLPMA	Synchrophasor voltage angle	degrees
VALPMR, VBLPMR, VCLPMR	Synchrophasor voltage, real component	kV[b]
VALPMI, VBLPMI, VCLPMI	Synchrophasor voltage, imaginary component	kV[b]
V1LPMM	Synchrophasor positive-sequence voltage magnitude	kV[b]
V1LPMA	Synchrophasor positive-sequence voltage angle	degrees
V1LPMR	Synchrophasor positive-sequence voltage, real component	kV[b]
V1LPMI	Synchrophasor positive-sequence voltage, imaginary component	kV[b]
SODPM	Second-of-day of the synchrophasor data	s
FOSPM	Fraction-of-second of the synchrophasor data	s

[a] Measured value if the voltages are valid and EMPU = Y, otherwise FREQ_PM = nominal frequency setting NFREQ, and DFDT is zero.
[b] Primary value of measurement.

View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-451 synchrophasor measurements. See *METER on page R.9.34* for general information on the **MET** command.

There are multiple ways to use the **MET PM** command:

- As a test tool, to verify connections, phase rotation, and scaling
- As an analytical tool, to capture synchrophasor data at an exact time, in order to compare it with similar data captured in other phasor measurement unit(s) at the same time
- As a method of periodically gathering synchrophasor data through a communications processor

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings MFRMT, PHDATAV, PHDATAI, and PHCURR. The **MET PM** command can function even when no serial ports are sending synchrophasor data—it is unaffected by serial port setting PROTO.

The **MET PM** command will only operate when the SEL-451 is in the HIRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1.

Figure 7.5 shows a sample **MET PM** command response. The synchrophasor data is also available via the **HMI > Meter & Control** menu in ACSELERATOR QuickSet, and has a similar format to *Figure 7.5*.

The **MET PM *time*** command can be used to direct the SEL-451 to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure 7.5* occurring just after 14:14:12, with the time stamp 14:14:12.000000.

This method of data capture will always report from the exact second, even if the time parameter is entered with fractional seconds. For example, entering **MET PM 14:14:12.200** will result in the same data capture as **MET PM 14:14:12**, because the relay ignores the fractional seconds.

See *MET PM on page R.9.37* for complete command options, and error messages.

```
=>MET PM <Enter>

Relay 1                                     Date: 10/26/2004  Time: 19:18:23.000
Station A                                   Serial Number: 0000000000

Time Quality   Maximum time synchronization error:    0.000 (ms)  TSOK = 1

Synchrophasors
                     Phase Voltages             Pos. Sequence Voltage
                 VA        VB        VC                 V1
MAG (kV)       134.140   131.646   128.600            131.447
ANG (DEG)      129.896    10.262  -111.764            129.477

                     IW Phase Currents          IW Pos. Sequence Current
                 IA        IB        IC                 I1W
MAG (kV)       365.261   359.225   379.917            367.912
ANG (DEG)      114.930    -2.786  -120.238            117.338

                     IX Phase Currents          IX Pos. Sequence Current
                 IA        IB        IC                 I1X
MAG (kV)       617.050   587.237   599.044            600.935
ANG (DEG)      136.345    13.617  -106.733            134.434

                     IS Phase Currents          IS Pos. Sequence Current
                 IA        IB        IC                 I1S
MAG (kV)       966.340   937.347   972.512            958.708
ANG (DEG)      128.412     7.404  -111.967            127.955

FREQ (Hz) 60.029
Rate-of-change of FREQ (Hz/s)    0.00

Digitals

PSV40  PSV39  PSV38  PSV37  PSV36  PSV35  PSV34  PSV33
  0      0      0      0      0      0      0      0
PSV48  PSV47  PSV46  PSV45  PSV44  PSV43  PSV42  PSV41
  0      0      0      0      0      0      0      0
PSV56  PSV55  PSV54  PSV53  PSV52  PSV51  PSV50  PSV49
  0      0      0      0      0      0      0      0
PSV64  PSV63  PSV62  PSV61  PSV60  PSV59  PSV58  PSV57
  1      0      1      0      0      0      0      0

Analogs

PMV57      0.000  PMV58      0.000  PMV59      0.000  PMV60      0.000
PMV61      0.000  PMV62      0.000  PMV63    127.000  PMV64     23.400


=>
```

Figure 7.5 Sample MET PM Command Response

C37.118 Synchrophasor Protocol

The SEL-451 complies with *IEEE C37.118, Standard for Synchrophasors for Power Systems*, when Global setting MFRMT := C37.118.

The protocol is available on serial ports 1, 2, 3, and F by setting the corresponding Port setting PROTO := PMU.

The protocol is available on the ethernet port when EPMIP := Y. This subsection does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The SEL-451 allows several options for transmitting synchrophasor data. These are controlled by Global settings described in *Settings for Synchrophasors on page R.7.6*. You can select how often to transmit the synchrophasor messages (MRATE), which synchrophasors to transmit (PHDATAV, PHDATAI, and PHCURR), which numeric representation to use (PHNR), and which coordinate system to use (PHFMT).

The SEL-451 automatically includes the frequency and rate-of-change-of-frequency in the synchrophasor messages. Global setting FNR selects the numeric format to use for these two quantities.

The relay can include up to eight user-programmable analog values in the synchrophasor message, as controlled by Global setting NUMANA, and 0, 16, or 32 digital status values, as controlled by Global setting NUMDSW.

The SEL-451 always includes the results of four synchrophasor trigger reason SELOGIC equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC equation result PMTRIG, in the synchrophasor message.

Communications Bandwidth

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors, analog values, or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

If the SPEED setting on any serial port set with PROTO := PMU is insufficient for the PMU Global settings, the SEL-451 or SEL-5030 software will display an error message and fail to save settings until the error is corrected.

The C37.118 synchrophasor message format always includes 18 bytes for the message header and terminal ID, time information, and status bits. The selection of synchrophasor data, numeric format, programmable analog, and programmable digital data will add to the byte requirements. *Table 7.12* can be used to calculate the number of bytes in a synchrophasor message.

Table 7.12 Size of a C37.118 Synchrophasor Message

Item	Possible number of quantities	Bytes per quantity	Minimum number of bytes	Maximum number of bytes
Fixed			18	18
Synchrophasors	0, 1, 2, 3, 4, 5, 6, 8, 9, or 12	4 {PHNR := I} 8 {PHNR := F}	0	96
Frequency	2 (fixed)	2 {FNR := I} 4 {FNR := F}	4	8
Analog Values	0–8	4	0	32
Digital Status Words	0–2	2	0	4
Total (Minimum and Maximum)			22	158

Table 7.13 lists the baud settings available on any SEL-451 serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 20 bytes.

Table 7.13 Serial Port Bandwidth for Synchrophasors (in Bytes)

Global setting MRATE	Port setting SPEED								
	300	600	1200	2400	4800	9600	19200	38400	57600
1	21	42	85	170	340	680	1360	2720	4080
2		21	42	85	170	340	680	1360	2040
4 (60 Hz only)			21	42	85	170	340	680	1020
5				34	68	136	272	544	816
10					34	68	136	272	408
12 (60 Hz only)					28	56	113	226	340
15 (60 Hz only)					21	45	90	181	272
20 (60 Hz only)						34	68	136	204
25 (50 Hz only)						27	54	108	163
30 (60 Hz only)						22	45	90	136
50 (50 Hz only)							27	54	81
60 (60 Hz only)							22	45	68

Referring to *Table 7.12* and *Table 7.13*, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one synchrophasor and one digital status word, and this message would consume between 26 and 34 bytes, depending on the numeric format settings. This type of message could be sent at any message rate (MRATE) when SPEED := 38400 or 57600, up to MRATE := 50 or 30 when SPEED := 19200, and up to MRATE := 25 or 20 when SPEED := 9600.

Another example application has messages comprised of eight synchrophasors, one digital status word, and two analog values. This type of message would consume between 62 and 98 bytes, depending on the numeric format settings. The 62-byte version, using integer numeric representation, could be sent at any message rate (MRATE) when SPEED := 57600. The

98-byte version, using floating-point numeric representation, could be sent at up to MRATE := 30 when SPEED := 57600, up to MRATE := 25 when SPEED := 38400, and up to MRATE := 12 when SPEED := 19200.

Protocol Operation

The SEL-451 will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-451, with IEEE C37.118 commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor can automatically build a database structure.

Transmit Mode Control

The SEL-451 will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The SEL-451 can also indicate when a configuration change occurs, so the synchrophasor processor can request a new configuration block and keep its database up-to-date.

The SEL-451 will only respond to configuration block request messages when it is in the non-transmitting mode.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the slowest SPEED setting on a PROTO := PMU port will affect the maximum Global MRATE setting that can be used.

PMU Setting Example

A power utility is upgrading the line protection on its 230 kV system to use the SEL-451 relay as main protection. The grid operator also wants the utility to install phasor measurement units (PMUs) in each 230 kV substation to collect data for a new remedial action scheme, and to eventually replace their present state-estimation system.

The PMU data collection requirements call for the following data, collected at 10 messages per second:

- Frequency
- Positive-sequence voltage from the bus in each substation
- Three-phase and positive-sequence current for each line terminal
- Indication when the line breaker is open
- Indication when the voltage or frequency information is unusable
- Ambient temperature (one reading per station)

- Station battery voltage
- No relay control from the PMU communications port, for the initial stage of the project

The utility is able to meet the grid operator requirements with the SEL-451, an SEL-2600 series RTD Module, an SEL-2407 Satellite-Synchronized Clock, and an SEL-3306 Synchrophasor Processor in each substation.

This example will cover the PMU settings in one of the SEL-451 relays.

Some system details:

- The nominal frequency is 60 Hz.
- The line is protected by a breaker-and-a-half scheme (similar to *Figure 1.7*).
- The station ambient temperature is collected by an SEL-2600 series, channel RTD01.
- The line pts and wiring have a phase error of 4.20 degrees (lagging) at 60 Hz.
- The breaker 1 cts and wiring have a phase error of 3.50 degrees (lagging) at 60 Hz.
- The breaker 2 cts and wiring have a phase error of 5.50 degrees (lagging) at 60 Hz.
- The synchrophasor data will be using port 3, and the maximum baud allowed is 19200.
- The system designer specified floating point numeric representation for the synchrophasor data, and rectangular coordinates.
- The system designer specified integer numeric representation for the frequency data.
- The system designer specified fast synchrophasor response, because the data is being used for system monitoring.

The protection settings and RTD serial port settings will not be shown.

Determining Settings

The protection engineer performs a bandwidth check, using *Table 7.12*, and determines the required message size. The system requirements, in order of appearance in *Table 7.12*, are:

- 5 Synchrophasors, in floating point representation
- Integer representation for the frequency data
- 2 analog values
- 3 digital status bits, which require one status word

The message size is 16 + 5 • 8 + 2 • 2 + 2 • 4 + 1 • 2 = 70 bytes. Using *Table 7.13*, the engineer verifies that the port baud of 19200 is adequate for the message, at 10 messages per second.

Protection Math Variables PMV64 and PMV63 will be used to transmit the RTD01 ambient temperature data and the station battery voltage DC1, respectively.

The Protection SELOGIC Variables PSV64, PSV63, and PSV62 will be used to transmit the breaker status, loss-of-potential alarm, and frequency measurement status, respectively.

The Port 3 FASTOP setting will be set to N, to disable any control attempts from the PMU port.

Make the Global settings as shown in *Table 7.14*.

Table 7.14 Example Synchrophasor Global Settings

Setting	Description	Value
NFREQ	Nominal System Frequency (50, 60 Hz)	60
NUMBK	Number of Breakers in Scheme (1, 2)	2
EPMU	Enable Synchronized Phasor Measurement (Y, N)	Y
MFRMT	Message Format (C37.118, FM)	C37.118
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)	10
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	F
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	SAMPLE1
PMID	PMU Hardware ID (1–65534)	14
PHDATAV	Phasor Data Set, Voltages (V1, ALL, NA)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	4.20
PHDATAI	Phasor Data Set, Currents (I1, ALL, NA)	ALL
PHCURR	Current Source (IW, IX, BOTH, COMB)	COMB
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	3.50
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	5.50
PHNR	Phasor Numeric Representation (I = Integer, F = Floating point)	F
PHFMT	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMANA	Number of Analog Values (0–8)	2
NUMDSW	Number of 16-bit Digital Status Words (0, 1, 2)	1
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)	NA
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)	NA
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)	NA
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)	NA
PMTRIG	Trigger (SELOGIC Equation)	NA

The two analog quantities and three Relay Word bits required in this example must be placed in certain protection math variables and protection SELOGIC variables. Make the Protection Free-Form logic settings in *Table 7.15* in all six settings groups.

Table 7.15 Example Synchrophasor Protection Free-Form Logic Settings

Setting	Value
PSV64	NOT 3PO # Line breaker status
PSV63	LOP # Loss-of-Potential
PMV62	RTD01 # Ambient Temperature
PMV63	DC1 # Station Battery Voltage

Make the *Table 7.16* settings for serial port 3, using the **SET P 3** command.

Table 7.16 Example Synchrophasor Port Settings

Setting	Description	Value
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	PMU
SPEED	Data Speed (300 to 57600)	19200
STOPBIT	Stop Bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Enable Fast Operate Messages (Y, N)	N

The sample **MET PM** capture in *Figure 7.5* shows data that could be measured by this system, including the digital and analog data near the bottom of the figure, that represent the protection free-form logic from *Table 7.15*.

SEL Fast Message Synchrophasor Protocol

SEL Fast Message Unsolicited Write (synchrophasor) messages are general Fast Messages (A546h) that transport measured synchrophasor information. The SEL-451 can send unsolicited write messages as fast as every 50 ms on a 60 Hz system, and 100 ms on a 50 Hz system. Use Global settings PHDATAV, PHDATAI, and PHCURR to select the voltage and current data to include in the Fast Message. *Table 7.19* and *Table 7.20* list analog quantities included in the Fast Message for various Global settings (frequency is included in all messages). Not all messages are supported at all data speeds. If the selected data rate is not sufficient for the given message length, the relay responds with an error message.

Table 7.17 lists the Synchrophasor Fast Message Write function codes and the actions the relay takes in response to each command.

Table 7.17 Fast Message Command Function Codes for Synchrophasor Fast Write

Function Code (Hex)	Function	Relay Action
00h	Fast message definition block request	Relay transmits Fast Message definition request acknowledge (Function Code 80)
01h	Enable unsolicited transfer	Relay transmits Fast Message command acknowledged message (Function Code 81). Relay transmits Synchrophasor Measured Quantities (function to enable: Unsolicited Write broadcast, Function Code 20)
02h	Disable unsolicited transfer	Relay sends Fast Message command acknowledge message (Function Code 82) and discontinues transferring unsolicited synchrophasor messages (function to disable: Unsolicited Write broadcast, Function Code 20)
05h	Ping: determine if channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85)

See SEL *Application Guide AG2002-08* for more information on the SEL Fast Message Synchrophasor protocol. This application guide refers to previous SEL-451 firmware versions, and the relay-specific portions (pages 1 and 2) should be disregarded.

Differences in New SEL-451 Fast Message Synchrophasor Implementation

One of the differences between the C37.118 and SEL Fast Message formats relates to data transmission speed. When the C37.118 format is used, Global Setting MRATE determines the message rate—the synchrophasor processor cannot request a data rate via the enable message.

In the SEL Fast Message format, the synchrophasor processor must request a particular data message period, which is embedded in the enable message. If the requested message period can be supported, the SEL-451 will acknowledge the request (if an acknowledge was requested) and begin transmitting synchrophasors. If the requested message period is not permitted, the SEL-451 will respond with a bad data message (if an acknowledge was requested), and will not transmit any synchrophasor data.

On a 60 Hz nominal power system (NFREQ := 60), SEL-451 firmware version R104 can support the same message periods (1000, 500, 250, 200, 100, and 50 ms) as those supported by prior firmware versions.

On a 50 Hz nominal power system (NFREQ := 50), SEL-451 firmware version R104 can support all but two of the same message periods that prior firmware versions supported. Message periods 1000, 500, 200, and 100 ms are supported, while message periods 250 and 50 ms are unavailable.

Another difference is found in the serial port PROTO settings, where a new settings choice, PMU, is available. Beginning with SEL-451 firmware version R104, the SEL Fast Message synchrophasor protocol is only available on ports set to PROTO := PMU. In previous firmware versions, the SEL Fast Message synchrophasor protocol operated on ports set to PROTO := SEL. This separation of general serial port access from the PMU function was designed to enhance security and performance.

Beginning with SEL-451 firmware version R104, the settings for SEL Fast Message format are different than firmware version R102 and R103. The new settings are in the Global settings class—see *Upgrading Previous SEL-451 Synchrophasor Settings on page R.7.27*.

SEL-451 Fast Message Synchrophasor Settings

The settings for SEL Fast Message synchrophasors are listed in *Table 7.18*. Many of these settings are identical to the settings for the C37.118 format. See *Settings for Synchrophasors on page R.7.6*.

Table 7.18 PMU Settings in the SEL-451 for SEL Fast Message Protocol, in Global Settings

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b]	C37.118
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMID	PMU Hardware ID (0x00000000–0xFFFFFFFF)	0x00000001
PHDATAV	Phasor Data Set, Voltages (V1, ALL)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI[c]	Phasor Data Set, Currents (ALL, NA)	NA
PHCURR[d]	Current Source (IW, IX, COMB)	IW
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	0.00
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	0.00

[a] Set EPMU := Y to access the remaining settings.
[b] C37.118 = IEEE C37.118 Standard—see Table 7.1; FM := SEL Fast Message. Set MFRMT := FM to enter the Fast Message settings.
[c] When PHDATAV := V1, this setting is forced to NA and cannot be changed.
[d] Setting hidden when PHDATAI := NA.

Certain settings in *Table 7.18* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the PHCURR setting is hidden to limit the number of settings for your synchrophasor application.

Descriptions of Fast Message Synchrophasor Settings

The SEL Fast Message synchrophasor settings are a subset of the C37.118 settings. See *Descriptions of Synchrophasor Settings on page R.7.8* for details on settings PMAPP, PHCOMP, VCOMP, IWCOMP, and IXCOMP. For the remaining settings, the differences are explained in the following pages.

PMID

Defines the number of the PMU.

The PMID setting is a 32-bit numeric value. Use your utility or synchrophasor data concentrator labeling convention to determine this setting.

PHDATAV, PHDATAI, and PHCURR

These settings define the synchrophasors to be included in the data stream.

There are fewer combinations of synchrophasor data available in the SEL Fast Message synchrophasor format. For example, it is not possible to send only current synchrophasors. You must also send voltages.

See *Table 7.19* for a list of synchrophasors that can be sent in SEL Fast Message format, and the order.

Table 7.19 SEL Fast Message Voltage and Current Selections Based on PHDATAV and PHDATAI

Global Settings	Number of Synchrophasor Magnitude and Angle Pairs Transmitted	Synchrophasor Magnitude and Angle Pairs to Transmit, and the Transmit Order[a]
PHDATAV := V1 PHDATAI := NA	1	V_1
PHDATAV := ALL PHDATAI := NA	4	V_A, V_B, V_C, V_1
PHDATAV := ALL PHDATAI := ALL	8	V_A, V_B, V_C, V_1, I_A, I_B, I_C, I_1

[a] The voltages and currents are defined in Table 7.20.

Table 7.20 SEL Fast Message Voltage and Current Synchrophasor Sources

Synchrophasor labels from Table 7.19	Synchrophasor magnitude and angle pair definition (Analog Quantities)	
	Magnitude	**Angle**
V_A	VALPMM	VALPMA
V_B	VBLPMM	VBLPMA
V_C	VCLPMM	VCLPMA
V_1	V1LPMM	V1LPMA
I_A	IA*c*PMM[a]	IA*c*PMA[a]
I_B	IB*c*PMM[a]	IB*c*PMA[a]
I_C	IC*c*PMM[a]	IC*c*PMA[a]
I_1	I1*c*PMM[a]	I1*c*PMA[a]

[a] The letter c is defined in Table 7.21.

Table 7.21 SEL Fast Message Current Channel c Definition

PHCURR setting	c in Table 7.20
IW	W
IX	X
COMB	S

Other Settings Not Present

The SEL Fast Message format does not require the following settings: PHNR, PHFMT, FNR, NUMANA, NUMDSW, TREA1–TREA4, and PMTRIG.

The SEL Fast Message synchrophasor protocol always includes the frequency information in floating-point representation, and fourteen user-programmable SELOGIC variables PSV51 through PSV64. There are no user-programmable analog quantities in the SEL Fast Message synchrophasor protocol.

Upgrading Previous SEL-451 Synchrophasor Settings

See *Table 7.22* and *Table 7.23* for equivalent settings for your new SEL-451 synchrophasor installation.

Table 7.22 Synchrophasor Voltage and Current Settings Conversion From Previous SEL-451 Firmware Version

Previous Port setting PMDATA (SEL-451 firmware version R102 and R103)	Synchrophasors transmitted	Required Global settings in SEL-451 version R104
V1	V1	PHDATAV := V1 PHDATAI := NA
V	VA, VB, VC, V1	PHDATAV := ALL HDATAI := NA
A	VA, VB, VC, V1, IA, IB, IC, I1	PHDATAV := ALL HDATAI := ALL

Table 7.23 Synchrophasor Current Source Settings Conversion From Previous SEL-451 Firmware Version

Global Settings[a]		Required Global settings in SEL-451 version R104
ESS := N		PHCURR := IW
ESS ≠ N	LINEI := IW	PHCURR := IW
ESS ≠ N	LINEI := IX	PHCURR := IX
ESS ≠ N	LINEI := COMB	PHCURR := COMB

[a] Starting in SEL-451 firmware version R104, if the SEL-451 ALINEI feature is used to select an alternate line current source, the synchrophasor current measurement data source will not switch over to the new source.

Global settings PMAPP, PHCOMP, VCOMP, IWCOMP, and IXCOMP are new settings (there are no equivalent settings in prior SEL-451 firmware versions) and may be set as needed.

Communications Bandwidth

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message period of one second places little burden on the communications channel. As more synchrophasors are added, or if the message rate is increased, some communications channel restrictions come into play.

In the SEL Fast Message synchrophasor protocol, the master device determines the message period (the time between successive synchrophasor message time-stamps) in the enable request. If the SEL-451 can support the requested message period on that serial port, the relay acknowledges the request (if an acknowledge was requested) and commences synchrophasor data transmission. If the SEL-451 cannot support the requested message period, the relay responds with a response code indicating bad data (if an acknowledge was requested).

The SPEED setting on any serial port set with PROTO := PMU should be set as high as possible, to allow for the largest number of possible message period requests to be successful.

The SEL-451 Fast Message synchrophasor format always includes 32 bytes for the message header and terminal ID, time information, frequency, and status bits. The selection of synchrophasor data will add to the byte requirements. *Table 7.24* can be used to calculate the number of bytes in a synchrophasor message.

Table 7.24 Size of an SEL Fast Message Synchrophasor Message

Item	Possible Number of Quantities	Bytes per Quantity	Minimum Number of Bytes	Median Number of Bytes	Maximum Number of Bytes
Fixed			32	32	32
Synchrophasors	1, 4, or 8	8	8	32	64
Total (Minimum, Median, and Maximum)			40	64	96

Table 7.25 lists the baud settings available on any SEL-451 serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 40 bytes.

Table 7.25 Serial Port Bandwidth for Synchrophasors (in Bytes)

Requested Message Period (ms)	Equivalent Message Rate (messages per second)	Port setting SPEED								
		300	600	1200	2400	4800	9600	19200	38400	57600
1000	1		41	83	166	333	666	1332	2665	3998
500	2			41	83	166	333	666	1332	1999
250 (60 Hz only)	4				41	83	166	333	666	999
200	5					66	133	266	533	799
100	10						66	133	266	399
50 (60 Hz only)	20							66	133	199

Referring to *Table 7.24* and *Table 7.25*, it is clear that the lower SPEED settings are very restrictive.

Some observations from *Table 7.25*:

- A serial port set with SPEED := 38400 or 57600 can handle any size message at any data rate.
- A serial port set with SPEED := 19200 can handle a single-synchrophasor or four-synchrophasor message at any data rate, and any size message up to 10 messages per second.
- A serial port set with SPEED := 9600 can handle a single-synchrophasor message at any data rate, a four-synchrophasor message at up to 10 messages per second, and any size message at up to 5 messages per second.
- A serial port set with SPEED := 300 cannot be used for Fast Message synchrophasors.

Protocol Operation

The SEL-451 will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-451, with SEL Fast Message commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor determine the correct configuration for storing the synchrophasor data.

Transmit Mode Control

The SEL-451 will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission on a particular serial port when the disable command is received from the synchrophasor processor, or when the relay settings for that port are changed. The SEL-451 will stop synchrophasor transmission on all serial ports when any Global settings change is made.

The SEL-451 will respond to configuration block request messages regardless of the present transmit status, waiting only as long as it takes for any partially-sent messages to be completely transmitted.

The SEL-451 will respond to a Ping request immediately upon receipt, terminating any partially sent messages.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the SPEED setting on each PROTO := PMU port will affect the minimum synchrophasor message data period that can be used on that port.

Synchrophasor Protocols and SEL Fast Operate Commands

The SEL-451 can be configured to process SEL Fast Operate commands received on serial ports that have Port setting PROTO := PMU, when the Port setting FASTOP := Y.

This functionality can allow a host device to initiate control actions in the PMU without the need for a separate communications interface.

If port setting FASTOP := Y on a serial port set to PROTO := PMU, the SEL-451 will provide Fast Operate support. The host device can request a Fast Operate Configuration Block when the relay is in the non transmitting mode, and the relay will respond with the message, which includes codes that define the circuit breaker and remote bit control points that are available via Fast Operate commands.

The SEL-451 will process Fast Operate requests regardless of whether synchrophasors are being transmitted, as long as serial port setting FASTOP := Y. When FASTOP := N, the relay will ignore Fast Operate commands. Use the FASTOP := N option to lockout any control actions from that serial port if required by your company operating practices.

The SEL-451 does not acknowledge received Fast Operate commands, however, it is easy to program one or more Relay Word bits in the digital status word to observe the controlled function. For example, a Fast Operate Circuit Breaker 1 close command could be confirmed by monitoring the breaker status bit 52AA1 by assigning SELOGIC free-form protection logic setting PMV64 := 52AA1.

SEL Fast Operate commands are discussed in *SEL Fast Meter, Fast Operate, and Fast SER Messages on page R.5.8*. Note that only the Fast Operate function is available on ports set to PROTO := PMU. The protocols SEL Fast Meter and SEL Fast SER are unavailable on PROTO := PMU ports.

Section 8

IEC 61850 Communications

Features

The SEL-451 Relay supports the following features using Ethernet and IEC 61850:

- **SCADA**—Connect up to six simultaneous Ethernet client sessions. The SEL-451 also supports 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.
- **Firmware Upgrades**—Use FTP client software to transfer the Ethernet port firmware upgrade file to the relay.

NOTE: The SEL-451 supports one CID file, which should be transferred only if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will no longer have a valid IEC 61850 configuration, and the protocol will stop operating. To restart protocol operation, a valid CID must be transferred to the relay.

This section presents the information you need to use the IEC 61850 features of the SEL-451:

- *Introduction to IEC 61850 on page R.8.2*
- *IEC 61850 Operation on page R.8.3*
- *IEC 61850 Configuration on page R.8.12*
- *Logical Nodes on page R.8.16*
- *ACSI Conformance Statements on page R.8.37*

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 8.1*.

Table 8.1 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-451 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-451 Port 5 settings to configure all of the Ethernet settings, including IEC 61850 network settings.

The SEL Ethernet card supports IEC 61850 services, including transport of Logical Node objects, over TCP/IP. The Ethernet port 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 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 8.2* shows how the A-phase current expressed as MMXUAphsA$cVal is broken down into its component parts.

Table 8.2 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-451 logical nodes are grouped under Logical Devices for organization based on function. See *Table 8.3* for descriptions of the Logical Devices in an SEL-451. See *Logical Nodes on page R.8.16* for a description of the LNs that make up these Logical Devices.

Table 8.3 SEL-451 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 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 8.11* 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-451 CCIN bits for controls, you must create SELOGIC® equations to define these operations. The CCIN Logical Nodes only contain CCIN status, and only those CCINs that are part of the SER dataset 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-451, 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-451 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 8.1* are available by default via IEC 61850.

Figure 8.1 SEL-451 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 dataset 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 8.4*.

Table 8.4 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 8.5*.

Table 8.5 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 at a time resulting in a client association for that BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB.

For unbuffered reports, up to six clients can enable the RptEna attribute of an 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-451 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 8.2* are the defaults for an SEL-451 device.

Figure 8.2 SEL-451 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.
- 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.

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.

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-451. 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-451 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 dataset, 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-451 has predetermined LN data attributes that are available with SER quality timestamps. These data attributes are listed in the SER dataset in the default relay ICD file. Modifications to this dataset *do not* modify which data attributes have SER quality timestamps. If your application requires SER quality timestamps on data attributes not in this dataset, contact SEL for possible modification to your relay 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.

The SEL-451 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 8.3* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from SEL-451 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-451 will set the Validity attribute to invalid and the Failure attribute to TRUE. Note that the SEL-451 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 8.3 GOOSE Quality

GOOSE Processing

SEL 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 dataset to multiple GOOSE control blocks.
- High-speed GOOSE messaging (as defined under *GOOSE Performance on page R.8.11*) is only available for CCOUT*n* data.
- The SEL-451 will transmit all configured GOOSE immediately upon successful initialization. If a GOOSE is not retriggered, then following initial transmission, the SEL-451 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-451 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-451 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-451 to subscribe to as many as 24 incoming GOOSE messages.
- Control bits in the SEL-451 get data from incoming GOOSE messages which are mapped to CCIN*n* bits. Note: MMS can independently operate these bits.
- The SEL-451 will recognize incoming GOOSE messages as valid based on the following content:
  - Source broadcast MAC address.
  - Dataset 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 dataset 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-451.
- 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-451 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.8.10*), transmission of GOOSE begins within 2 ms of transition of data within the SEL-451. For all other data contained in outgoing GOOSE, transmission of GOOSE begins within 500 ms of transition of data within the SEL-451. Appropriate control commands are issued to the SEL-451 within 2 ms of a GOOSE reception.

IEC 61850 Configuration

Settings

Table 8.6 lists IEC 61850 settings. IEC 61850 settings are only available if your device includes the optional IEC 61850 protocol.

Table 8.6 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.

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. ACSELERATOR Architect generates CID files from ICD files so the ICD file version ACSELERATOR Architect uses also determines the CID file version generated.

As of this writing, ACSELERATOR Architect comes with four versions of the SEL-451 ICD file file (two for each relay type) for use with SEL-451-2 or SEL-451-4 on new or existing projects. These versions are:

- **002 (SEL-451-2/-4 8-Pushbutton Models):** This file is compatible with Ethernet card firmware R107 to R112 and the 8-pushbutton model of the SEL-451.
- **002 (SEL-451-2/-4 12-Pushbutton Models):** Identical in content to the file above, with additional logical nodes for extra pushbuttons made accessible in SEL-451 R117 or higher firmware. Select this file to enable access to these additional logical nodes when using the 12-pushbutton model of the SEL-451.

  Note: Using this file with SEL-451 R116 and lower 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. Note that the version 003 file created this way for the SEL-451-2 or SEL-451-4 is completely different from the version 003 file intended for the SEL-451-5 relay with firmware R300 or higher. This conversion is the only method ACSELERATOR Architect supports to download a CID file to a relay with Ethernet card firmware R113 or higher. Do not attempt to download the version 003 file supplied for the SEL-451-5 in the default IED Palette to an SEL-451-2 or SEL-451-4.

ACSELERATOR Architect will only prompt you to perform this conversion when it recognizes that it is trying to download an unsupported CID file to a relay. This is done on a per-file basis. That is, there is no option to do a batch conversion of all CID files in a project.

See *Table 8.8* for a summary of the logical nodes provided with each ICD file version.

Table 8.7 ICD Logical Nodes Summary (Sheet 1 of 2)

Logical Device	Logical Nodes by ICD Version			Description
	Ver 001 Ver 002L	Ver 002	Ver 002 R117+	
PRO	P1PIOC1	P1PIOC1	P1PIOC1	Level 1 phase overcurrent element
PRO	G1PIOC2	G1PIOC2	G1PIOC2	Level 1 residual overcurrent element
PRO	Q1PIOC3	Q1PIOC3	Q1PIOC3	Level 1 negative-sequence overcurrent element
PRO	P2PIOC4	P2PIOC4	P2PIOC4	Level 2 phase overcurrent element
PRO	G2PIOC5	G2PIOC5	G2PIOC5	Level 2 residual overcurrent element
PRO	Q2PIOC6	Q2PIOC6	Q2PIOC6	Level 2 negative-sequence overcurrent element
PRO	P3PIOC7	P3PIOC7	P3PIOC7	Level 3 phase overcurrent element
PRO	G3PIOC8	G3PIOC8	G3PIOC8	Level 3 residual overcurrent element
PRO	Q3PIOC9	Q3PIOC9	Q3PIOC9	Level 3 negative-sequence overcurrent element
PRO	G4PIOC10	G4PIOC10	G4PIOC10	Level 4 residual overcurrent element
PRO	Q4PIOC11	Q4PIOC11	Q4PIOC11	Level 4 negative-sequence overcurrent element
PRO	-	-	P4PIOC12	Level 4 phase overcurrent element (missing in previous versions)
PRO	P1PTOC1	P1PTOC1	P1PTOC1	Level 1 phase directional overcurrent element
PRO	G1PTOC2	G1PTOC2	G1PTOC2	Level 1 residual directional overcurrent element
PRO	Q1PTOC3	Q1PTOC3	Q1PTOC3	Level 1 negative-sequence directional overcurrent element
PRO	P2PTOC4	P2PTOC4	P2PTOC4	Level 2 phase directional overcurrent element
PRO	G2PTOC5	G2PTOC5	G2PTOC5	Level 2 residual directional overcurrent element
PRO	Q2PTOC6	Q2PTOC6	Q2PTOC6	Level 2 negative-sequence directional overcurrent element
PRO	P3PTOC7	P3PTOC7	P3PTOC7	Level 3 phase directional overcurrent element
PRO	G3PTOC8	G3PTOC8	G3PTOC8	Level 3 residual directional overcurrent element
PRO	Q3PTOC9	Q3PTOC9	Q3PTOC9	Level 3 negative-sequence directional overcurrent element
PRO	P4PTOC10	P4PTOC10	P4PTOC10	Level 4 phase directional overcurrent element
PRO	G4PTOC11	G4PTOC11	G4PTOC11	Level 4 residual directional overcurrent element
PRO	Q4PTOC12	Q4PTOC12	Q4PTOC12	Level 4 negative-sequence directional overcurrent element
PRO	S1PTOC13	S1PTOC13	S1PTOC13	Inverse-Time Overcurrent Element 1 pickup
PRO	S2PTOC14	S2PTOC14	S2PTOC14	Inverse-Time Overcurrent Element 2 pickup
PRO	S3PTOC15	S3PTOC15	S3PTOC15	Inverse-Time Overcurrent Element 3 pickup
PRO	POTTPSCH1	POTTPSCH1	POTTPSCH1	POTT Scheme
PRO	DCBPSCH2	DCBPSCH2	DCBPSCH2	DCB Trip Scheme
PRO	DCUBPSCH3	DCUBPSCH3	DCUBPSCH3	DCUB Trip Scheme
PRO	TRIPPTRC1	TRIPPTRC1	TRIPPTRC1	Trip status
PRO	BK1TRPPTRC2	BKR1PTRC2[a]	BKR1PTRC2	Breaker 1 Trip Status
PRO	BK2TRPPTRC3	BKR2PTRC3[a]	BKR2PTRC3	Breaker 2 Trip Status
PRO	F32GRDIR1	F32GRDIR1	F32GRDIR1	Forward ground directional element
PRO	R32GRDIR2	R32GRDIR2	R32GRDIR2	Reverse ground directional element
PRO	F32QRDIR3	F32QRDIR3	F32QRDIR3	Forward negative-sequence phase directional element

Table 8.7 ICD Logical Nodes Summary (Sheet 2 of 2)

Logical Device	Logical Nodes by ICD Version			Description
	Ver 001 Ver 002L	Ver 002	Ver 002 R117+	
PRO	R32QRDIR4	R32QRDIR4	R32QRDIR4	Reverse negative-sequence phase directional element
PRO	F32PRDIR5	F32PRDIR5	F32PRDIR5	Forward phase directional element
PRO	R32PRDIR6	R32PRDIR6	R32PRDIR6	Reverse phase directional element
PRO	BFR1RBRF1	BFR1RBRF1	BFR1RBRF1	Circuit Breaker 1 circuit breaker failure
PRO	BFR2RBRF2	BFR2RBRF2	BFR2RBRF2	Circuit Breaker 2 circuit breaker failure
PRO	BK1XCBR1	BK1XCBR1	BK1XCBR1	Circuit Breaker 1
PRO	BK2XCBR2	BK2XCBR2	BK2XCBR2	Circuit Breaker 2
PRO	BKR1CSWI1	BKR1CSWI1	BKR1CSWI1	
PRO	BKR2CSWI2	BKR2CSWI2	BKR2CSWI2	
MET	METMMXU1	METMMXU1	METMMXU1	Measured Values (Currents and Voltages)
MET	SEQMSQI1	SEQMSQI1	SEQMSQI1	Positive and Zero-sequence currents and voltages
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	RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Channel A Receive MIRRORED BITS
ANN	TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Channel A Transmit MIRRORED BITS
ANN	RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Channel B Receive MIRRORED BITS
ANN	TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Channel B Transmit MIRRORED BITS
ANN	MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	MIRRORED BITS Communications Status
ANN	INPUT1GGIO14	IN1GGIO14[a]	IN1GGIO14	Mainboard inputs
ANN	INPUT2GGIO15	IN2GGIO15[a]	IN2GGIO15	I/O Board 2 inputs, active data only if additional I/O Card(s) installed
ANN	INPUT3GGIO16	IN3GGIO16[a]	IN3GGIO16	I/O Board 3 inputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT1GGIO17	OUT1GGIO17[a]	OUT1GGIO17	Mainboard outputs
ANN	OUTPUT2GGIO18	OUT2GGIO18[a]	OUT2GGIO18	I/O Board 2 outputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT3GGIO19	OUT3GGIO19[a]	OUT3GGIO19	I/O Board 3 outputs, active data only if additional I/O Card(s) installed
ANN	CCINGGIO20	CCINGGIO20	CCINGGIO20	Communications Card Inputs
ANN	CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Communications Card Outputs

[a] Indicates that this logical node name has been changed in this version and differs from the ICD file version in the adjacent left-hand column.
[b] Indicates that this logical node has been modified in this version and differs from the ICD file version in the adjacent left-hand column.

Logical Nodes

Table 8.8 through *Table 8.11* show the logical nodes (LNs) supported in the SEL-451 and the Relay Word bits or Measured Values mapped to those LNs. Any differences between ICD file versions are also indicated in the tables.

Table 8.8 shows the LNs associated with protection elements, defined as Logical Device PRO.

Table 8.8 Logical Device: PRO (Protection) (Sheet 1 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002 Ver 002 R117+	Ver 002 Ver 002 R117+			
P1PIOC1	P1PIOC1	P1PIOC1	Op.general	50P1	
G1PIOC2	G1PIOC2	G1PIOC2	Op.general	50G1	
Q1PIOC3	Q1PIOC3	Q1PIOC3	Op.general	50Q1	
P2PIOC4	P2PIOC4	P2PIOC4	Op.general	50P2	
G2PIOC5	G2PIOC5	G2PIOC5	Op.general	50G2	
Q2PIOC6	Q2PIOC6	Q2PIOC6	Op.general	50Q2	
P3PIOC7	P3PIOC7	P3PIOC7	Op.general	50P3	
G3PIOC8	G3PIOC8	G3PIOC8	Op.general	50G3	
Q3PIOC9	Q3PIOC9	Q3PIOC9	Op.general	50Q3	
G4PIOC10	G4PIOC10	G4PIOC10	Op.general	50G4	
Q4PIOC11	Q4PIOC11	Q4PIOC11	Op.general	50Q4	
-	-	P4PIOC7	Op.general	50P4	
P1PTOC1	P1PTOC1	P1PTOC1	Str.general	67P1	
P1PTOC1	P1PTOC1	P1PTOC1	Str.dirGeneral	0	unknown
P1PTOC1	P1PTOC1	P1PTOC1	Opr.general	67P1T	
G1PTOC2	G1PTOC2	G1PTOC2	Str.general	67G1	
G1PTOC2	G1PTOC2	G1PTOC2	Str.dirGeneral	1	Always forward
G1PTOC2	G1PTOC2	G1PTOC2	Op.general	67G1T	
Q1PTOC3	Q1PTOC3	Q1PTOC3	Str.general	67Q1	
Q1PTOC3	Q1PTOC3	Q1PTOC3	Str.dirGeneral	1	Always forward
Q1PTOC3	Q1PTOC3	Q1PTOC3	Op.general	67Q1T	
P2PTOC4	P2PTOC4	P2PTOC4	Str.general	67P2	
P2PTOC4	P2PTOC4	P2PTOC4	Str.dirGeneral	0	unknown
P2PTOC4	P2PTOC4	P2PTOC4	Op.general	67P2T	
G2PTOC5	G2PTOC5	G2PTOC5	Str.general	67G2	
G2PTOC5	G2PTOC5	G2PTOC5	Str.dirGeneral	1	Always forward
G2PTOC5	G2PTOC5	G2PTOC5	Op.general	67G2T	
Q2PTOC6	Q2PTOC6	Q2PTOC6	Str.general	67Q2	
Q2PTOC6	Q2PTOC6	Q2PTOC6	Str.dirGeneral	1	Always forward
Q2PTOC6	Q2PTOC6	Q2PTOC6	Op.general	67Q2T	
P3PTOC7	P3PTOC7	P3PTOC7	Str.general	67P3	

Table 8.8 Logical Device: PRO (Protection) (Sheet 2 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002 Ver 002 R117+	Ver 002 Ver 002 R117+			
P3PTOC7	P3PTOC7	P3PTOC7	Str.dirGeneral	0	unknown
P3PTOC7	P3PTOC7	P3PTOC7	Op.general	67P3T	
G3PTOC8	G3PTOC8	G3PTOC8	Str.general	67G3	
G3PTOC8	G3PTOC8	G3PTOC8	Str.dirGeneral		If DIR3=F: forward (1); If DIR3=R: reverse (2)
G3PTOC8	G3PTOC8	G3PTOC8	Op.general	67G3T	
Q3PTOC9	Q3PTOC9	Q3PTOC9	Str.general	67Q3	
Q3PTOC9	Q3PTOC9	Q3PTOC9	Str.dirGeneral		If DIR3=F: forward (1); If DIR3=R: reverse (2)
Q3PTOC9	Q3PTOC9	Q3PTOC9	Op.general	67Q3T	
P4PTOC10	P4PTOC10	P4PTOC10	Str.general	67P4	
P4PTOC10	P4PTOC10	P4PTOC10	Str.dirGeneral	0	unknown
P4PTOC10	P4PTOC10	P4PTOC10	Op.general	67P4T	
G4PTOC11	G4PTOC11	G4PTOC11	Str.general	67G4	
G4PTOC11	G4PTOC11	G4PTOC11	Str.dirGeneral		If DIR4=F: forward (1); If DIR4=R: reverse (2)
G4PTOC11	G4PTOC11	G4PTOC11	Op.general	67G4T	
Q4PTOC12	Q4PTOC12	Q4PTOC12	Str.general	67Q4	
Q4PTOC12	Q4PTOC12	Q4PTOC12	Str.dirGeneral		If DIR4=F: forward (1); If DIR4=R: reverse (2)
Q4PTOC12	Q4PTOC12	Q4PTOC12	Op.general	67Q4T	
S1PTOC13	S1PTOC13	S1PTOC13	Str.general	51S1	
S1PTOC13	S1PTOC13	S1PTOC13	Str.dirGeneral	0	unknown
S1PTOC13	S1PTOC13	S1PTOC13	Op.general	51S1T	
S2PTOC14	S2PTOC14	S2PTOC14	Str.general	51S2	
S2PTOC14	S2PTOC14	S2PTOC14	Str.dirGeneral	0	unknown
S2PTOC14	S2PTOC14	S2PTOC14	Op.general	51S2T	
S3PTOC15	S3PTOC15	S3PTOC15	Str.general	51S3	
S3PTOC15	S3PTOC15	S3PTOC15	Str.dirGeneral	0	unknown
S3PTOC15	S3PTOC15	S3PTOC15	Op.general	51S3T	
POTTPSCH1	POTTPSCH1	POTTPSCH1	Str.general	KEY	
POTTPSCH1	POTTPSCH1	POTTPSCH1	Op.general	RXPRM	
POTTPSCH1	POTTPSCH1	POTTPSCH1	Echo.general	EKEY	
POTTPSCH1	POTTPSCH1	POTTPSCH1	WeiOp.general	ECTT	
POTTPSCH1	POTTPSCH1	POTTPSCH1	RvABlk.general	Z3RB	
DCBPSCH2	DCBPSCH2	DCBPSCH2	Str.general	DSTRT OR NSTRT	
DCBPSCH2	DCBPSCH2	DCBPSCH2	Op.general	RXPRM	
DBCPSCH2	DBCPSCH2	DBCPSCH2	RvABlk.general	Z3RB	
DCUBPSCH3	DCUBPSCH3	DCUBPSCH3	Str.general	KEY	

Table 8.8 Logical Device: PRO (Protection) (Sheet 3 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002 Ver 002 R117+	Ver 002 Ver 002 R117+			
DCUBPSCH3	DCUBPSCH3	DCUBPSCH3	Op.general	RXPRM	
DCUBPSCH3	DCUBPSCH3	DCUBPSCH3	Echo.general	EKEY	
DCUBPSCH3	DCUBPSCH3	DCUBPSCH3	WeiOp.general	ECTT	
DCUBPSCH3	DCUBPSCH3	DCUBPSCH3	RvABlk.general	Z3RB	
TRIPPTRC1	TRIPPTRC1	TRIPPTRC1	Tr.general	TRIP	
BK1TRPPTRC2	BKR1PTRC2	BKR1PTRC2	Tr.general	TRIP	
BK2TRPPTRC3	BKR2PTRC3	BKR2PTRC3	Tr.general	TRIP	
F32GRDIR1	F32GRDIR1	F32GRDIR1	Dir.general	32GF	
R32GRDIR2	R32GRDIR2	R32GRDIR2	Dir.general	32GR	
F32QRDIR3	F32QRDIR3	F32QRDIR3	Dir.general	F32Q	
R32QRDIR4	R32QRDIR4	R32QRDIR4	Dir.general	R32Q	
F32PRDIR5	F32PRDIR5	F32PRDIR5	Dir.general	F32P	
R32PRDIR6	R32PRDIR6	R32PRDIR6	Dir.general	R32P	
BFR1RBRF1	BFR1RBRF1	BFR1RBRF1	Str.general	BFI3P1	
BFR1RBRF1	BFR1RBRF1	BFR1RBRF1	OpIn.general	FBF1	
BFR2RBRF2	BFR2RBRF2	BFR2RBRF2	Str.general	BFI3P2	
BFR2RBRF2	BFR2RBRF2	BFR2RBRF2	OpIn.general	FBF2	
BK1XCBR1	BK1XCBR1	BK1XCBR1	Opcnt.stVal	NOPA1	
BK1XCBR1	BK1XCBR1	BK1XCBR1	Pos.stVal	52ACL1	
BK2XCBR2	BK2XCBR2	BK2XCBR2	Opcnt.stVal	NOPA2	
BK2XCBR2	BK2XCBR2	BK2XCBR2	Pos.stVal	52ACL2	
SW1XSWI1[a]	SW1XSWI1[a]	SW1XSWI1[a]	Loc.stVal	LOCAL	
SW1XSWI1[a]	SW1XSWI1[a]	SW1XSWI1[a]	Pos.stVal	89CL1	
SW2XSWI2[a]	SW2XSWI2[a]	SW2XSWI2[a]	Loc.stVal	LOCAL	
SW2XSWI2[a]	SW2XSWI2[a]	SW2XSWI2[a]	Pos.stVal	89CL2	
SW3XSWI3[a]	SW3XSWI3[a]	SW3XSWI3[a]	Loc.stVal	LOCAL	
SW3XSWI3[a]	SW3XSWI3[a]	SW3XSWI3[a]	Pos.stVal	89CL3	
SW2XSWI4[a]	SW2XSWI4[a]	SW2XSWI4[a]	Loc.stVal	LOCAL	
SW2XSWI4[a]	SW2XSWI4[a]	SW2XSWI4[a]	Pos.stVal	89CL4	
SW2XSWI5[a]	SW2XSWI5[a]	SW2XSWI5[a]	Loc.stVal	LOCAL	
SW2XSWI5[a]	SW2XSWI5[a]	SW2XSWI5[a]	Pos.stVal	89CL5	
BKR1CSWI1	BKR1CSWI1	BKR1CSWI1	Pos.stVal	52ACL1	
BKR1CSWI1	BKR1CSWI1	BKR1CSWI1	OpOpn.general	OC1	
BKR1CSWI1	BKR1CSWI1	BKR1CSWI1	OpCls.general	CC1	
BKR2CSWI2	BKR2CSWI2	BKR2CSWI2	Pos.stVal	52ACL2	
BKR2CSWI2	BKR2CSWI2	BKR2CSWI2	OpOpn.general	OC1	
BKR2CSWI2	BKR2CSWI2	BKR2CSWI2	OpCls.general	CC1	
SW1CSWI3[a]	SW1CSWI3[a]	SW1CSWI3[a]	Loc.stVal	LOCAL	

Table 8.8 Logical Device: PRO (Protection) (Sheet 4 of 4)

Logical Nodes by ICD Version			Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002 Ver 002 R117+	Ver 002 Ver 002 R117+			
SW1CSWI4[a]	SW1CSWI4[a]	SW1CSWI4[a]	Pos.stVal	89CL1	
SW1CSWI4[a]	SW1CSWI4[a]	SW1CSWI4[a]	OpOpn.general	89OPN1	
SW1CSWI4[a]	SW1CSWI4[a]	SW1CSWI4[a]	OpCls.general	89CLS1	
SW2CSWI5[a]	SW2CSWI5[a]	SW2CSWI5[a]	Loc.stVal	LOCAL	
SW2CSWI5[a]	SW2CSWI5[a]	SW2CSWI5[a]	Pos.stVal	89CL2	
SW2CSWI5[a]	SW2CSWI5[a]	SW2CSWI5[a]	OpOpn.general	89OPN2	
SW2CSWI5[a]	SW2CSWI5[a]	SW2CSWI5[a]	OpCls.general	89CLS2	
SW3CSWI6[a]	SW3CSWI6[a]	SW3CSWI6[a]	Loc.stVal	LOCAL	
SW3CSWI6[a]	SW3CSWI6[a]	SW3CSWI6[a]	Pos.stVal	89CL3	
SW3CSWI6[a]	SW3CSWI6[a]	SW3CSWI6[a]	OpOpn.general	89OPN3	
SW3CSWI6[a]	SW3CSWI6[a]	SW3CSWI6[a]	OpCls.general	89CLS3	
SW2CSWI7[a]	SW2CSWI7[a]	SW2CSWI7[a]	Loc.stVal	LOCAL	
SW2CSWI7[a]	SW2CSWI7[a]	SW2CSWI7[a]	Pos.stVal	89CL4	
SW2CSWI7[a]	SW2CSWI7[a]	SW2CSWI7[a]	OpOpn.general	89OPN4	
SW2CSWI7[a]	SW2CSWI7[a]	SW2CSWI7[a]	OpCls.general	89CLS4	
SW2CSWI8[a]	SW2CSWI8[a]	SW2CSWI8[a]	Loc.stVal	LOCAL	
SW2CSWI8[a]	SW2CSWI8[a]	SW2CSWI8[a]	Pos.stVal	89CL5	
SW2CSWI8[a]	SW2CSWI8[a]	SW2CSWI8[a]	OpOpn.general	89OPN5	
SW2CSWI8[a]	SW2CSWI8[a]	SW2CSWI8[a]	OpCls.general	89CLS5	

[a] SEL-451-4 only.

Table 8.9 shows the LNs associated with measuring elements, defined as Logical Device MET.

Table 8.9 Logical Device: MET (Metering) (Sheet 1 of 2)

Logical Node (All ICD Versions)	Measurand	Comment
METMMXU1	TotW.mag	P, Total real power
METMMXU1	TotVAr.mag	Q, Total reactive power
METMMXU1	TotVA.mag	S, Total apparent power
METMMXU1	TotPF.mag	PF, Three-phase power factor
METMMXU1	Hz.mag	FREQ, System frequency
METMMXU1	PhV.phsA.cVal.mag	VA, Phase A voltage magnitude
METMMXU1	PhV.phsA.cVal.ang	VA, Phase A voltage angle
METMMXU1	PhV.phsB.cVal.mag	VB, Phase A voltage magnitude
METMMXU1	PhV.phsB.cVal.ang	VB, Phase A voltage angle
METMMXU1	PhV.phsC.cVal.mag	VC, Phase A voltage magnitude
METMMXU1	PhV.phsC.cVal.ang	VC, Phase A voltage angle
METMMXU1	A1.phsA.cVal.mag	IA1, Line phase A current magnitude
METMMXU1	A1.phsA.cVal.ang	IA1, Line phase A-phase current angle
METMMXU1	A1.phsB.cVal.mag	IB1, Line phase B current magnitude

Table 8.9 Logical Device: MET (Metering) (Sheet 2 of 2)

Logical Node (All ICD Versions)	Measurand	Comment
METMMXU1	A1.phsB.cVal.ang	IB1, Line phase B-phase current angle
METMMXU1	A1.phsC.cVal.mag	IC1, Line phase C current magnitude
METMMXU1	A1.phsC.cVal.ang	IC1, Line phase C-phase current angle
METMMXU1	A2.phsA.cVal.mag	IA2, Breaker 1 A-phase current magnitude
METMMXU1	A2.phsA.cVal.ang	IA2, Breaker 1 A-phase current angle
METMMXU1	A2.phsB.cVal.mag	IB2, Breaker 1 B-phase current magnitude
METMMXU1	A2.phsB.cVal.ang	IB2, Breaker 1 B-phase current angle
METMMXU1	A2.phsC.cVal.mag	IC2, Breaker 1 C-phase current magnitude
METMMXU1	A2.phsC.cVal.ang	IC2, Breaker 1 C-phase current angle
METMMXU1	A3.phsA.cVal.mag	IA3, Breaker 2 A-phase current magnitude
METMMXU1	A3.phsA.cVal.ang	IA3, Breaker 2 A-phase current angle
METMMXU1	A3.phsB.cVal.mag	IB3, Breaker 2 B-phase current magnitude
METMMXU1	A3.phsB.cVal.ang	IB3, Breaker 2 B-phase current angle
METMMXU1	A3.phsC.cVal.mag	IC3, Breaker 2 C-phase current magnitude
METMMXU1	A3.phsC.cVal.ang	IC3, Breaker 2 C-phase current angle
SEQMSQI1	SeqA.c1.cVal.mag	I1_1, Line positive-sequence current magnitude
SEQMSQI1	SeqA.c1.cVal.ang	I1_1, Line positive-sequence current angle
SEQMSQI1	SeqA.c2.cVal.mag	I2_1, Line negative-sequence current magnitude
SEQMSQI1	SeqA.c2.cVal.ang	I2_1, Line negative-sequence current angle
SEQMSQI1	SeqA.c3.cVal.mag	I0_1, Line zero-sequence current magnitude
SEQMSQI1	SeqA.c3.cVal.ang	I0_1, Line zero-sequence current angle
SEQMSQI1	SeqV.c1.cVal.mag	V1, Positive-sequence voltage magnitude
SEQMSQI1	SeqV.c1.cVal.ang	V1, Positive-sequence voltage angle
SEQMSQI1	SeqV.c2.cVal.mag	V2, Negative-sequence voltage magnitude
SEQMSQI1	SeqV.c2.cVal.ang	V2, Negative-sequence voltage angle
SEQMSQI1	SeqV.c3.cVal.mag	V0, Zero-sequence voltage magnitude
SEQMSQI1	SeqV.c3.cVal.ang	V0, Zero-sequence voltage angle

Table 8.10 shows the LNs associated with control elements, defined as Logical Device CON.

Table 8.10 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	

Table 8.10 Logical Device: CON (Remote Control) (Sheet 2 of 2)

Logical Node (All ICD Versions)	Control	Relay Word or Database Bit	Comment
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	

Table 8.11 shows the LNs associated with the annunciation element, defined as Logical Device ANN.

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 1 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind01.stVal	PSV01	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind02.stVal	PSV02	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind03.stVal	PSV03	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind04.stVal	PSV04	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind05.stVal	PSV05	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind06.stVal	PSV06	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind07.stVal	PSV07	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind08.stVal	PSV08	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind09.stVal	PSV09	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind10.stVal	PSV10	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 2 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
…	…	…	…	…	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind63.stVal	PSV63	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind64.stVal	PSV64	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind01.stVal	PLT01	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind02.stVal	PLT02	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind03.stVal	PLT03	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind04.stVal	PLT04	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind05.stVal	PLT05	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind06.stVal	PLT06	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind07.stVal	PLT07	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind08.stVal	PLT08	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind09.stVal	PLT09	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind10.stVal	PLT10	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind11.stVal	PLT11	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind12.stVal	PLT12	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind13.stVal	PLT13	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind14.stVal	PLT14	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind15.stVal	PLT15	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind16.stVal	PLT16	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind17.stVal	PLT17	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind18.stVal	PLT18	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind19.stVal	PLT19	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind20.stVal	PLT20	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind21.stVal	PLT21	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind22.stVal	PLT22	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind23.stVal	PLT23	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind24.stVal	PLT24	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind25.stVal	PLT25	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind26.stVal	PLT26	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind27.stVal	PLT27	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind28.stVal	PLT28	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind29.stVal	PLT29	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind30.stVal	PLT30	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind31.stVal	PLT31	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind32.stVal	PLT32	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn01.mag	PMV01	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn02.mag	PMV02	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn03.mag	PMV03	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn04.mag	PMV04	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 3 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn05.mag	PMV05	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn06.mag	PMV06	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn07.mag	PMV07	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn08.mag	PMV08	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn09.mag	PMV09	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn10.mag	PMV10	
…	…	…	…	…	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn63.mag	PMV63	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn64.mag	PMV64	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind001.stVal	ASV001	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind002.stVal	ASV002	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind003.stVal	ASV003	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind004.stVal	ASV004	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind005.stVal	ASV005	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind006.stVal	ASV006	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind007.stVal	ASV007	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind008.stVal	ASV008	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind009.stVal	ASV009	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind010.stVal	ASV010	
…	…	…	…	…	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind127.stVal	ASV127	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind128.stVal	ASV128	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind01.stVal	ALT01	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind02.stVal	ALT02	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind03.stVal	ALT03	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind04.stVal	ALT04	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind05.stVal	ALT05	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind06.stVal	ALT06	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind07.stVal	ALT07	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind08.stVal	ALT08	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind09.stVal	ALT09	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind10.stVal	ALT10	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind11.stVal	ALT11	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind12.stVal	ALT12	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind13.stVal	ALT13	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind14.stVal	ALT14	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind15.stVal	ALT15	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind16.stVal	ALT16	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind17.stVal	ALT17	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 4 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind18.stVal	ALT18	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind19.stVal	ALT19	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind20.stVal	ALT20	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind21.stVal	ALT21	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind22.stVal	ALT22	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind23.stVal	ALT23	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind24.stVal	ALT24	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind25.stVal	ALT25	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind26.stVal	ALT26	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind27.stVal	ALT27	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind28.stVal	ALT28	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind29.stVal	ALT29	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind30.stVal	ALT30	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind31.stVal	ALT31	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind32.stVal	ALT32	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn01.mag	AMV01	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn02.mag	AMV002	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn03.mag	AMV003	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn04.mag	AMV004	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn05.mag	AMV005	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn06.mag	AMV006	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn07.mag	AMV007	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn08.mag	AMV008	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn09.mag	AMV009	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn10.mag	AMV010	
…	…	…	…	…	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn63.mag	AMV63	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn64.mag	AMV64	
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”

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 5 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
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”
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”
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind01.stVal	RMB1A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind02.stVal	RMB2A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind03.stVal	RMB3A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind04.stVal	RMB4A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind05.stVal	RMB5A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind06.stVal	RMB6A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind07.stVal	RMB7A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind08.stVal	RMB8A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind01.stVal	TMB1A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind02.stVal	TMB2A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind03.stVal	TMB3A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind04.stVal	TMB4A	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 6 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind05.stVal	TMB5A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind06.stVal	TMB6A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind07.stVal	TMB7A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind08.stVal	TMB8A	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind01.stVal	RMB1B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind02.stVal	RMB2B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind03.stVal	RMB3B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind04.stVal	RMB4B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind05.stVal	RMB5B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind06.stVal	RMB6B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind07.stVal	RMB7B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind08.stVal	RMB8B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind01.stVal	TMB1B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind02.stVal	TMB2B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind03.stVal	TMB3B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind04.stVal	TMB4B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind05.stVal	TMB5B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind06.stVal	TMB6B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind07.stVal	TMB7B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind08.stVal	TMB8B	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind01.stVal	ROKA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind02.stVal	RBADA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind03.stVal	CBADA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind04.stVal	LBOKA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind05.stVal	ANOKA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind06.stVal	DOKA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind07.stVal	ROKB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind08.stVal	RBADB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind09.stVal	CBADB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind10.stVal	LBOKB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind11.stVal	ANOKB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind12.stVal	DOKB	
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind01.stVal	IN101	Mainboard input, point 1 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind02.stVal	IN102	Mainboard input, point 2 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind03.stVal	IN103	Mainboard input, point 3 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind04.stVal	IN104	Mainboard input, point 4 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind05.stVal	IN105	Mainboard input, point 5 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind06.stVal	IN106	Mainboard input, point 6 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind07.stVal	IN107	Mainboard input, point 7 value

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 7 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind01.stVal	IN201	I/O Board 2 input, point 1 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind02.stVal	IN202	I/O Board 2 input, point 2 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind03.stVal	IN203	I/O Board 2 input, point 3 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind04.stVal	IN204	I/O Board 2 input, point 4 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind05.stVal	IN205	I/O Board 2 input, point 5 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind06.stVal	IN206	I/O Board 2 input, point 6 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind07.stVal	IN207	I/O Board 2 input, point 7 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind08.stVal	IN208	I/O Board 2 input, point 8 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind09.stVal	IN209	I/O Board 2 input, point 9 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind10.stVal	IN210	I/O Board 2 input, point 10 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind11.stVal	IN211	I/O Board 2 input, point 11 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind12.stVal	IN212	I/O Board 2 input, point 12 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind13.stVal	IN213	I/O Board 2 input, point 13 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind14.stVal	IN214	I/O Board 2 input, point 14 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind15.stVal	IN215	I/O Board 2 input, point 15 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind16.stVal	IN216	I/O Board 2 input, point 16 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind17.stVal	IN217	I/O Board 2 input, point 17 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind18.stVal	IN218	I/O Board 2 input, point 18 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind19.stVal	IN219	I/O Board 2 input, point 19 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind20.stVal	IN220	I/O Board 2 input, point 20 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind21.stVal	IN221	I/O Board 2 input, point 21 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind22.stVal	IN222	I/O Board 2 input, point 22 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind23.stVal	IN223	I/O Board 2 input, point 23 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind24.stVal	IN224	I/O Board 2 input, point 24 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind01.stVal	IN301	I/O Board 3 input, point 1 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind02.stVal	IN302	I/O Board 3 input, point 2 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind03.stVal	IN303	I/O Board 3 input, point 3 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind04.stVal	IN304	I/O Board 3 input, point 4 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind05.stVal	IN305	I/O Board 3 input, point 5 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind06.stVal	IN306	I/O Board 3 input, point 6 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind07.stVal	IN307	I/O Board 3 input, point 7 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind08.stVal	IN308	I/O Board 3 input, point 8 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind09.stVal	IN309	I/O Board 3 input, point 9 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind10.stVal	IN310	I/O Board 3 input, point 10 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind11.stVal	IN311	I/O Board 3 input, point 11 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind12.stVal	IN312	I/O Board 3 input, point 12 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind13.stVal	IN313	I/O Board 3 input, point 13 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind14.stVal	IN314	I/O Board 3 input, point 14 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind15.stVal	IN315	I/O Board 3 input, point 15 value

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 8 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind16.stVal	IN316	I/O Board 3 input, point 16 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind17.stVal	IN317	I/O Board 3 input, point 17 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind18.stVal	IN318	I/O Board 3 input, point 18 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind19.stVal	IN319	I/O Board 3 input, point 19 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind20.stVal	IN320	I/O Board 3 input, point 20 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind21.stVal	IN321	I/O Board 3 input, point 21 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind22.stVal	IN322	I/O Board 3 input, point 22 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind23.stVal	IN323	I/O Board 3 input, point 23 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind24.stVal	IN324	I/O Board 3 input, point 24 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind01.stVal	OUT101	Mainboard output, point 1 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind02.stVal	OUT102	Mainboard output, point 2 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind03.stVal	OUT103	Mainboard output, point 3 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind04.stVal	OUT104	Mainboard output, point 4 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind05.stVal	OUT105	Mainboard output, point 5 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind06.stVal	OUT106	Mainboard output, point 6 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind07.stVal	OUT107	Mainboard output, point 7 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind08.stVal	OUT108	Mainboard output, point 8 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind01.stVal	OUT201	I/O Board 2 output, point 1 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind02.stVal	OUT202	I/O Board 2 output, point 2 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind03.stVal	OUT203	I/O Board 2 output, point 3 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind04.stVal	OUT204	I/O Board 2 output, point 4 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind05.stVal	OUT205	I/O Board 2 output, point 5 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind06.stVal	OUT206	I/O Board 2 output, point 6 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind07.stVal	OUT207	I/O Board 2 output, point 7 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind08.stVal	OUT208	I/O Board 2 output, point 8 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind09.stVal	OUT209	I/O Board 2 output, point 9 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind10.stVal	OUT210	I/O Board 2 output, point 10 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind11.stVal	OUT211	I/O Board 2 output, point 11 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind12.stVal	OUT212	I/O Board 2 output, point 12 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind13.stVal	OUT213	I/O Board 2 output, point 13 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind14.stVal	OUT214	I/O Board 2 output, point 14 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind15.stVal	OUT215	I/O Board 2 output, point 15 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind16.stVal	OUT216	I/O Board 2 output, point 16 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind01.stVal	OUT301	I/O Board 3 output, point 1 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind02.stVal	OUT302	I/O Board 3 output, point 2 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind03.stVal	OUT303	I/O Board 3 output, point 3 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind04.stVal	OUT304	I/O Board 3 output, point 4 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind05.stVal	OUT305	I/O Board 3 output, point 5 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind06.stVal	OUT306	I/O Board 3 output, point 6 value

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 9 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind07.stVal	OUT307	I/O Board 3 output, point 7 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind08.stVal	OUT308	I/O Board 3 output, point 8 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind09.stVal	OUT309	I/O Board 3 output, point 9 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind10.stVal	OUT310	I/O Board 3 output, point 10 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind11.stVal	OUT311	I/O Board 3 output, point 11 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind12.stVal	OUT312	I/O Board 3 output, point 12 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind13.stVal	OUT313	I/O Board 3 output, point 13 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind14.stVal	OUT314	I/O Board 3 output, point 14 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind15.stVal	OUT315	I/O Board 3 output, point 15 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind16.stVal	OUT316	I/O Board 3 output, point 16 value
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind001.stVal	CCIN001	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind002.stVal	CCIN002	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind003.stVal	CCIN003	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind004.stVal	CCIN004	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind005.stVal	CCIN005	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind006.stVal	CCIN006	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind007.stVal	CCIN007	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind008.stVal	CCIN008	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind009.stVal	CCIN009	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind010.stVal	CCIN010	
…	…	…	…	…	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind127.stVal	CCIN127	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind128.stVal	CCIN128	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind01.stVal	CCOUT001	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind02.stVal	CCOUT002	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind03.stVal	CCOUT003	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind04.stVal	CCOUT004	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind05.stVal	CCOUT005	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind06.stVal	CCOUT006	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind07.stVal	CCOUT007	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind08.stVal	CCOUT008	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind09.stVal	CCOUT009	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind10.stVal	CCOUT010	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind11.stVal	CCOUT011	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind12.stVal	CCOUT012	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind13.stVal	CCOUT013	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind14.stVal	CCOUT014	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind15.stVal	CCOUT015	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind16.stVal	CCOUT016	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 10 of 10)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R117+			
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind17.stVal	CCOUT017	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind18.stVal	CCOUT018	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind19.stVal	CCOUT019	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind20.stVal	CCOUT020	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind21.stVal	CCOUT021	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind22.stVal	CCOUT022	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind23.stVal	CCOUT023	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind24.stVal	CCOUT024	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind25.stVal	CCOUT025	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind26.stVal	CCOUT026	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind27.stVal	CCOUT027	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind28.stVal	CCOUT028	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind29.stVal	CCOUT029	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind30.stVal	CCOUT030	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind31.stVal	CCOUT031	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind32.stVal	CCOUT032	

[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 8.12 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 8.13 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 *ACSI Conformance Statements on page R.8.37* for information on the supported services.

MMS Conformance

The Manufacturing Message Specification (MMS) stack provides the basis for many IEC 61850 Protocol services. *Table 8.14* 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 8.14 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	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

Table 8.14 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
createProgramInvocation		
deleteProgramInvocation		
start		
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		

Table 8.14 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAt-tributes		
reportAccessControlledOb-jects		
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvoca-tion		

Table 8.15 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table 8.15 MMS Parameter

MMS Service Supported 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 8.16 AlternateAccessSelection Conformance Statement

AlternateAccessSelection	Client-CR	Server-CR
	Supported	Supported
accessSelection		Y
component		Y
index		
indexRange		
allElements		
alternateAccess		Y
selectAccess		Y
component		Y
index		
indexRange		
allElements		

Table 8.17 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR	Server-CR
	Supported	Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table 8.18 VariableSpecification Conformance Statement

VariableSpecification	Client-CR	Server-CR
	Supported	Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table 8.19 Read Conformance Statement

Read	Client-CR	Server-CR
	Supported	Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table 8.20 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table 8.21 DefineNamedVariableList Conformance Statement

DefineNamedVariableList	Client-CR	Server-CR
	Supported	Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table 8.22 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
ObjectName		
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table 8.23 DeleteNamedVariableList Conformance Statement

DeleteNamedVariableList	Client-CR	Server-CR
	Supported	Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table 8.24 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 8.25 ACSI Basic Conformance Statement

		Client/Subscriber	Server/Publisher	SEL-451 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 8.26 ACSI Models Conformance Statement (Sheet 1 of 2)

		Client/Subscriber	Server/Publisher	SEL-451 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	Dataset	c5[d]	c5[d]	YES
M5	Substitution	O[e]	O[e]	
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]	

Table 8.26 ACSI Models Conformance Statement (Sheet 2 of 2)

		Client/Subscriber	Server/Publisher	SEL-451 Support
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 8.27 ACSI Services Conformance Statement (Sheet 1 of 3)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-451 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
Dataset (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]	

Table 8.27 ACSI Services Conformance Statement (Sheet 2 of 3)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-451 Support
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
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]	

Table 8.27 ACSI Services Conformance Statement (Sheet 3 of 3)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-451 Support
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
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 9

ASCII Command Reference

This section covers: *Description of Commands on page R.9.2*.

You can use a communications terminal or terminal emulation program to set and operate the SEL-451 Relay. This section explains the commands that you send to the SEL-451 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. Lower case italic letters and words in a command represent command variables that you determine based on the application (for example, circuit breaker number *n* = 1 or 2, remote bit number *nn* = 01–32, 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; 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 5: 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-451 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 9.1 2AC Command

Command	Description	Access Level
2AC	Go to Access Level 2 (full relay control).	1, B, P, A, O, 2

89CLOSE n (SEL-451-4)

Use the **89CLOSE *n*** command to close disconnect switches (*n* = 1–10). The main board circuit breaker jumper (on connector **J18C**) must be in place.

If the disconnect switch is open and Relay Word bit LOCAL is deasserted, the **89CLOSE *n*** command asserts Relay Word bit 89CLS*n* for the 89CSIT*n* time. See *Disconnect Switch Close and Open Control Logic on page A.5.3*. If the Relay Word bit 89OIP*n* asserts, indicating that the disconnect has started to close, the relay displays `Operation in Progress...` With Relay Word bit 89OIP*n* asserted and Relay Word bit 89ALP*n* deasserted, a dot (.) is appended to the above message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89CLOSE** command was executed. Assertion of Relay Word bit 89OIP*n* starts the 89ALP*n* alarm timer. The relay waits for the 89ALP*n* timer to expire and then checks the status of the 89AM*n* and 89BM*n* disconnect inputs. If the 89ALP*n* timer does not expire within 30 seconds, the relay exits the **89CLOSE** command and reads the status of the disconnect inputs. The state of Relay Word bits 89AM*n* and 89BM*n* determine which disconnect status message the relay displays (`Disconnect OPEN`, `Disconnect CLOSED`, or `Status Undetermined - check wiring`). See *Disconnect Switch Close and Open Control Logic on page A.5.3*. Use the 89CLS*n* Relay Word bit as part of a SELOGIC Output control equation to close the appropriate disconnect switch.

Table 9.2 89CLOSE n Command

Command	Description	Access Level
89CLOSE *n*	Set Relay Word bit 89CLS*n* (*n* = 1–10)	B, P, A, O, 2

NOTE: The number of disconnects supported depends on the pre-defined one-line diagram selected by the Bay Control Setting, MIMIC.

NOTE: If a disconnect switch is not defined in the one-line diagram selected, the open and close logic for the undefined disconnect switch still operates.

If the relay is disabled and you attempt an **89CLOSE *n*** command, the relay responds `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper **J18C** is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. For information on placing relay jumpers, see *Password and Circuit Breaker Jumpers on page U.2.18*.

When the **89CLOSE *n*** command is issued and the circuit breaker control enable jumper is in place, the relay responds, `CLOSE DISNAMn (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Are you sure (Y/N)?` If you answer **Y <Enter>**, the command is executed. If the response to either prompt is not y or Y, the relay responds with `Command Aborted`.

89OPEN n (SEL-451-4)

Use the **89OPEN *n*** command to open disconnect switches (*n* = 1–10). The main board circuit breaker jumper (on connector **J18C**) must be in place.

If the disconnect switch is closed and Relay Word bit LOCAL is deasserted, the **89OPEN *n*** command asserts Relay Word bit 89OPEN*n* for the 89OSIT*n* time. See *Disconnect Switch Close and Open Control Logic on page A.5.3*. If

the Relay Word bit 89OIP*n* asserts, indicating that the disconnect has started to open, the relay displays `Operation in Progress`... With Relay Word bit 89OIP*n* asserted and Relay Word bit 89ALP*n* deasserted, a dot (.) is appended to the above message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89OPEN** command was executed. Assertion of Relay Word bit 89OIP*n* starts the 89ALP*n* alarm timer. The relay waits for the 89ALP*n* timer to expire and then checks the status of the 89AM*n* and 89BM*n* disconnect inputs. If the 89ALP*n* timer does not expire within 30 seconds, the relay exits the **89OPEN** command and reads the status of the disconnect inputs. The state of Relay Word bits 89AM*n* and 89BM*n* determine which disconnect status message the relay displays (`Disconnect OPEN`, `Disconnect CLOSED`, or `Status Undetermined - check wiring`). See *Disconnect Switch Close and Open Control Logic on page A.5.3*. Use the 89OPEN*n* Relay Word bit as part of a SELOGIC Output control equation to open the appropriate disconnect switch.

Table 9.3 89OPEN n Command

Command	Description	Access Level
89OPEN *n*	Set Relay Word bit 89OPEN*n* (*n* = 1–10)	B, P, A, O, 2

NOTE: The number of disconnects supported depends on the pre-defined one-line diagram selected by the Bay Control Setting, MIMIC.

NOTE: If a disconnect switch is not defined in the one-line diagram selected, the open and close logic for the undefined disconnect switch still operates.

If the relay is disabled and you attempt an **89OPEN *n*** command, the relay responds `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper **J18C** is not in place, the relay aborts the command and responds `Aborted: the breaker jumper is not installed`. For information on placing relay jumpers, see *Password and Circuit Breaker Jumpers on page U.2.18*.

When the **89OPEN *n*** command is issued and the circuit breaker control enable jumper is in place, the relay responds `Open DISNAMn (Y/N)?` If you answer **Y <Enter>**, the relay responds `Are you sure (Y/N)?` If you answer **Y <Enter>**, the command is executed. If the response to either prompt is not y or Y, the relay responds with `Command Aborted`.

AACCESS

Use the **AAC** command to gain access to Access Level A (automation). See *Access Levels on page U.4.6* for more information.

Table 9.4 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 on page U.4.6* for more information.

Table 9.5 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 on page U.4.6* for more information.

Table 9.6 BAC Command

Command	Description	Access Level
BAC	Go to Access Level B (breaker).	1, B, P, A, O, 2

BNAME

The **BNA** command produces ASCII names of all relay status bits for Fast Meter Compressed ASCII. See *Section 5: SEL Communications Protocols* for more information on Fast Meter and the Compressed ASCII command set.

Table 9.7 BNA Command

Command	Description	Access Level
BNA	Display ASCII names of all relay status bits.	0, 1, B, P, A, O, 2

BREAKER

Use the **BREAKER** command to display circuit breaker reports and the circuit breaker history reports. You can also preload accumulated breaker monitor data. The **BRE** command also resets the circuit breaker monitor data. To use the BRE command, you must enable the circuit breaker monitor with monitor settings EB1MON := Y and EB2MON :=Y for one and two circuit breaker applications, respectively. See *Circuit Breaker Monitor on page A.2.1* for more information.

BRE n

The **BRE *n*** command displays the comprehensive circuit breaker report that includes interrupted currents, number of operations, and mechanical and electrical operating times, among many parameters. The relay displays a listing of breaker monitor alarms with the breaker report.

Table 9.8 BRE n Command[a]

Command	Description	Access Level
BRE *n*	Display the breaker report for the most recent Circuit Breaker *n* operation.	1, B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

BRE n C and BRE n R

The **BRE *n* C** and **BRE *n* R** commands clear/reset the circuit breaker monitor data. Options **C** and **R** are identical.

Table 9.9 BRE n C and BRE n R Commands[a]

Command	Description	Access Level
BRE *n* C	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2
BRE *n* R	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

BRE C A and BRE R A

The **BRE C A** and **BRE R A** commands clear all circuit breaker monitor data for both circuit breakers from memory. Options **C A** and **R A** are identical.

Table 9.10 BRE C A and BRE R A Commands

Command	Description	Access Level
BRE C A	Clear all circuit breaker data.	B, P, A, O, 2
BRE R A	Clear all circuit breaker data.	B, P, A, O, 2

BRE n H

Display the circuit breaker monitor history report with the **BRE *n* H** command. The breaker history report is a summary of recent circuit breaker operations.

Table 9.11 BRE n H Command

Command	Description	Access Level
BRE *n* H[a]	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

BRE n P

Use the **BRE *n* P** command to preload existing circuit breaker contact wear, operation counts, and accumulated currents to the circuit breaker monitor.

Table 9.12 BRE n P Command

Command	Description	Access Level
BRE *n* P[a]	Preload previously accumulated Breaker *n* data.	B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 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 9.13 CAL Command

Command	Description	Access Level
CAL	Go to Access Level C.	2, C

CASCII

The **CAS** command produces the Compressed ASCII configuration message. This configuration instructs an external computer on the method for extracting data from other Compressed ASCII commands. See *Section 5: SEL Communications Protocols* for an example of the **CAS** command configuration message and for further information on the Compressed ASCII command set.

Table 9.14 CAS Command

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0, 1, B, P, A, O, 2

CBREAKER

The **CBREAKER** command provides a Compressed ASCII response circuit breaker report that is similar to the **BREAKER** command. You must enable the Breaker Monitor function for either Circuit Breaker 1 or Circuit Breaker 2 to generate the Compressed ASCII report. You can specify Circuit Breaker 1 or Circuit Breaker 2 to retrieve a report for one circuit breaker only. See *Section 5: SEL Communications Protocols* for information on the Compressed ASCII command set.

CBR

Use the **CBR** command to gather the comprehensive circuit breaker report in Compressed ASCII format. For a detailed example, see *Section 2: Monitoring and Metering in the Applications Handbook*.

Table 9.15 CBR Command

Command	Description	Access Level
CBR	Return the most recent circuit breaker reports for Circuit Breaker 1 and Circuit Breaker 2 in Compressed ASCII format.	1, B, P, A, O, 2
CBR *n*[a]	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

CBR TERSE

The **CBR TERSE** command omits the breaker report labels.

Table 9.16 CBR TERSE Command

Command	Description	Access Level
CBR TERSE	Return the most recent circuit breaker report for Circuit Breaker 1 and Circuit Breaker 2 in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2
CBR *n* TERSE[a]	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2

[a] Parameter n = 1 or 2 to represent Circuit Breaker 1 and Circuit Breaker 2.

CEVENT

The **CEVENT** command provides a Compressed ASCII response similar to the **EVENT** command. See *Section 5: SEL Communications Protocols* for information on the Compressed ASCII command set. For detailed examples of the items in the Compressed ASCII event report, see *CEVENT on page A.3.28*.

CEV

Use the **CEV** command to gather relay event reports. When parameter *n* is 1 through 9999, *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.

Table 9.17 CEV Command

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

[a] Parameter n indicates event order or serial number.

CEV ACK

Use **CEV ACK** to acknowledge viewing the oldest unacknowledged event on the present communications port. View this event with the **CEV NEXT** or **EVE NEXT** commands.

Table 9.18 CEV ACK Command

Command	Description	Access Level
CEV ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2

CEV C

Use **CEV C** to return a 15-cycle length event report with analog and digital information in Compressed ASCII format. The **L*yyy*** option overrides the **C** option (see **CEV L*yyy***).

Table 9.19 CEV C Command

Command	Description	Access Level
CEV C	Return the most recent event report at a 15-cycle length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV C *n*[a]	Return particular *n* event report at a 15-cycle length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see CEV on page R.9.6.

CEV L

Use **CEV L** to return a large resolution (8-samples/cycle) event report in Compressed ASCII format. The **S*x*** option overrides the **L** option (see **CEV S*x***).

Table 9.20 CEV L Command

Command	Description	Access Level
CEV L	Return the most recent event report at full length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* L[a]	Return particular *n* event report at full length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see CEV on page R.9.6.

CEV Lyyy

Command **CEV L*yyy*** returns a specified length event report in Compressed ASCII format, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle to a value including and beyond the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full event report. The **L*yyy*** option overrides the **C** option.

Table 9.21 CEV Lyyy Command

Command	Description	Access Level
CEV L*yyy*	Return *yyy* 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* L*yyy*[a]	Return *yyy* cycles of a particular *n* event report 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 CEV on page R.9.6.

CEV NEXT

CEV NEXT returns the oldest unacknowledged event report on the present communications port in Compressed ASCII format.

Table 9.22 CEV N Command

Command	Description	Access Level
CEV N	Return the oldest unacknowledged event report with 4-samples/cycle sampling in Compressed ASCII format.	1, B, P, A, O, 2

CEV NSET

The **CEV NSET** command returns the Compressed ASCII event report with no relay settings.

Table 9.23 CEV NSET Command

Command	Description	Access Level
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 *n* NSET[a]	Return a particular *n* event report without settings at full length 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 CEV on page R.9.6.

CEV NSUM

The **CEV NSUM** returns the Compressed ASCII event report with no event summary.

Table 9.24 CEV NSUM Command

Command	Description	Access Level
CEV NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* NSUM[a]	Return a particular *n* event report without the event summary at full length 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 CEV on page R.9.6.

CEV Sx

Use the **CEV S*x*** command to specify the sample data resolution of the Compressed ASCII event report. The sample data resolution *x* is either 4 samples/cycle or 8 samples/cycle; the default value is 4 samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 9.25 CEV Sx Command[a]

Command	Description	Access Level
CEV S*x*	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 *n* S*x*	Return a particular *n* event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see CEV on page R.9.6.

CEV TERSE

The **CEV TERSE** command returns a Compressed ASCII event report without the event report labels.

Table 9.26 CEV TERSE Command

Command	Description	Access Level
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
CEV *n* TERSE[a]	Return a particular *n* 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 CEV on page R.9.6.

Use the **TERSE** option with any of the **CEV** commands except **CEV ACK**.

CEV Command Option Combinations

You can combine options **C**, **L**, **L*yyy***, ***n***, **NSET**, **NSUM**, **S*x***, and **TERSE** in one command. Enter the options according to the following guidelines:

- The **L*yyy*** option overrides the **C** option
- The **S*x*** option overrides the **L** option
- Enter the options in any order

Table 9.27 lists the choices you can make in the **CEV** command. Combine options on each row, selecting one option from each column, to create a **CEV** command.

Table 9.27 CEV Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Type	Report Length	Omit
ACK					
	***n*, NEXT**	**S*x*, L**	**C**	**L*yyy*, C**	**NSET, NSUM, TERSE**

The following examples illustrate some possible option combinations:

Example	Description
CEV L10 S8	Return 10 cycles of an 8-samples/cycle Compressed ASCII event report for the most recent event.
CEV L10 L	Return 10 cycles of an 8-samples/cycle Compressed ASCII event report for the most recent event (same as above).
CEV 2 C NSUM TERSE	For the second most recent event, return 15 cycles of the event in Compressed ASCII format with no event summary and no report label lines with 8-samples/cycle data.

CHISTORY

The **CHISTORY** command is the **HISTORY** command for the Compressed ASCII command set. See *Section 5: 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.

Table 9.28 CHI Command

Command	Description	Access Level
CHI	Return the data as contained in the History report for the most recent 100 event reports in Compressed ASCII format (for SEL-2030 compatibility).	1, B, P, A, O, 2
CHI A	Return one-line descriptions of the most recent 100 event reports in Compressed ASCII format.	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 TERSE

The **CHI TERSE** command returns a Compressed ASCII event report without the event report label lines.

Table 9.29 CHI TERSE Command

Command	Description	Access Level
CHI TERSE	Return one-line descriptions for the most recent 100 event reports without the 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 label lines in Compressed ASCII format.	1, B, P, A, O, 2

CHI HIF

Use the **CHI HIF** command to gather one-line descriptions of HIF event reports. This command is only available when the relay supports HIF detection.

Table 9.30 CHI HIF Command

Command	Description	Access Level
CHI HIF	Return the data as contained in the HIF History report for the most recent 100 HIF event reports in Compressed ASCII format (for SEL-2030 compatibility).	1, B, P, A, O, 2
CHI HIF A	Return one-line descriptions of the most recent 100 HIF event reports in Compressed ASCII format.	1, B, P, A, O, 2
CHI HIF *k*	Return one-line descriptions for the most recent **k** number of HIF event reports in Compressed ASCII format.	1, B, P, A, O, 2

CHI HIF TERSE

The **CHI HIF TERSE** command returns a Compressed ASCII HIF event report without the event report label lines. This command is only available when the relay supports HIF detection.

Table 9.31 CHI HIF TERSE Command

Command	Description	Access Level
CHI HIF TERSE	Return one-line descriptions of the most recent 100 event reports without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CHI HIF *k* TERSE	Return one-line descriptions for the most recent *k* number of HIF event reports without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

CLOSE n

Use the **CLOSE *n*** command to close a circuit breaker. The main board circuit breaker jumper (on connector J18C) must be in place. Further, you must set relay setting NUMBK := 2 to issue a **CLOSE 2** command.

The **CLOSE 1** and **CLOSE 2** commands assert Relay Word bits CC1 and CC2, respectively. Relay Word bit CC1 is a variable in the factory default manual close SEL equation BK1MCL Circuit Breaker 1. Typically, you program Relay Word bit CC2 in the manual close SELOGIC control equation BK2MCL for Circuit Breaker 2. The relay uses these equations and additional relay logic to assert a control output (for example, OUT103 := BK1CL) to close a circuit breaker. See *Control Outputs on page U.2.8*, and *Section 2: Auto-Reclosing and Synchronism Check* for more information.

Table 9.32 CLOSE n Command

Command	Description	Access Level
CLOSE 1	Command the relay to close Circuit Breaker 1.	B, P, A, O, 2
CLOSE 2	Command the relay to close Circuit Breaker 2 (if NUMBK := 2).	B, P, A, O, 2

If the circuit breaker control enable jumper J18C is in place, the relay responds, `Close breaker (Y/N)?` When you answer **Y <Enter>** (for yes), the relay prompts, `Are you sure (Y/N)?` If you again answer **Y <Enter>**, the relay asserts the Relay Word bit for one processing interval.

If you have assigned a circuit breaker auxiliary contact (52A) to a relay control input (based on the 52AAn setting), the relay waits 0.5 second, checks the state of the circuit breaker, and issues either a `Breaker OPEN` or `Breaker CLOSED` message.

If circuit breaker control enable jumper J18C is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. If the relay is disabled, the relay responds, `Command aborted because relay is disabled`. If setting NUMBK := 1 and you issue the **CLOSE 2** command, the relay responds `Breaker 2 is not available`.

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.5.15*.

COM c

Use the **COM *c*** command to view records in the communications buffers for specific relay communications channels.

Table 9.33 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/reset the communications buffer data for the specified channel ***c***. Options **C** and **R** are identical.

Table 9.34 COM c C and COM c R Command

Command	Description	Access Level
COM A C	Clear/reset communications buffer data for MIRRORED BITS communications Channel A.	P, A, O, 2
COM B R	Clear/reset communications buffer data for MIRRORED BITS communications Channel B.	P, A, O, 2
COM M C	Clear/reset communications buffer data for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	P, A, O, 2

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 10: Settings* for more information.

The relay organizes the records in rows in a 256-entry buffer 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 9.35 is a representative list of options for listing records in the communications buffer.

Table 9.35 COM c L Command (Sheet 1 of 2)

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*[a]	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*[b]	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*[c]	Display the records from MIRRORED BITS communications Channel A on the date *date1*.	1, B, P, A, O, 2

Table 9.35 COM c L Command (Sheet 2 of 2)

Command	Description	Access Level
COM B L *date1 date2*[c]	Display the records from MIRRORED BITS communications Channel B between the dates *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 k indicates a specific number of communications buffer records.
[b] Parameters m and n are communications buffer row numbers.
[c] Enter date1 and date2 in the same format as Global setting DATE_F.

CONTROL nn

Use the **CONTROL *nn*** command to set, clear, or pulse internal Relay Word bits RB01 through RB32 (Remote Bit 1 through Remote Bit 32). 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 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 *Control Points on page A.6.11* for information on remote bits.

Table 9.36 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 32 representing Remote Bit 01 through Remote Bit 32.

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 `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 one group to another. 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 9.37*.

Table 9.37 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 *c* to instance *n* of Class *c*.	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, and L for group settings, port settings, and protection SELOGIC control equations, 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), and protection SELOGIC control equations (L). The **COPY** command is not available within the Automation class and is not available for the Breaker Monitor settings.

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. If you attempt such a copy, the relay responds, `Cannot copy to a port involved in transparent communication`. In addition, you cannot copy to the present port (the port you are using to communicate with the relay). If you attempt such a copy, the relay responds, `Cannot copy port settings to present port`.

When you enter the **COPY** command with valid parameters, the relay responds, `Are you sure (Y/N)?` Answer **Y <Enter>** (for yes) to complete copying.

If the destination instance is the active group, the relay changes to the new settings and pulses the SALARM Relay Word bit.

CSER

The **CSER** command is the **SER** command for the Compressed ASCII command set. See *SEL Compressed ASCII Commands on page R.5.4* 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 *Figure 3.25 on page A.3.44*.

CSE

Use the **CSE** command to gather Sequential Events Recorder records. You can sort these records in numerical or date order.

Table 9.38 CSE Command (Sheet 1 of 2)

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

Table 9.38 CSE Command (Sheet 2 of 2)

Command	Description	Access Level
CSE *date1*[c]	Return the Sequential Events Recorder records in Compressed ASCII format on date *date1*.	1, B, P, A, O, 2
CSE *date1 date2*[c]	Return the Sequential Events Recorder records in Compressed ASCII format from date *date1* to date *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 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 (including header data). You can apply the **TERSE** option with any of the **CSE** commands.

Table 9.39 CSE TERSE Command

Command	Description	Access Level
CSE TERSE	Return all Sequential Events Recorder records without the 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 label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *m n* TERSE[b]	Return the Sequential Events Recorder records in Compressed ASCII format from *m* to *n* without the 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 date *date1* without the 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 date *date1* to date *date2* without the 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 Global setting DATE_F.

CSTATUS

The **CSTATUS** command is the **STATUS** command for the Compressed ASCII command set. The **TERSE** option eliminates the report label lines. See *Section 5: SEL Communications Protocols* for information on the Compressed ASCII command set. For an example of the **CST** command, see *Figure 6.29 on page U.6.38*.

Table 9.40 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 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. You can combine the *n*, **ACK**, **MB**, and **TERSE** options. See *SEL Compressed ASCII Commands on page R.5.4* for information on the Compressed ASCII command set. For a detailed example of the items in the Compressed ASCII summary report, see *Figure 3.17 on page A.3.34*.

CSU

Use the **CSU** command to gather event report summaries.

Table 9.41 CSU Command

Command	Description	Access Level
CSU	Return the most recent event summary (with label lines) in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n*[a]	Return a particular *n* event summary (with 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 9999, *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 9.42 CSU 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 9.43 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 9.44 CSU N Command

Command	Description	Access Level
CSU N	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 labels; the relay sends only the data (including header data).

Table 9.45 CSU TERSE Command

Command	Description	Access Level
CSU TERSE	Return the event summary report without the 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 label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU N TERSE	View the oldest unacknowledged event summary without the 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**.

CSU HIF

Use the **CSU HIF** command to gather HIF event report summaries. This command is only available when the relay supports HIF detection.

Table 9.46 CSU HIF Command

Command	Description	Access Level
CSU HIF	Return the most recent HIF event summary (with label lines) in Compressed ASCII format.	1, B, P, A, O, 2
CSU HIF *n*[a]	Return a particular n HIF event summary (with label lines) in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see the HIF event history report (HIS HIF command).

When parameter n is 1 through 9999, 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 HIF ACK

Use the **CSU HIF ACK** command to acknowledge an HIF event summary that you recently retrieved with the **CSU HIF NEXT** command on the present communications port.

Table 9.47 CSU HIF ACK Command

Command	Description	Access Level
CSU HIF ACK	Acknowledge the oldest unacknowledged HIF event summary at the present communications port for Compressed ASCII format.	1, B, P, A, O, 2

CSU HIF NEXT

Use the **CSU HIF NEXT** command to view the oldest unacknowledged HIF event summary in Compressed ASCII format.

Table 9.48 CSU HIF NEXT Command

Command	Description	Access Level
CSU HIF NEXT	View the oldest unacknowledged HIF event summary at the present communications port in Compressed ASCII format.	1, B, P, A, O, 2

CSU HIF TERSE

The **TERSE** command option returns an HIF event summary report in Compressed ASCII format without labels; the relay sends only the data (including header data).

Table 9.49 CSU HIF NEXT Command

Command	Description	Access Level
CSU HIF	Return the most recent HIF event summary without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU HIF na	Return a particular n HIF event summary without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU HIF NEXT	View the oldest unacknowledged HIF event summary without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

You can apply the **TERSE** option to any of the **CSU HIF** commands except **CSU HIF ACK**.

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 PPS, IRIG, and DNP (see *Configuring High-Accuracy Timekeeping on page U.4.73* 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 10: Settings* for more information).

Table 9.50 DATE Command[a]

Command	Description	Access Level
DATE	Display the internal clock date.	1, B, P, A, O, 2
DATE ***date***	Set the internal clock date (for setting DATE_F set to MDY).	1, B, P, A, O, 2

[a] Enter date setting in the same format as 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.5.8* for more information on SEL Fast Meter.

Table 9.51 DNA 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 accesses the serial port DNP3 settings and is similar to the **SHOW D** command. Type **DNP <Enter>** to show the relay's serial port DNP3 settings beginning at the first setting label. Issue the **DNP** command with any parameter *param* to set the serial port DNP3 settings; the relay begins at the first DNP3 setting. For more information, see the **SET D** command and *Section 5: SEL Communications Protocols*.

Table 9.52 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

Use the **EVENT** command to view the SEL-451 filtered event reports (see *Event Report on page A.3.14* for information on event reports).

EVE

The **EVE** command displays the full-length event reports stored in relay memory. (Set event report length with setting LER; see *Table 10.87*). When parameter *n* is 1 through 9999, *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.

Table 9.53 EVE Command

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 *n*[a]	Return a particular *n* event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

EVE A

The **EVE A** command returns only the analog information in the event report.

Table 9.54 EVE A Command

Command	Description	Access Level
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 A *n*[a]	Return only the analog information for a particular *n* event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVE.

EVE ACK

Use **EVE ACK** to acknowledge the oldest unacknowledged event that you recently viewed with the **EVE NEXT** or the **CEV NEXT** commands on the present communications port.

Table 9.55 EVE ACK Command

Command	Description	Access Level
EVE ACK	Acknowledge the oldest unacknowledged event 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 **EVE NEXT** command, the relay responds, `Event report number n has not been viewed with the NEXT option`.

EVE C

Use **EVE C** to return a 15-cycle length event report with both analog and digital data. You cannot mix the A and D options with the **EVE C** command. The **L*yyy*** option overrides the **C** option (see **EVE L*yyy***).

Table 9.56 EVE C Command

Command	Description	Access Level
EVE C	Return the most recent event report at a 15-cycle length with 8-samples/cycle data.	1, B, P, A, O, 2
EVE C *n*[a]	Return a particular *n* event report at a 15-cycle length with 8-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.20).

EVE D

Use **EVE D** to return only the digital information in the event report.

Table 9.57 EVE D Command

Command	Description	Access Level
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 D *n*[a]	Return only the digital information for a particular *n* event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.20).

EVE L

Use **EVE L** to return a large resolution (8-samples/cycle) event report. The **S*x*** option overrides the **L** option (see **EVE S*x***).

Table 9.58 EVE L Command

Command	Description	Access Level
EVE L	Return the most recent event report at full length with 8-samples/cycle data.	1, B, P, A, O, 2
EVE *n* L[a]	Return a particular *n* event report at full length with 8-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.20).

EVE Lyyy

Command **EVE L*yyy*** returns a specified length event report, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle up to a value including and exceeding the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full duration event report. The **L*yyy*** option overrides the **C** option.

Table 9.59 EVE Lyyy Command

Command	Description	Access Level
EVE L*yyy*	Return *yyy* cycles of the most recent event report (including settings) with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n* L*yyy*[a]	Return *yyy* cycles of a particular *n* event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.20).

EVE NEXT

EVE NEXT returns the oldest unacknowledged event report on the present communications port.

Table 9.60 EVE N Command

Command	Description	Access Level
EVE N	Return the oldest unacknowledged event report with 4-samples/cycle data.	1, B, P, A, O, 2

EVE NSET

The **EVE NSET** command returns the event report with no relay settings.

Table 9.61 EVE NSET Command

Command	Description	Access Level
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 *n* NSET[a]	Return a particular *n* event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.20).

EVE NSUM

The **EVE NSUM** returns the event report with no event summary.

Table 9.62 EVE NSUM Command

Command	Description	Access Level
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 *n* NSUM[a]	Return a particular *n* event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.20).

EVE Sx

Use the **EVE S*x*** command to specify the sample data resolution of the event report. The sample data resolution *x* is either 4 samples/cycle or 8 samples/cycle; the default value is 4 samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 9.63 EVE Sx Command

Command	Description	Access Level
EVE Sx	Return the most recent event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2
EVE *n* S*x*[a]	Return a particular *n* event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.20); x is 4 or 8 to represent data at 4 samples/cycle or 8 samples/cycle, respectively.

EVE Command Option Combinations

You can combine options **C**, **L**, **L*yyy***, ***n***, **NSET**, **NSUM**, and **S*x***, in one command. Enter the options according to the following guidelines:

- The **L*yyy*** 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*yyy*** at L015 to specify a 15-cycle report.
- Enter the options in any order.

Table 9.64 lists the choices you can make in the **EVE** command. Combine options on each row, selecting one option from each column, to create an **EVE** command.

Table 9.64 EVE Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Type	Report Length	Omit
ACK					
	***n*, NEXT**	**S*x*, L**	**C, A, D**	**L*yyy*, C**	**NSET, NSUM**

The following examples illustrate some possible option combinations.

Table 9.65 EVE Command Examples

Example	Description
EVE L010 S8	Return 10 cycles of an 8-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 C NSUM	For the second most recent event, return the event with 8-samples/cycle data, and omit the event summary.

FILE

The **FILE** command provides a safe and efficient means of transferring files between intelligent electronic devices (IEDs) and external support software (ESS). The **FILE** commands are especially useful for retrieving high-resolution sampled data in binary COMTRADE format from the relay. For examples of retrieving data captures from the relay, see *Reading Oscillograms, Event Reports, and SER on page U.4.43*. For more information on the **FILE** command, see *Virtual File Interface on page R.5.11*.

Table 9.66 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, P, O, 2
FILE READ ***[directory1 [directory2]] filename***	Initiates a file transfer of the file *filename* (in the folder *directory1*, subdirectory *directory2*) from the relay to external support software. The *filename* parameter is required.	1, B, P, A, P, O, 2
FILE WRITE SETTINGS ***[directory1 [directory2]] filename***	Initiates a file transfer of the file *filename* 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-451 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.

GROUP

Use the **GROUP** command to view the present group number or to change the active group.

Table 9.67 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 responds with a 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. The relay responds `No group change: SELogic equations SS1-SS6 have priority over GROUP command`. For information on SELOGIC control equations SS1 through SS6, see *Multiple Setting Groups on page R.3.8*.

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 about access levels and passwords, see *Access Levels on page U.4.6*.

Table 9.68 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 serial number, date, time, location, maximum current, active group, and targets. See *Event History on page A.3.34* 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 9.69 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 date *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 an event number.
[b] Enter date1 and date2 in the same format as Global setting DATE_F.

HIS C and HIS R

The **HIS C** and **HIS R** commands clear/reset the history data and corresponding high-resolution/event report data on the present port. Options **C** and **R** are identical.

Table 9.70 HIS C and HIS R Commands

Command	Description	Access Level
HIS C	Clear/reset event data on the present port only.	1, B, P, A, O, 2
HIS R	Clear/reset event data on the present port only.	1, B, P, A, O, 2

The relay prompts, `Clear all event reports for this port. Are you sure (Y/N)?` when you issue the **HIS C** and **HIS R** commands. 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 high-resolution/event report data captures.

Table 9.71 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** or **HIS RA** commands, the relay prompts, `Clear all event reports for all ports. 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.

HIS HIF

The **HIS HIF** command displays a quick synopsis of the last 100 high-impedance fault (HIF) events that the relay has captured. The rows in the HIS HIF report contain the event serial number, date, time, event type, location, maximum current, active group, and targets. See *High-Impedance Fault Event History on page A.3.40* for the HIS HIF report format. Use the **HIS HIF**

command to list one-line descriptions of relay events. You can list HIF event histories by number or by date. This command is only available when the relay supports HIF detection.

Table 9.72 HIS HIF Command

Command	Description	Access Level
HIS HIF	Return HIF 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 HIF *k*[a]	Return the *k* most recent HIF 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 HIF *date1*[b]	Return the HIF event histories on date date1	1, B, P, A, O, 2
HIS HIF *date1 date2*[b]	Return the HIF 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 an event number.
[b] Enter date1 and date2 in the same format as Global setting DATE_F.

HIS HIF C and HIS HIF R

The **HIS HIF C** and **HIS HIF R** commands clear/reset the HIF history data and corresponding HIF event report data on the present port. Options C and R are identical.

Table 9.73 HIS HIF C and HIS HIF R Commands

Command	Description	Access Level
HIS HIF C	Clear/reset HIF event data on the present port only.	1, B, P, A, O, 2
HIS HIF R	Clear/reset HIF event data on the present port only.	1, B, P, A, O, 2

The relay prompts, `Clear all HIF event reports for this port. Are you sure (Y/N)?` when you issue the **HIS HIF C** and **HIS HIF R** commands. If you answer **Y <Enter>**, the relay clears the present port history data.

HIS HIF CA and HIS HIF RA

The **HIS HIF CA** and **HIS HIF RA** commands clear all HIF history data and event reports from memory. Use these commands to completely delete HIF event report data captures.

Table 9.74 HIS HIF CA and HIS HIF RA Commands

Command	Description	Access Level
HIS HIF CA	Clear all HIF event data for all ports.	P, A, O, 2
HIS HIF RA	Clear all HIF event data for all ports.	P, A, O, 2

If you issue the **HIS HIF CA** or **HIS HIF RA** commands, the relay prompts, `Clear all HIF event reports for all ports. 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.

HIZ

The HIZ command displays a report of ground overcurrent high-impedance fault (50G HIZ) detection activity. This command is only available when the relay supports 50G HIZ detection. See *Figure 9.1* for a sample report.

```
=>HIZ

Relay 1                                    Date: 06/10/2007  Time: 08:04:16.698
Station A                                  Serial Number: 0000000000

Begining Date/Time           Ending Date/Time            Counts
2007/06/02 14:56:18.038      2006/08/02 14:56:23.663     9
2007/06/02 14:56:29.537      2006/08/02 14:56:39.166     18
```

Figure 9.1 Sample HIZ Report

The rows in the HIZ report contain the event beginning date/time, ending date/time, and counts.

Table 9.75 HIZ Command

Command	Description	Access Level
HIZ	Return HIZ event histories with the oldest at the top of the list and the most recent at the bottom of the list.	1, B, P, A, O, 2
HIZ *k*[a]	Return the *k* most recent HIF event histories with the oldest at the top of the list and the most recent at the bottom of the list.	1, B, P, A, O, 2

[a] Parameter k indicates an event number.

HIZ C and HIZ R

The **HIZ C** and **HIZ R** commands clear/reset the HIZ event report data on the present port. Options C and R are identical.

Table 9.76 HIZ C and HIZ R Commands

Command	Description	Access Level
HIZ C	Clear/reset HIZ event data on the present port only.	1, B, P, A, O, 2
HIZ R	Clear/reset HIZ event data on the present port only.	1, B, P, A, O, 2

The relay prompts, `Clear all HIZ event reports for this port. Are you sure (Y/N)?` when you issue the **HIZ C** and **HIZ R** commands. If you answer **Y <Enter>**, the relay clears the present port HIZ event data.

HIZ CA and HIZ RA

The **HIZ CA** and **HIZ RA** commands clear all HIZ event reports from memory. Use these commands to completely delete HIZ event report data captures.

Table 9.77 HIZ CA and HIZ RA Commands

Command	Description	Access Level
HIZ CA	Clear all HIZ event data for all ports.	P, A, O, 2
HIZ RA	Clear all HIZ event data for all ports.	P, A, O, 2

If you issue the **HIZ CA** or **HIZ RA** commands, the relay prompts, `Clear all HIZ event reports for all ports. Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay clears all HIZ event data.

HSG and HSG D

The **HSG** command displays 100 long-term histogram counter values and 100 short-term histogram counter values of three phases, plus the learned limits for histograms: HISLIMA, HISLIMB, HISLIMC, and HISLIMGC and the fault thresholds NFZ, NFB, and NFC.

HSG consists of data associated with the long term and short term bin numbers and the associated counters, mean, standard deviation, HISLIM, and NFA.

The **HSG D** command provides a snapshot of data in a HISWIN window. Data includes dISM raw values, bin number, and digital status to identify if the logic is in tuning mode.

The **HSG** command is available only if HIZ fault detection is enabled by the relay part number.

If EHIF = N, then the relay response should be `HIF Not Enabled`.

If the **HSG** command is issued, the relay should display `Command is synchronizing with HISWIN` while it is waiting for the HISWIN period to expire.

Table 9.78 HSG and HSG D Commands

Command	Description	Access Level
HSG	Displays long and short term histogram of bin numbers and associated counters, mean, standard deviation, HISLIM and NFA.	1, B, P, A. O, 2
HSG D	Displays snap shot of HISWIN window including dISM raw values, bin number and digital status to identify if the logic is in tuning mode.	1, B, P, A. O, 2

ID

Use the **ID** command to extract relay identification codes.

Table 9.79 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 ID string as stored in the relay settings of the IED

DEVCODE: a unique Device Code (for Modus identification purposes)

PARTNO: the Part Number

CONFIG: abcdef.

The designator positions indicate a specific relay configuration:

"a" represents the nominal frequency; where 0 = N/A, 1 = 60 Hz, and 2 = 50 Hz.

"b" represents the phase rotation; where 0 = N/A, 1 = ABC, and 2 = ACB.

"c" represents the phase input current scaling; where 0 = N/A, 1 = 5 A, and 2 = 1 A.

"d" = 0 (The SEL-451 does not have a dedicated neutral current input).

"e" represents the voltage input connection; where 0 = N/A, 1 = Delta, and 2 = Wye.

"f" represents the current input connection; where 0 = N/A, 1 = Delta, and 2 = Wye.

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 9.2*.

```
"FID=SEL-451-2-R117-V0-Z008008-D20070223","0909"
"BFID=SLBT-4XX-R100-V0-Z001001-D20010703","0972"
"CID=B616","025C"
"DEVID=Relay 1","0467"
"DEVCODE=39","0313"
"PARTNO=045126151A0AXH21XXXXX","07B5"
"CONFIG=111022","038A"
"SPECIAL=000000","03CE"
"CARD5FID=SEL-2702-R103-V0-Z001001-D20070223","0A25"
"CARD5BFID=SLBT-2701-R102-V0-Z000000-D20051107","0AAA"
"CARD5PARTNO=2702A0X","0564"
```

Figure 9.2 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-451_OtterTail)
- type: the IED type (e.g., SEL-451)
- configVersion: the CID file configuration version (e.g., ICD-451-R100-V0-Z001001-20060512

The optional Ethernet card provides support for IEC 61850 in the SEL-451. 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 9.3*.

```
"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_451_OtterTail","05BC"
"type=SEL_451","04A4"
"configVersion=ICD-451-R117-V0-Z001001-D20060524","0698"
```

Figure 9.3 Sample ID Command Response From Ethernet Card

INI HIF

The **INI HIF** command is used to re-start the 24 -hour tuning process used in high-impedance fault detection. This command is only available when the relay supports HIF detection and EHIF is not set to 'N'.

Table 9.80 INI HIF Command

Command	Description	Access Level
INI HIF	Initiate the 24 -hour tuning process used in high-impedance fault detection.	2

If you issue the **INI HIF** commands, the relay prompts, `Initiate HIF 24-hour tuning (Y/N)?` If you answer **Y <Enter>**, the relay initiates the tuning process.

IRIG

The **IRIG** command directs the relay to use the next available demodulated IRIG-B time code to update the relay internal clock. For information on the IRIG time mode, see *IRIG-B on page U.4.73*.

Table 9.81 IRIG Command

Command	Description	Access Level
IRIG	Lock the relay internal clock to the IRIG-B time code input.	1, B, P, A, O, 2

The **IRIG** command was originally provided in the SEL-451 as a testing aid. The **IRIG** command was used to update the relay internal clock with the IRIG-B time value without waiting for the 30-second confirmation time delay.

There is no longer a 30-second confirmation time delay—the relay uses the IRIG time source as soon as it determines that the signal is valid, a process that may take several seconds. Once the IRIG signal is verified, the relay clock is updated once per second. The **IRIG** command is still available, but is no longer necessary. To check IRIG status, use the **TIME Q** command instead—see *TIME Q Descriptions on page U.4.77*.

If the relay has no valid IRIG-B time code at the rear panel, or if the **TIME Q** command reports a relay time source other than IRIG or HIRIG, the relay responds to the **IRIG** command with the following error message, `IRIG-B DATA ERROR`. See the **TIME** command for more information.

LOG HIF

The **LOG HIF** command displays the progress of the HIF detection in the percentage to their final pickup. This command is only available when EHIF setting is set to Y and the Relay Word bit ITUNE_*X* (*X* = A, B, C, or G) is deasserted (after the tuning process).

Table 9.82 LOG HIF Command

Command	Description	Access Level
LOG HIF	Displays the progress of the HIF detection.	A, O, 2

If EHIF is set to N, the command response will be `Command Not Available`.

If EHIF is set to Y and ITUNE_*X* is asserted, the command response will be `HIF Algorithm Tuning in Progress`.

A sample of the LOG HIF response is shown in *Figure 9.4*.

```
==>>LOG HIF

Relay 1                                    Date: 09/17/2012 Time: 14:56:59.694
Station A                                  Serial Number: 2007179312

Date       Time         Percent ALG.1A ALG.1B ALG.1C ALG.2A ALG.2B ALG.2C HI1 HI2
09/17/2012 14:54:58.068 ALARM     0.00   0.00   0.00   0.00   0.00   0.00 000 000
                        FAULT     0.00   0.00   0.00   0.00   0.00   0.00 000 000
```

Figure 9.4 Sample LOG HIF Command Response

LOOPBACK

Use the **LOOPBACK** command to instruct the relay to receive the transmitted MIRRORED BITS communications data on the same serial port. See *SEL MIRRORED BITS Communications on page R.5.15* 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, then the relay assumes that channel if you do not specify that channel in the command. If you do not specify a timeout period, the relay provides a 5-minute timeout.

Table 9.83 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 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
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 `Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Loopback Mode Started`.

In the loopback mode, ROK drops out and the relay uses LBOK 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 tells the relay to pass input MIRRORED BITS communications data through to the receive (RMB) bits, as in the nonloopback mode.

Table 9.84 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*, then the relay disables loopback on both channels. If you specify a channel, you can enter the options in any order.

Table 9.85 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-451 is very similar to the **MAP** command in the SEL-2020 and SEL-2030 Communications Processors. See *Section 4: Communications Interfaces* 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, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS.

Table 9.86 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, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS.

Table 9.87 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 67G1T, 25W1BK2, and ASV256.

METER

The **METER** command displays reports about quantities the relay measures in the power system (voltages, currents, frequency, remote analogs, and so on) and internal relay operating quantities (math variables and synchronism-check values). For more information on power system measurements, see *Section 2: Monitoring and Metering in the Applications Handbook*. For information on math variables, see *Section 3: SELOGIC Control Equations*. Find a discussion of synchronism check in *Section 2: Auto-Reclosing and Synchronism Check*.

LINE, BK1, and BK2 command options generally measure feeder line quantities and circuit breaker currents, depending on relay configuration (see *Current and Voltage Source Selection on page R.1.2*).

MET

Use the **MET** command to view fundamental metering quantities. The relay rejects harmonics and dc components to present only measured quantities at the power system fundamental operating frequency.

Table 9.88 MET Command

Command	Description	Access Level
MET	Display Line fundamental metering data.	1, B, P, A, O, 2
MET *k*	Display Line fundamental metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n*[a]	Display Circuit Breaker *n* fundamental metering data.	1, B, P, A, O, 2
MET BK*n k*	Display Circuit Breaker *n* fundamental metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter n is 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

The **MET** command without options defaults to the LINE fundamental metering data. Specify Circuit Breaker 1 and Circuit Breaker 2 by using the BK1 and BK2 command options, respectively.

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 9.89 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 automation math variables.	1, B, P, A, O, 2
MET AMV A *k*	Display all 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. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET ANA

Use the **MET ANA** command to view the analog quantities from the MIRRORED BITS communications channels.

Table 9.90 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 response to this command will not include any values. If MIRRORED BITS communications is enabled but not communicating, the relay will display `ERROR` under the `RMBA` or `RMBB` entries, depending on settings.

The relay shows the analog quantities with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET BAT

Use the **MET BAT** command to view the station dc monitor quantities for Vdc1 and Vdc2.

Table 9.91 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, `DC Monitor Is Not Enabled`. (Enable the dc monitor with the Global setting EDCMON; see *Section 10: Settings*.)

The reset command, **MET RBM**, resets the dc monitor maximum/minimum metering quantities. When you issue the **MET RBM** command, the relay responds, `Reset Max/Min Battery Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Max/Min Battery Reset`.

MET D

Use the **MET D** command to view the demand and peak demand quantities.

Table 9.92 MET D Command

Command	Description	Access Level
MET D	Display Line demand metering data.	1, B, P, A, O, 2
MET D *k*	Display Line demand metering data successively for *k* times	1, B, P, A, O, 2
MET RD	Reset Line demand metering data.	P, A, O, 2
MET RP	Reset Line peak demand metering data.	P, A, O, 2

The reset command (**MET RD**) resets the Line demand metering quantities. When you issue the **MET RD** command, the relay responds, `Reset Demands (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Demands Reset`.

The reset command, **MET RP**, resets the Line peak demand metering quantities. When you issue the **MET RP** command, the relay responds, `Reset Peak Demands (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Peak Demands Reset`.

MET E

Use the **MET E** command to view the energy import and export quantities.

Table 9.93 MET E Command

Command	Description	Access Level
MET E	Display Line energy metering data.	1, B, P, A, O, 2
MET E *k*	Display Line energy metering data successively for *k* times.	1, B, P, A, O, 2
MET RE	Reset Line energy metering data.	P, A, O, 2

The reset command, **MET RE**, resets the Line, BK1, and BK2 energy metering quantities. When you issue the **MET RE** command, the relay responds, `Reset Energy Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Energy Metering Reset`.

MET HIF

Use the **MET HIF** command to view high-impedance fault data.

Table 9.94 MET HIF Command

Command	Description	Access Level
MET HIF	Displays high-impedance fault data.	I, B, P, A, O, 2

A sample of the **MET HIF** response is shown in *Figure 9.5*.

```
==>>MET HIF

Relay 1                                    Date: 09/17/2012 Time: 15:00:35.807
Station A                                  Serial Number: 2007179312

            ALG.1A   ALG.1B   ALG.1C   ALG.2A   ALG.2B   ALG.2C   HI1   HI2
Alarm (%)     0.00     0.00     0.00     0.00     0.00     0.00   000   000
Fault (%)     0.00     0.00     0.00     0.00     0.00     0.00   000   000
```

Figure 9.5 Sample MET HIF Command Response

MET M

Use the **MET M** command to view power system maximum and minimum quantities.

Table 9.95 MET M Command

Command	Description	Access Level
MET M	Display Line maximum/minimum metering data.	1, B, P, A, O, 2
MET M *k*	Display Line maximum/minimum metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n* M[a]	Display Breaker *n* maximum/minimum metering data.	1, B, P, A, O, 2
MET BK*n* M *k*[a]	Display Breaker *n* maximum/minimum metering data successively for *k* times.	1, B, P, A, O, 2
MET RM	Reset maximum/minimum metering data.	P, A, O, 2

[a] Parameter n is 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

The reset command, **MET RM**, resets the Line, BK1, and BK2 maximum/minimum metering quantities. When you issue the **MET RM** command, the relay responds, `Reset Max/Min Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Max/Min Reset`.

MET PM

Use the **MET PM** command to view the time-synchronized line quantities. The relay must be in the high-accuracy timekeeping HIRIG mode. For more information on high-accuracy timekeeping, see *Configuring High-Accuracy Timekeeping on page U.4.73*.

Table 9.96 MET PM Command (Sheet 1 of 2)

Command	Description	Access Level
MET PM	Display time-synchronized line values.	1, B, P, A, O, 2
MET PM *k*	Display time-synchronized line values successively for *k* times.	1, B, P, A, O, 2

Table 9.96 MET PM Command (Sheet 2 of 2)

Command	Description	Access Level
MET PM *time*	Display time-synchronized line values captured at trigger *time*.	1, B, P, A, O, 2
MET PM HIS	Display time-synchronized line values captured for the previous **MET PM** command.	1, B, P, A, O, 2

If the relay is not in the high-accuracy IRIG (HIRIG) timekeeping mode, it will respond to the **MET PM** command with the following message:

```
Aborted: A High Accuracy Time Source is Required
```

If Global enable setting EPMU := N, the relay will respond to the **MET PM** command with:

```
Synchronized phasor measurement is not enabled
```

To request a report of the synchrophasor data at a specific time, enter the optional *time* parameter as a time of day. For example, the relay will respond to the **MET PM 16:40:10** command with:

```
Synchronized Phasor Measurement Data Will Be Displayed at
16:40:10.000
```

In this example, when the internal clock reaches 16:40:10.000, the relay will display the synchrophasor data from that exact time. If the relay is not in HIRIG mode at that time, it will display the following message:

```
Aborted: A High Accuracy Time Source is Required
```

After the **MET PM *time*** command is issued, other **MET PM** commands may be entered without affecting the timing request, even if the stated time has not arrived. However, issuing a second **MET PM *time*** command while the first command is still pending will cancel the first command request in favor of the newer request.

If you are not connected to the relay when the **MET PM *time*** command issues its timed response, you can use the **MET PM HIS** command to view this response. This permits you to issue **MET PM *time*** to multiple relays using a common time and then go back later to see the results from all the relays at this common instant in time.

See *Section 7: Synchrophasors* for more information on phasor measurement functions, and *View Synchrophasors by Using the MET PM Command on page R.7.16* for sample **MET PM** responses.

MET PMV

Use the **MET PMV** command to view the protection math variables.

Table 9.97 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 protection math variables.	1, B, P, A, O, 2
MET PMV A *k*	Display all 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. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET RMS

Use the **MET RMS** command to view rms (root mean square) metering quantities. The relay includes power system harmonics in rms quantities.

Table 9.98 MET RMS Command

Command	Description	Access Level
MET RMS	Display Line rms metering data.	1, B, P, A, O, 2
MET RMS *k*	Display Line rms metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n* RMS[a]	Display Circuit Breaker *n* rms metering data.	1, B, P, A, O, 2
MET BK*n* RMS *k*	Display Circuit Breaker *n* rms metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter n is 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

MET SYN

Use the **MET SYN** command to view the synchronism-check reference voltage, normalized source voltages, angles, and slip calculations.

Table 9.99 MET SYN Command

Command	Description	Access Level
MET SYN	Display the synchronism-check values.	1, B, P, A, O, 2
MET SYN *k*	Display the synchronism-check values successively for *k* times.	1, B, P, A, O, 2

If you have not enabled the synchronism-check function, the relay responds, `Synchronism Check Element Is Not Available`. (Enable synchronism check with the Global settings E25BK1, E25BK2, and NUMBK; see *Section 2: Auto-Reclosing and Synchronism Check* and *Section 10: Settings*).

MET T

Use the **MET T** command to view the temperature data from the SEL-2600 series RTD Module. This command requires setting PROTO = RTD for the serial port connected to the SEL-2600 series RTD Module.

Table 9.100 MET T Command

Command	Description	Access Level
MET T	Display up to 12 temperature analog values from the SEL-2600 series RTD Module.	1, B, P, A, O, 2
MET T *k*	Display up to 12 temperature analog values from the SEL-2600 series RTD Module successively for *k* times.	1, B, P, A, O, 2

The relay displays the number of RTD channels specified by the RTDNUM Port Setting. If the RTD protocol is not enabled on any of the relay ports, the relay displays the following:

```
No data available
```

If there is a communications failure between the relay and the SEL-2600 series, as indicated by the RTDCOMF Relay Word bit, the relay displays the following:

```
Communication Failure
```

If the RTDFL Relay Word bit is set to indicate a SEL-2600 series failure, the relay displays the following:

```
SEL-2600 Failure
```

If any of the RTDxTY Port Settings are set to NA, the relay displays the following for that channel:

```
Channel Not Used
```

If the RTDxxST Relay Word bit is set for any of the RTDNUM channels being reported, the relay displays the following:

```
Channel Failure
```

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 9.101 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*** command to open a circuit breaker(s). The **OPEN 1** command pulses Relay Word bit OC1, and the **OPEN 2** command pulses Relay Word bit OC2. Usually, you configure these Relay Word bits as part of the SELOGIC control equations that trip the appropriate circuit breaker. The factory default manual trip SELOGIC control equation, BK1MTR, includes OC1. Typically, you program Relay Word bit OC2 in the manual trip SELOGIC control equation BK2MTR. See *Trip Logic on page R.1.86* for information on trip SELOGIC control equations.

Table 9.102 OPEN n Command

Command	Description	Access Level
OPEN 1	Change Relay Word bit OC1 to logical 1.	B, P, A, O, 2
OPEN 2	Change Relay Word bit OC2 to logical 1.	B, P, A, O, 2

If you have disabled the relay and attempt an **OPEN *n*** command, the relay responds, `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper J18C is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. For information on placing relay jumpers, see *Password and Circuit Breaker Jumpers on page U.2.18*.

When you issue the **OPEN 1** command, and the circuit breaker control enable jumper is in place, the relay responds, `Open breaker (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay asserts OC1 for one processing interval. Circuit Breaker 1 opens if you have programmed Relay Word bit OC1 in the TR SELOGIC control equation.

If you have assigned auxiliary contact 52A inputs for this circuit breaker (based on setting 52AA1), the relay waits 0.5 seconds, checks the state of the breaker auxiliary contacts, and responds `Breaker OPEN` or `Breaker CLOSED`, as appropriate.

A similar procedure holds for the **OPEN 2** command and Circuit Breaker 2. To successfully issue the **OPEN 2** command, setting NUMBK must be 2. If setting NUMBK is 1, the relay responds, `Breaker 2 is not available`.

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 9.103 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 9.104 PAS level new_password Command

Command	Description	Access Levels
PAS *level new_password*[a]	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 characters. 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, `Set`.

PAS level DISABLE

Issuing the **PAS *level DISABLE*** command disables password checking for the specified access level. You must type **DISABLE** in upper case.

Table 9.105 PAS level DISABLE Command

Command	Description	Access Levels
PAS *level* DISABLE[a]	Disable password protection for the Access Level *level*.	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, `Password Disabled`. SEL does not recommend disabling passwords (see *Changing the Default Passwords on page U.4.6*).

PORT

The **PORT** command can be used to connect to either an installed Ethernet card or a remote relay.

PORT p

The **PORT *p*** command connects a relay serial or Ethernet port to another device through a virtual terminal session.

In the SEL-451, 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.5.15* for information on the MIRRORED BITS communications protocol.

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 9.106 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, `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 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`.

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 (shown in *Table 9.107*).

Table 9.107 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, F, or 5 to indicate Communications PORT 1 through PORT 3, PORT 5, or 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, `Kill connection between ports m and n (Y/N)?` Answer **Y <Enter>** to terminate the connection. 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, and 300-series addresses.

Table 9.108 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, `Aborted: the breaker jumper is not installed`. See *Jumpers on page U.2.18* for more information on relay jumpers.

When you issue the **PUL** command and the breaker jumper is in place, the relay responds, `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 (or deasserts); 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 9.109 QUI Command

Command	Description	Access Level
QUI	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 7: 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 9.110 SER Command

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
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 date *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 number, which the relay assigns at each SER trigger.
[b] Enter date1 and date2 in the same format as Global setting DATE_F.

SER C and SER R

The **SER C** and **SER R** commands clear/reset the SER records for the present port. Options **C** and **R** are identical.

Table 9.111 SER C and SER R Commands

Command	Description	Access Level
SER C	Clear/reset SER records on the present port.	1, B, P, A, O, 2
SER R	Clear/reset SER records on the present port.	1, B, P, A, O, 2

The relay prompts, `Clear the sequential events recorder for this port. Are you sure (Y/N)?` when you issue the **SER C** and **SER R** commands. If you answer **Y <Enter>**, the relay clears the particular port SER records.

SER CA and SER RA

The **SER CA** and **SER RA** commands clear all SER records from memory.

Table 9.112 SER CA and SER RA Commands

Command	Description	Access Level
SER CA	Clear SER data for all ports.	P, A, O, 2
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, `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 9.113 SER CV or SER RV Commands

Command	Description	Access Level
SER CV	Clear SER data for this port	1, B, P, A, O, 2
SER RV	Clear 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 from other ports and to file transfer access, and they must be cleared independently for those ports. Data not yet viewed remains 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 9.114 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, `Automatic removal of chattering SER elements not enabled`.

SET

Use the **SET** command to change relay settings. The SEL-451 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, Breaker Monitor, Protection, Automation, Outputs, Front Panel, Report, DNP, and Ports)

Instances (some classes have instances: Group = 1–6; Protection = 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.4.14*.

The order that specific settings appear in the relay settings structure is factory programmed. See *Section 10: 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 9.115 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 each instance.	P, 2
SET *label*	Set the Group relay settings, beginning at the active group setting label *label*.	P, 2
SET *n label*[a]	Set the Group *n* relay settings, beginning at setting label *label*.	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, `Save settings (Y,N)?` If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait.....` The relay saves the new settings, then responds, `Settings Saved`. If you answer **N <Enter>** to the save settings prompt, the relay responds, `Settings aborted`.

SET A

Use the **SET A** command to set the Automation SELOGIC control equations. See *Section 3: SELOGIC Control Equations* for more information on SELOGIC control equations.

Table 9.116 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.4.19* for information on settings text-edit mode.

SET B

Use the **SET B** command to set the Bay Control settings in the SEL-451-4. There is only one instance for the Bay Control settings. See *Section 5: Bay Control in the Applications Handbook* for more information on Bay Control settings.

Table 9.117 SET B Command

Command	Description	Access Level
SET B	Set the Bay Control relay settings, beginning at the first setting in this class.	P, 2
SET B *label*	Set the Bay Control relay settings, beginning at the settings label *label*.	P, 2

SET D

Issue the **SET D** command to remap the serial port DNP3 values. To set the general DNP settings, use the Port settings for the appropriate port (see *SET P on page R.9.49*). 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 6: DNP3 Communications*.

Table 9.118 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 9.119 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 *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 9.120 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 *label*.	P, A, O, 2

SET L

Use the **SET L** command to set the Protection SELOGIC control equations. See *Section 3: SELOGIC Control Equations* for more information on SELOGIC control equations.

Table 9.121 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 Instance *n*, which is 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.4.19* for information on settings text-edit mode.

SET M

Use the **SET M** command to set the circuit breaker monitor settings. There is only one instance for the Breaker Monitor class. See *Section 2: Monitoring and Metering in the Applications Handbook* for information on the circuit breaker monitor.

Table 9.122 SET M Command

Command	Description	Access Level
SET M	Set the Breaker Monitor relay settings, beginning at the first setting in this class.	P, 2
SET M *label*	Set the Breaker Monitor relay settings, beginning at the settings label *label*.	P, 2

SET O

Use the **SET O** command to set the Output SELOGIC control equations. See *Control Outputs on page U.2.8* for more information on relay control outputs.

Table 9.123 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 *label*.	O, 2

SET P

Use the **SET P** command to configure the relay communications ports; each port is a settings instance. The SEL-451 communications ports include serial ports at PORT F, PORT 1, PORT 2, and PORT 3. PORT 5 is the communications card port into which the optional Ethernet card or other communications cards may be installed.

Table 9.124 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 settings label *label*.	P, A, O, 2
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 settings label *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 aliases. You can also set event report parameters and program event report digital elements. There is only one instance for the Report settings.

Table 9.125 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 settings label *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.4.14* for settings entry methods for these modes.

SET T

Use the **SET T** command to set aliases for Relay Word bits and analog quantities. There is only one instance for the alias settings.

Table 9.126 SET T Command

Command	Description	Access Level
SET T	Set the alias settings.	P, A, O, 2

SET TERSE

Use the **TERSE** option to inhibit the relay from sending the settings class or instance readback when you end a settings session. SEL recommends that you use the **TERSE** option sparingly; you should review the readback information to confirm that you have entered the settings that you intended.

Table 9.127 SET TERSE Command Examples

Command	Description	Access Level
SET TERSE	SET Group settings, beginning at the first setting in the active group; omit settings readback.	P, 2
SET 3 TE *label*[a]	SET Group 3 settings, beginning at the settings label *label*; omit settings readback.	P, 2
SET P *p label* TERSE	Set the communications Port relay settings for Port *p*, beginning at the settings label *label*; omit readback.	P, A, O, 2

[a] TERSE may be entered as TE as shown in this example.

You can use the **TERSE** option in any **SET** command at any position after typing **SET**. When you end the settings edit session, the relay responds, `Save settings (Y,N)?` If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait.....`. The relay saves the new settings, then responds, `Settings Saved`. If you answer **N <Enter>** to the save settings prompt, the relay responds, `Settings aborted`.

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* for information on settings organization. The relay displays each setting in the order specified in the settings tables in the *Section 10: 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.4.14* 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 9.128 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*[a]	Show the Group *n* relay settings, beginning at the first setting in each instance.	1, B, P, A, O, 2
SHO *label*	Show the Group relay settings, beginning at the active group settings label *label*.	1, B, P, A, O, 2
SHO *n label*	Show the Group *n* relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

[a] Parameter n = 1–6, representing Group 1 through Group 6.

SHO A

Use the **SHO A** command to show the Automation SELOGIC control equations. See *Section 3: SELOGIC Control Equations* for more information on SELOGIC control equations.

Table 9.129 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.

SHO B

Use the **SHO B** command to show the Bay Control settings in the SEL-451-4. There is only one instance for the Bay Control settings. See *Section 5: Bay Control in the Applications Handbook* for more information on Bay Control settings.

Table 9.130 SHO B Command

Command	Description	Access Level
SHO B	Show the Bay Control relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO B *label*	Show the Bay Control relay settings, beginning at settings label *label*.	1, B, P, A, O, 2

SHO 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 *SHO P on page R.9.53*). 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 6: DNP3 Communications*.

Table 9.131 SHOW D Command

Command	Description	Access Level
SHO D	Show the serial port DNP3 remapping settings.	P, A, O, 2
SHO D *label*	Show the serial port DNP3 remapping settings, beginning at setting *label*.	P, A, O, 2

SHO 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 9.132 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
SHO F *label*	Show the Front Panel relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO G

Use the **SHO G** command to show the Global class settings. There is only one instance for the Global class.

Table 9.133 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
SHO G *label*	Show the Global relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO L

Use the **SHO L** command to show the Protection SELOGIC control equations. See *Section 3: SELOGIC Control Equations* for more information on SELOGIC control equations.

Table 9.134 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 Instance *n*, which is Group *n*.	1, B, P, A, O, 2

[a] Parameter n is 1–6 for Group 1 through Group 6.

SHO M

Use the **SHO M** command to show the circuit breaker monitor settings. There is only one instance for the Breaker Monitor class. See *Section 2: Monitoring and Metering in the Applications Handbook* for information on the circuit breaker monitor.

Table 9.135 SHO M Command

Command	Description	Access Level
SHO M	Show the Breaker Monitor relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO M *label*	Show the Breaker Monitor relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO O

Use the **SHO O** command to show the Output SELOGIC control equations. See *Control Outputs on page U.2.8* for more information on relay control outputs.

Table 9.136 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
SHO O *label*	Show the Output SELOGIC control equation relay settings, beginning at the output label *label*.	1, B, P, A, O, 2

SHO P

Use the **SHO P** command to configure the relay communications ports; each port is a settings instance. The SEL-451 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 9.137 SHO P Command

Command	Description	Access Level
SHO P	Show the relay settings for the port presently in use, beginning at the first Port F setting.	1, B, P, A, O, 2
SHO P *label*	Show the relay settings for the port presently in use, beginning at the settings label *label.*	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
SHO P *p label*	Show the communications Port relay settings for Port *p*, beginning at the settings label *label*.	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 port.

SHO R

Use the **SHO R** command to show Report settings and to program SER Points and Aliases. You can also show event report parameters and program Event Report Digital Elements. There is only one instance for the Report settings.

Table 9.138 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
SHO R *label*	Show the Report relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO T

Use the **SHO T** command to show aliases for Relay Word bits or analog quantities. There is only one instance for the alias settings.

Table 9.139 SHO T Command

Command	Description	Access Level
SHO T	Show the alias settings.	1, B, P, A, O, 2

SNS

In response to the **SNS** command, the relay sends the names of the Sequential Events Recorder elements. This is a comma-delimited string used to support the SEL Fast SER report. See *Section 5: SEL Communications Protocols* for more information.

Table 9.140 SNS Command

Command	Description	Access Level
SNS	Send the names 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.6.35* 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 9.141 STA Command

Command	Description	Access Level
STA	Return the relay status.	1, B, P, A, O
STA	Return the relay status and show a new hardware configuration prompt.	2

If you change an I/O interface board, the relay detects the new configuration and initiates a status warning. When you issue the **STA** command at Access Level 2, the relay responds to this situation, `Accept new hardware configuration (Y/N)?` If you answer **Y <Enter>**, the relay responds, `New configuration accepted`. If you answer **N <Enter>**, the relay responds, `Command aborted`.

STA A

Use the **STA A** command to view the entire relay status report. Items in the full status report include the short-form status report items plus data on A/D (analog/digital) channel offsets, power supply voltages, temperature, communications interfaces, and time-source synchronization.

Table 9.142 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 9.143 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 3: SELOGIC Control Equations* for more information.

Table 9.144 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/reset 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 3: SELOGIC Control Equations* for more information.

Table 9.145 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 9.146 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 command).

When parameter *n* is 1 through 9999, *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

Use **SUM ACK** to acknowledge an event summary that you recently viewed with the **SUM NEXT** command on the present communications port. Acknowledge the oldest summary (specify no event number).

Table 9.147 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, `Event summary number n has not been viewed with the NEXT option`.

SUM NEXT

Use the **SUM N** command to view the oldest (next) unacknowledged event summary.

Table 9.148 SUM N Command

Command	Description	Access Level
SUM N	View the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

SUM HIF

Use the **SUM HIF** command to view the HIF event summary reports in the relay memory. This command is only available when the relay supports HIF detection.

Table 9.149 SUM HIF Command

Command	Description	Access Level
SUM HIF	Return the most recent HIF event summary.	1, B, P, A, O, 2
SUM HIF *k*[a]	Return an event summary for HIF event *k*.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see the HIF event history report (HIS HIF command).

SUM HIF ACK

Use **SUM HIF ACK** to acknowledge an event summary that you recently viewed with the **SUM HIF NEXT** command on the present communications port. Acknowledge the oldest summary (specify no event number).

Table 9.150 SUM HIF ACK Command

Command	Description	Access Level
SUM HIF ACK	Acknowledge the oldest unacknowledged HIF 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, HIF Event summary number n has not been viewed with the NEXT option.

SUM HIF NEXT

Use the **SUM HIF NEXT** command to view the oldest (next) unacknowledged HIF event summary.

Table 9.151 SUM HIF NEXT Command

Command	Description	Access Level
SUM HIF NEXT	View the oldest unacknowledged HIF 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 bit elements or aliases. When using the **TAR** command, you can specify the row number or element name.

Table 9.152 TAR Command

Command	Description	Access Level
TAR	Display target Row 0 or display the most recently viewed target row.	1, B, P, A, O, 2
TAR *n*	Display target Row *n*.	1, B, P, A, O, 2
TAR *n k*[a]	Display target Row *n* and repeat for *k* times; the repeat count *k* must follow the row number.	1, B, P, A, O, 2
TAR *name*	Display the target row with the element name *name*.	1, B, P, A, O, 2
TAR *name k*	Display the target row with the element name *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 target 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 8, the relay displays the repeated target rows on the terminal screen in groups of eight, with the target row elements listed above each grouping.

TAR ALL

Use the **TAR ALL** command to display all of the relay targets.

Table 9.153 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 target row that the relay reports when you issue a simple **TAR** command.

Table 9.154 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 target row in the Relay Word bit table than the target row in the target row repeat memory. This function is useful for relay testing. See *Section 6: Testing and Troubleshooting in the User's Guide* for more information.

Table 9.155 TAR X Command

Command	Description	Access Level
TAR *n* X	Display target Row *n*, but do not memorize Row *n*.	1, B, P, A, O, 2
TAR X *n k*[a]	Display target 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
TAR *name* X	Display the target row with the element name *name*; do not memorize the row number.	1, B, P, A, O, 2
TAR *name* X *k*	Display the target row with the element name *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.

TEC

Enter the **TEC** (Time-Error Calculation) command to display the present time-error estimation and the status of the time-error control equations, and to modify the time-error correction value. For more information on the time-error calculation, see *Time-Error Calculation on page R.1.15*.

Table 9.156 TEC Command

Command	Description	Access Level
TEC	Display Time-Error data	1, B, P, A, O, 2
TEC *n*	Preload time-error correction value *n*, where –30.000 <= *n* <= 30.000	B, P, A, O, 2

See *Figure 1.12* for a sample **TEC** command response.

Use the **TEC *n*** command to preload the time-error correction value, TECORR. If the value n is within range, the relay will prompt `Are you sure (Y/N)?` If the prompt is acknowledged, the relay sets analog quantity TECORR = n, and asserts Relay Word bit PLDTE value, along with the remaining **TEC** command data. See *Figure 1.13* for a sample response.

The TECORR value does not affect the TE (time-error) estimation until the LOADTE SELOGIC equation asserts, as explained in *Time-Error Calculation on page R.1.15*.

TEST DB

Use the **TEST DB** command for testing interfaces to a virtual device database. For the SEL-451, 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-451 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; see *Section 4: Communications Interfaces* for more information.

TEST DB

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 9.157 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 9.158 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 serial port DNP3 interface only. For more information on Serial DNP3 and the SEL-451, see *Section 6: DNP3 Communications* in the Reference Manual.

TEST DNP

Values you enter in the DNP map are override values. Use the **TEST DNP** command to write override values in the DNP map.

Table 9.159 TEST DNP Command

Command	Description	Access Level
TEST DNP	Display present override values.	1, B, P, A, O, 2
TEST DNP *type n value1*[a]	Write new data *value1* of type *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 overrides with the **TEST DNP** command, 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 value1*** 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 *value1* is a

value you specify. The point number and override value must be valid for the given data type (see *Section 6: DNP3 Communications*).

When you have successfully added a new DNP test value (for example, **TEST DNP A 17 -357**), the relay responds, `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 9.160 TEST DNP Command

Command	Description	Access Level
TEST DNP *type n* OFF[a]	Clear the override testing value of type *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, `Override Removed`. When an attempt to remove a DNP test value fails, the relay responds, `Override Not Found`. When removing all DNP test values (for example, **TEST DNP OFF**), the relay responds, `All Overrides Removed`.

TEST FM

The **TEST FM** command overrides normal Fast Meter quantities for testing purposes. You can override only "reported" Fast Meter values (per-phase voltages and currents). For more information on Fast Meter and the SEL-451, see *Section 5: 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 9.161 TEST FM Command

Command	Description	Access Level
TEST FM	Display present override values.	1, B, P, A, O, 2
TEST FM *label value1 value2*	Write new data *value1* and *value2* to the Fast Meter report at the item label *label*. Parameter *value2* is optional.	B, P, A, O, 2

When you display 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 value1 value2*** command. The item label *label* is any analog channel label in the Fast Meter configuration (if available), any digital element label (from the **DNA** command), and any status element label (from the **BNA** command) except the TEST and FMTEST items.

The value *value1* can be logical 0 or logical 1 for digital and status elements, or a floating-point value for all meter quantities. All meter values are in primary units. For meter items that report a pair of values in the Fast Meter message, *value1* is the magnitude and *value2*, if provided, is the angle. If you do not specify *value2*, the relay uses an angle of 0.

When you have successfully added a new Fast Meter test value (for example, **TEST FM IA1 3.7 0.0**), the relay responds, `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 bit. Similarly, if any item in any Fast Meter message is in test mode, the FMTEST is set in all three Fast Meter responses.

TEST FM DEM

Use the **TEST FM DEM** command to insert override values in Fast Meter demand metering.

Table 9.162 TEST FM DEM Command

Command	Description	Access Level
TEST FM DEM *label value1*	Write new data *value1* to the Fast Meter demand meter report at the item label *label*.	B, P, A, O, 2

TEST FM OFF

Use the **TEST FM OFF** command to remove override values. The relay returns the Fast Meter registers to the pre-test values.

Table 9.163 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 IA1 OFF**), the relay responds, `Override Removed`. When an attempt to remove an FM test value fails, the relay responds, `Override Not Found`. When removing all FM test values (for example, **TEST FM OFF**), the relay responds, `All Overrides Removed`.

TEST FM PEAK

Use the **TEST FM PEAK** command to insert override values in Fast Meter peak demand metering.

Table 9.164 TEST FM PEAK Command

Command	Description	Access Level
TEST FM PEAK *label value1*	Write new data *value1* to the Fast Meter peak demand meter report at the item label *label*.	B, P, A, O, 2

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 HIRIG time mode, IRIG time mode, and when using DNP. See *Configuring High-Accuracy Timekeeping on page U.4.73* for more information on configuring SEL-451 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 9.165 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, `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 9.166 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 time source and the last time value update source (see *Configuring High-Accuracy Timekeeping on page U.4.73*).

TRIGGER

The **TRIGGER** command initiates data captures for high-resolution oscillography and event reports. For information on high-resolution oscillography and event reports, see *Section 3: Analyzing Data in the Applications Handbook*. See *Reading Oscillograms, Event Reports, and SER on page U.4.43* for examples using the **TRI** command.

TRI

Use the **TRI** command to trigger the SEL-451 to record data for high-resolution oscillography and event reports.

Table 9.167 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, `Triggered`. If the event did not trigger within 1 second, the relay responds, `Did not trigger`.

TRI HIF

Use the **TRI HIF** command to trigger the SEL-451 to record data for high-impedance fault event reports. This command is only available when the relay supports HIF detection and EHIF is not set to 'N'.

Table 9.168 TRI HIF Command

Command	Description	Access Level
TRI HIF	Trigger relay data capture.	1, B, P, A, O, 2

When you issue the **TRI HIF** command, the relay responds, `HIF triggered`. If the event did not trigger within 1 second, the relay responds, `HIF 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 9.169 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 these items:

- FID
- CID
- Part number
- Serial number

- SELBOOT BFID
- Mainboard memory types and sizes
- Front-panel hardware
- Analog inputs (W, X, Y, Z) ratings
- Fiber port (installed or absent)
- Interface board inputs and outputs
- Communications card IDs and part number
- Extended relay features list (optional DNP communications capability)

A sample **VER** command response is shown in *Figure 9.6*:

```
=>VER <Enter>
FID=SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd
CID=xxxx
Part Number:  04511415XX11XXHX
Serial Number:  2004001234
SELboot:
    BFID= SLBT-4XX-R1XX-V0-zxxxxxx-Dyyymmdd
    Checksum:  xxxx
Mainboard:
    Code FLASH Size:    4 MB
    Data FLASH Size:    8 MB
    RAM Size:           2 MB
    EEPROM Size:       64 kB
Front Panel: installed
Analog Inputs:
    W:  Currents:  5 Amp
    X:  Currents:  5 Amp
    Y:  Voltage:   67 Volts
    Z:  Voltage:   67 Volts
Fiber Port:  not installed
Interface Boards:
    Board 1:  not installed
    Board 2:  not installed
Communications Card:
    not installed
Extended Relay Features:
    None

If the information above is not as expected, contact SEL for assistance.

=>
```

Figure 9.6 Sample VER Command Response

If an item is not installed, the **VER** report indicates `Not installed` at the appropriate line. If a detected hardware configuration does not match the component part number, the relay adds the statement `Warning - hardware does not match part number` on the corresponding line.

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-451 is very similar to the **VIEW** command in the SEL Communications Processors. See *Section 4: Communications Interfaces* for more information on the relay database regions and data types.

SEL-451 regions are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS; view this list with the **MAP 1** command.

The SEL-451 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 9.170* to view the contents of the database regions.

Table 9.170 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 9.171* 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 9.171 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 9.172* 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 67G1T, 25W1BK2, and ASV256.

Table 9.172 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*.

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Section 10

Settings

This section contains tables of relay settings for the SEL-451 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 fully explain the rules for hiding settings; these rules are discussed in the applications sections of the instruction manual where appropriate.

NOTE: When using the **SET** command to configure your SEL-451, enter the settings classes Global, Breaker Monitor, and Group in the order shown.

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 the *Applications Handbook*. The section arranges settings in the following order:

- *Alias Settings on page R.10.4*
- *Global Settings on page R.10.5*
  - General global settings
  - Global enables
  - DC monitors
  - Control inputs
  - Main board control inputs
  - Interface boards 1 and 2 control inputs
  - Settings group selection
  - Data reset control
  - Frequency estimation
  - Time-error calculation
  - Current and voltage source selection
  - Synchronized phasor measurement
- *Breaker Monitor Settings on page R.10.11*
  - Inputs
  - Monitor
  - Contact wear
  - Electrical operating time
  - Mechanical operating time
  - Pole scatter and pole discrepancy
  - Inactivity time
  - Motor running time
  - Current interrupted

- *Group Settings on page R.10.14*
  - Line configuration
  - Relay configuration
  - Zero-sequence compensation factor
  - Switch-onto-fault scheme
  - Load encroachment
  - Phase instantaneous overcurrent pickup
  - Phase definite-time overcurrent time delay
  - Phase instantaneous definite-time overcurrent torque control
  - Residual ground instantaneous overcurrent pickup
  - Residual ground definite-time overcurrent time delay
  - Residual ground instantaneous definite-time overcurrent torque control
  - Negative-sequence instantaneous overcurrent pickup
  - Negative-sequence definite-time overcurrent time delay
  - Negative-sequence instantaneous definite-time overcurrent
  - Torque control
  - Selectable operating quantity inverse time overcurrent element 1
  - Selectable operating quantity inverse time overcurrent element 2
  - Selectable operating quantity inverse time overcurrent element 3
  - Zone/level direction
  - Directional control element
  - Pole open detection
  - POTT trip scheme
  - DCUB trip scheme
  - DCB trip scheme
  - Breaker 1 and Breaker 2 failure logic
  - Synchronism check element reference
  - Breaker 1 synchronism check
  - Breaker 2 synchronism check
  - Recloser and manual closing
  - Single-pole reclose settings
  - Three-pole reclose settings
  - Voltage elements
  - Demand metering
  - Trip logic
  - High Impedance Fault Detection
  - 50G High-Z (HIZ) Fault Detection
- *Protection Free-Form SELOGIC Control Equations on page R.10.30*

- *Automation Free-Form SELOGIC Control Equations on page R.10.31*
- *Output Settings on page R.10.32*
  - Main board
  - Interface board outputs
  - Communications card outputs
  - MIRRORED BITS® communications transmit equations
- *Front-Panel Settings on page R.10.33*
  - Pushbuttons and target LEDs
  - Selectable screens
  - Selectable Operator Pushbuttons
  - Front Panel Event Display
  - Display points
  - Local control
  - Boolean display points
  - Analog display points
- *Report Settings on page R.10.41*
  - SER chatter criteria
  - SER points and aliases
  - Event reporting
  - Event report digital elements
- *Port Settings on page R.10.43*
  - Ports 1, 2, 3, F, and 5
- *DNP3 Settings—Serial Port on page R.10.47*

Alias Settings

Assign a valid seven-character alias name to any of the following:

- Relay Word bit (except target LEDs)
- Analog Quantity

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 (_).

For example, the default name for contact output OUT101 is OUT101. You could change the default name to an alias, BK1 Trip, for example.

BK1 Trip (including the space) consists of eight characters, one more than the allowable number of seven. Changing the name to BK1 Tr reduces the character count to six, but the alias contains two elements not permitted, a space and one lowercase letter (r). One possible alias for the existing name of OUT101 could be BK1_TR, entered using the following syntax:

primitive name, alias name,

e.g., OUT101, BK1_TR

Figure 10.1 shows the steps using the **SET T** command.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
? <Enter>
2:
?  OUT101, BK1_TR
3:
? END <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
2: OUT101,"BK1_TR"
.
.
.

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

=>>
```

Figure 10.1 Changing a Default Name to an Alias

Table 10.1 Default Alias Settings

Label	Default Value
EN	RLY_EN

Global Settings

Table 10.2 Global Settings Categories

Settings	Reference
General Global Settings	*Table 10.3*
Global Enables	*Table 10.4*
Station DC1 Monitor (and Station DC2 Monitor)	*Table 10.5*
Control Inputs (Global)	*Table 10.6*
Main Board Control Inputs	*Table 10.7*
Interface Board #1 Control Inputs	*Table 10.8*
Interface Board #2 Control Inputs	*Table 10.9*
Settings Group Selection	*Table 10.10*
Data Reset Control	*Table 10.11*
Frequency Estimation	*Table 10.12*
Time-Error Calculation	*Table 10.13*
Current and Voltage Source Selection	*Table 10.14*
Synchronized Phasor Measurement	*Table 10.15*

NOTE: See corresponding command descriptions SET G on page R.9.47 and SHO G on page R.9.52 to set or show the Global settings.

Table 10.3 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 in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Breaker 1
BID2	Breaker 2 Identifier (40 characters)	Breaker 2
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation (SELOGIC Equation)	51S1 OR 51S2 OR 50P1

Table 10.4 Global Enables

Label	Prompt	Default Value
EDCMON	Station DC Battery Monitor (N, 1, 2)	N
EICIS	Independent Control Input Settings (Y, N)	N
EDRSTC	Data Reset Control (Y, N)	N
EGADVS	Advanced Global Settings (Y, N)	N
EPMU	Synchronized Phasor Measurement (Y, N)	N

Make *Table 10.5* settings when Global enable setting EDCMON := 1 or 2. These settings are hidden when EDCMON := N.

Table 10.5 Station DC1 Monitor (and Station DC2 Monitor[a])

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 (1.00–2.00)	1.05

[a] Replace 1 with 2 in the setting label.

Make *Table 10.6* settings when Global enable setting EICIS := N.

NOTE: Main Board A I/O, INT1, INT5, and INT6 I/O interface boards have direct coupled contact inputs. Main Board B I/O, INT2, INT4, INT7, and INT8 I/O interface boards have optoisolated contact inputs. SEL-451-1 does not support Main Board B I/O, INT2, INT7, and INT8 I/O interface boards. SEL-451-2 supports all the boards.

Table 10.6 Control Inputs (Global)

Label	Prompt	Default Value
GINP[a]	Input Pickup Level (15–265 Vdc)	85[b]
GINDF[a,c]	Input Dropout Level (10–100 percent of pickup level)	80
IN1XXD[d]	Main Board Debouce Time (0.0000–5 cyc)	0.1250
IN2XXD[e]	Int Board #1 Debounce Time (0.0000–5 cyc[f])	0.1250
IN3XXD[g]	Int Board #2 Debounce Time (0.0000–5 cyc[f])	0.1250

[a] Setting applies to all direct coupled contact inputs if available, otherwise the setting is not available.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.6 for setting guidelines.
[c] Setting applies to all direct coupled contact inputs independent of EICIS set to Y or N.
[d] Setting applies to all the main board input contacts.
[e] Setting applies to all the Interface Board #1 input contacts.
[f] If the interface board has more than eight input contacts the upper range is 1 cycle.
[g] Setting applies to all the Interface Board #2 input contacts.

Make *Table 10.7* settings when Global enable setting EICIS := Y.

NOTE: Main Board A I/O, INT1, INT5, and INT6 I/O interface boards have direct coupled contact inputs. Main Board B I/O, INT2, INT4, INT7, and INT8 I/O interface boards have optoisolated contact inputs. SEL-451-1 does not support Main Board B I/O, INT2, INT7, and INT8 I/O interface boards. SEL-451-2 supports all the boards.

Table 10.7 Main Board Control Inputs

Label	Prompt	Default Value
IN101P[a]	Input IN101 Pickup Level (15–265 Vdc)	85[b]
•	•	•
•	•	•
•	•	•
IN107P[a]	Input IN107 Pickup Level (15–265 Vdc)	85[b]
IN101PU	Input IN101 Pickup Time (0.0000–5 cyc)	0.1250[c]
IN101DO	Input IN101 Debounce Time (0.0000–5 cyc)	0.1250[c]
•	•	•
•	•	•
•	•	•
IN107PU	Input IN107 Pickup Delay (0.0000–5 cyc)	0.1250[c]
IN107DO	Input IN107 Dropout Delay (0.0000–5 cyc)	0.1250[c]

[a] Setting is not available for Main Board B. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.6 for setting guidelines.
[c] Set at Global setting IN1XXD when EICIS := N.

Make *Table 10.8* settings for Interface Board #1 when Global enable setting EICIS := Y.

Table 10.8 Interface Board #1 Control Inputs

Label	Prompt	Default Value
IN201P[a]	Input IN201 Pickup Level (15–265 Vdc)	85[b]
•	•	•
•	•	•
•	•	•
IN208P[a]	Input IN208 Pickup Level (15–265 Vdc)	85[b]
IN201PU	Input IN201 Pickup Delay (0.0000–5 cyc[c])	0.1250[d]
IN201DO	Input IN201 Dropout Delay (0.0000–5 cyc[c])	0.1250[d]
•	•	•
•	•	•
•	•	•
IN2*mm*PU[e]	Input IN208 Debounce Time (0.0000–5 cyc[c])	0.1250[d]
IN2*mm*PU[e]	Input IN208 Debounce Time (0.0000–5 cyc[c])	0.1250[d]

[a] Setting is not available for interface boards INT2, INT4, INT7, and INT8. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.6 for setting guidelines.
[c] If the interface board has more than eight input contacts the upper range is 1 cycle.
[d] Set at Global setting IN2XXD when EICIS := N.
[e] mm is the number of available input contacts on the interface board.

Make *Table 10.9* settings for interface board #2 when Global enable setting EICIS := Y.

Table 10.9 Interface Board #2 Control Inputs

Label	Prompt	Default Value
IN301P[a]	Input IN301 Pickup Level (15–265 Vdc)	85[b]
•	•	•
•	•	•
•	•	•
IN308P[a]	Input IN308 Pickup Level (15–265 Vdc)	85[b]
IN301PU	Input IN301 Pickup Delay (0.0000–5 cyc[c])	0.1250[d]
IN301DO	Input IN301 Dropout Delay (0.0000–5 cyc[c])	0.1250[d]
•	•	•
•	•	•
•	•	•
IN3*mm*PU[e]	Input IN3*mm*[e] Pickup Delay (0.0000–5 cyc[c])	0.1250[b]
IN3*mm*DO[e]	Input IN3*mm*[e] Dropout Delay (0.0000–5 cyc[c])	0.1250[b]

[a] Setting is not available for interface boards INT2, INT4, INT7, and INT8. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.6 for setting guidelines.
[c] If the interface board has more than eight input contacts the upper range is 1 cycle.
[d] Set at Global setting IN3XXD when EICIS := N.
[e] mm is the number of available input contacts on the interface board.

Table 10.10 Settings Group Selection

Label	Prompt	Default Value
SS1	Select Setting Group 1 (SELOGIC Equation)	PB4 AND NOT SG1
SS2	Select Setting Group 2 (SELOGIC Equation)	PB4 AND SG1
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

Make *Table 10.11* settings when Global enable setting EDRSTC := Y.

Table 10.11 Data Reset Control

Label	Prompt	Default Value
RST_DEM	Reset Demand Metering (SELOGIC Equation)	NA
RST_PDM	Reset Peak Demand Metering (SELOGIC Equation)	NA
RST_ENE	Reset Energy Metering (SELOGIC Equation)	NA
RSTMML	Reset Maximum/Minimum Line (SELOGIC Equation)	NA
RSTMMB1	Reset Maximum/Minimum Breaker 1 (SELOGIC Equation)	NA
RSTMMB2	Reset Maximum/Minimum Breaker 2 (SELOGIC Equation)	NA
RST_BK1	Reset Monitoring Breaker 1 (SELOGIC Equation)	NA
RST_BK2	Reset Monitoring Breaker 2 (SELOGIC Equation)	NA
RST_BAT	Reset Battery Monitoring (SELOGIC Equation)	NA
RST_79C	Reset Recloser Shot Count Accumulators (SELOGIC Equation)	NA
RSTTRGT	Target Reset (SELOGIC Equation)	NA
RSTFLOC	Reset Fault Locator (SELOGIC Equation)	NA
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC Equation)	TRGTR

Make *Table 10.12* settings when Global enable setting EGADVS := Y.

Table 10.12 Frequency Estimation

Label	Prompt	Default Value
EAFSRC	Alternate Frequency Source (SELOGIC Equation)	NA
VF01	Local Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
VF02	Local Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBY
VF03	Local Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCY
VF11	Alternate Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF12	Alternate Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF13	Alternate Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO

NOTE: In firmware version R104, Global Time and Data Management Settings ETPPS and ETIRIG were removed. See Configuring High-Accuracy Timekeeping on page U.4.73 for an explanation.

Table 10.13 Time-Error Calculation

Label	Prompt	Default Value
STALLTE	Stall Time-Error Calculation (SELOGIC Equation)	NA
LOADTE	Load TECORR Factor (SELOGIC Equation)	NA

See *Current and Voltage Source Selection on page R.1.2* for more information on *Table 10.14* settings.

Table 10.14 Current and Voltage Source Selection

Label	Prompt	Default Value
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
LINEI	Line Current Source (IW, COMB)	IW
ALINEI	Alternate Line Current Source (IX, NA)	NA
ALTI	Alternate Current Source (SELOGIC Equation)	NA
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA

Make *Table 10.15* settings when Global enable setting EPMU := Y.

Table 10.15 Synchronized Phasor Measurement (Sheet 1 of 2)

Label	Prompt	Default Value
MFRMT	Message Format (C37.118, FM)	C37.118
MRATE[a]	Messages per Second (1, 2, 5, 10, 25, 50) {when NFREQ = 50} (1, 2, 4, 5, 10, 12, 15, 20, 30, 60) {when NFREQ = 60}	2
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency Based Phasor Compensation (Y, N)	Y
PMSTN[a]	Station Name (16 characters)	STATION A
PMID	PMU Hardware ID (1–65534)[b]	1
PHDATAV	Phasor Data Set, Voltages (V1, ALL, NA)[c]	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 deg)	0.00
PHDATAI	Phasor Data Set, Currents (I1, ALL, NA)[d]	NA
PHCURR	Current Source (IW, IX, BOTH, COMB)[e]	IW
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 deg)	0.00
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 deg)	0.00
PHNR[a]	Phasor Numerical Representation (I = Integer, F = Floating Point)	I
PHFMT[a]	Phasor Format (R = Rectangular, P = Polar)	R
FNR[a]	Frequency Numerical Representation (I = Integer, F = Floating Point)	I
NUMANA[a]	Number of Analog Values (0–8)	0
NUMDSW[a]	Number of 16-bit Digital Status Words (0, 1, 2)	1

Table 10.15 Synchronized Phasor Measurement (Sheet 2 of 2)

Label	Prompt	Default Value
TREA1[a]	Trigger Reason Bit 1 (SELOGIC Equation)	NA
TREA2[a]	Trigger Reason Bit 2 (SELOGIC Equation)	NA
TREA3[a]	Trigger Reason Bit 3 (SELOGIC Equation)	NA
TREA4[a]	Trigger Reason Bit 4 (SELOGIC Equation)	NA
PMTRIG[a]	Trigger (SELOGIC EQUATION)	NA

[a] Setting not available when MFRMT := FM.
[b] When MFRMT := FM, range is 0–0xFFFFFFFF.
[c] When MFRMT := FM, NA setting choice is hidden.
[d] When MFRMT := FM, I1 setting choice is hidden, and the ALL setting choice is only available when PHDATAV := ALL.
[e] When MFRMT := FM, BOTH setting choice is hidden.

Table 10.16 Time and Date Management

Label	Prompt	Default Value
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When MFRMT := C37.118, IRIGC is forced to C37.118.

Breaker Monitor Settings

NOTE: If you want to enable the circuit breaker monitor on Circuit Breaker 2, confirm that the relay is set for two-circuit breaker operation; global setting NUMBK must be 2. Once you have set NUMBK := 2, you can set the Circuit Breaker 2 monitor settings, including EB2MON.

Table 10.17 Breaker Monitor Settings Categories

Settings	Reference
Breaker Configuration	*Table 10.18*
Breaker 1 Inputs	*Table 10.19*
Breaker 2 Inputs	*Table 10.20*
Breaker 1 Monitor (and Breaker 2 Monitor)	*Table 10.21*
Breaker 1 Contact Wear (and Breaker 2 Contact Wear)	*Table 10.22*
Breaker 1 Electrical Operating Time (and Breaker 2 Electrical Operating Time)	*Table 10.23*
Breaker 1 Mechanical Operating Time (and Breaker 2 Mechanical Operating Time)	*Table 10.24*
Breaker 1 Pole Scatter and Pole Discrepancy (and Breaker 2 Pole Scatter and Pole Discrepancy)	*Table 10.25*
Breaker 1 Inactivity Time Elapsed (and Breaker 2 Inactivity Time Elapsed)	*Table 10.26*
Breaker 1 Motor Running Time (Breaker 2 Motor Running Time)	*Table 10.27*
Breaker 1 Current Interrupted (Breaker 2 Current Interrupted)	*Table 10.28*

Make *Table 10.18* EB1MON setting when Global setting NUMBK := 1 or 2. Make EB2MON setting when Global setting NUMBK := 2.

NOTE: See corresponding command descriptions SET M on page R.9.48 and SHO M on page R.9.52 to set or show the Breaker Monitor settings.

Table 10.18 Breaker Configuration

Label	Prompt	Default Value
EB1MON	Breaker 1 Monitoring (Y, N)	N
EB2MON	Breaker 2 Monitoring (Y, N)	N

Table 10.19 Breaker 1 Inputs

Label	Prompt	Default Value
52AA1	Normally Open Contact Input—BK1 (SELOGIC Equation)	IN101

Make *Table 10.20* 52AA2 setting if Global setting NUMBK := 2.

Table 10.20 Breaker 2 Inputs

Label	Prompt	Default Value
52AA2	Normally Open Contact Input—BK2 (SELOGIC Equation)	NA

Make *Table 10.21* through *Table 10.28* settings when Breaker Monitor setting EB1MON := Y or EB2MON := Y.

Table 10.21 Breaker 1 Monitor (and Breaker 2 Monitor[a])

Label	Prompt	Default Value
BM1TRPA	Breaker Monitor Trip—BK1 (SELOGIC Equation)	T3P1
BM1CLSA	Breaker Monitor Close—BK1 (SELOGIC Equation)	BK1CL

[a] Replace 1 with 2 in the setting label, prompt, and default value.

Table 10.22 Breaker 1 Contact Wear (and Breaker 2 Contact Wear[a])

Label	Prompt	Default Value
B1COSP1	Close/Open Set Point 1—BK1 (0–65000 operations)	1000
B1COSP2	Close/Open Set Point 2—BK1 (0–65000 operations)	100
B1COSP3	Close/Open Set Point 3—BK1 (0–65000 operations)	10
B1KASP1	kA Interrupted Set Point 1—BK1 (1.0–999 kA)	20.0
B1KASP2	kA Interrupted Set Point 2—BK1 (1.0–999 kA)	60.0
B1KASP3	kA Interrupted Set Point 3—BK1 (1.0–999 kA)	100.0
B1BCWAT	Contact Wear Alarm Threshold—BK1 (0–100%)	90

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.23 Breaker 1 Electrical Operating Time (and Breaker 2 Electrical Operating Time[a])

Label	Prompt	Default Value
B1ESTRT	Electrical Slow Trip Alarm Threshold—BK1 (1–999 ms)	50
B1ESCLT	Electrical Slow Close Alarm Threshold—BK1 (1–999 ms)	120

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.24 Breaker 1 Mechanical Operating Time (and Breaker 2 Mechanical Operating Time[a])

Label	Prompt	Default Value
B1MSTRT	Mechanical Slow Trip Alarm Threshold—BK1 (1–999 ms)	50
B1MSCLT	Mechanical Slow Close Alarm Threshold—BK1 (1–999 ms)	120

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.25 Breaker 1 Pole Scatter and Pole Discrepancy (and Breaker 2 Pole Scatter and Pole Discrepancy[a])

Label	Prompt	Default Value
B1PSTRT	Pole Scatter Trip Alarm Threshold—BK1 (1–999 ms)	20
B1PSCLT	Pole Scatter Close Alarm Threshold—BK1 (1–999 ms)	20
B1PDD	Pole Discrepancy Time Delay—BK1 (1–9999 ms)	1400
E1PDCS	Pole Discrepancy Current Supervision—BK1 (Y, N)	N

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.26 Breaker 1 Inactivity Time Elapsed (and Breaker 2 Inactivity Time Elapsed[a])

Label	Prompt	Default Value
B1ITAT	Inactivity Time Alarm Threshold—BK1 (N, 1–9999 days)	365

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.27 Breaker 1 Motor Running Time (and Breaker 2 Motor Running Time[a])

Label	Prompt	Default Value
B1MRTIN	Motor Run Time Contact Input—BK1 (SELOGIC Equation)	NA
B1MRTAT	Motor Run Time Alarm Threshold—BK1 (1–9999 seconds)	25

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.28 Breaker 1 Current Interrupted (and Breaker 2 Current Interrupted[a])

Label	Prompt	Default Value
B1KAIAT	kA Interrupt Capacity Alarm Threshold—BK1 (N, 1–100%)	90
B1MKAI	Maximum kA Interrupt Rating—BK1 (1–999 kA)	50

[a] Replace 1 with 2 in the setting label and prompt.

Group Settings

Table 10.29 Group Settings Categories

Settings	Reference
Line Configuration	*Table 10.30*
Relay Configuration	*Table 10.31*
Switch-Onto-Fault Scheme	*Table 10.32*
Load Encroachment	*Table 10.33*
Phase Instantaneous Overcurrent Pickup	*Table 10.34*
Phase Definite-Time Overcurrent Time Delay	*Table 10.35*
Phase Instantaneous Definite-Time Overcurrent Torque Control	*Table 10.36*
Residual Ground Instantaneous Overcurrent Pickup	*Table 10.37*
Residual Ground Definite-Time Overcurrent Time Delay	*Table 10.38*
Residual Ground Instantaneous Definite-Time Overcurrent Torque Control	*Table 10.39*
Negative-Sequence Instantaneous Overcurrent Pickup	*Table 10.40*
Negative-Sequence Definite-Time Overcurrent Time Delay	*Table 10.41*
Negative-Sequence Instantaneous Definite-Time Overcurrent Torque Control	*Table 10.42*
Selectable Operating Quantity Inverse Time Overcurrent Element 1	*Table 10.43*
Selectable Operating Quantity Inverse Time Overcurrent Element 2	*Table 10.44*
Selectable Operating Quantity Inverse Time Overcurrent Element 3	*Table 10.45*
Selectable Operating Quantity Inverse Time Overcurrent Element 4	*Table 10.45*
Selectable Operating Quantity Inverse Time Overcurrent Element 5	*Table 10.45*
Selectable Operating Quantity Inverse Time Overcurrent Element 6	*Table 10.45*
Level Direction	*Table 10.49*
Directional Control Element	*Table 10.50*
Pole Open Detection	*Table 10.51*
POTT Trip Scheme	*Table 10.52*
DCUB Trip Scheme	*Table 10.53*
DCB Trip Scheme	*Table 10.54*
Breaker 1 Failure Logic (and Breaker 2 Failure Logic)	*Table 10.55*
Synchronism Check Element Reference	*Table 10.56*
Breaker 1 Synchronism Check	*Table 10.57*
Breaker 2 Synchronism Check	*Table 10.58*
Recloser and Manual Closing	*Table 10.59*
Three-Pole Reclose Settings	*Table 10.60*
Voltage Elements	*Table 10.61*
Demand Metering	*Table 10.62*
Trip Logic	*Table 10.63*
High Impedance Fault (HIF) Detection	*Table 10.64*
50G High-Z (HIZ) Fault Detection	*Table 10.65*

NOTE: See corresponding command descriptions SET on page R.9.46 and SHO on page R.9.50 to set or show the Group settings.

Table 10.30 Line Configuration

Label	Prompt	Default Value 5 A	Default Value 1 A
CTRW	Current Transformer Ratio—Input W (1–50000)	120	120
CTRX	Current Transformer Ratio—Input X (1–50000)	120	120
PTRY	Potential Transformer Ratio—Input Y (1–10000)	180	180
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	180	180
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary) 5 A (0.25–1275 Ω secondary) 1 A	2.14	10.70
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	68.86	68.86
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary) 5 A (0.25–1275 Ω secondary) 1 A	6.38	31.90
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	72.47	72.47
EFLOC	Fault Location (Y, N)	Y	Y
LL	Line Length (0.10–999)	4.84	4.84

Table 10.31 Relay Configuration (Sheet 1 of 2)

Label	Prompt	Default Value
ESOTF	Switch-Onto-Fault (Y, N)	Y
ELOAD	Load Encroachment (Y, N)	N
E50P	Phase Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	1
E50G	Residual Ground Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	N
E50Q	Negative-Sequence Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	N
E51S	Selectable Operating Quantity Inverse Time Overcurrent Element (N, 1–6)	2
E32	Directional Control (Y, AUTO, N)	N
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, DCUB1, DCUB2)	N
EBFL1	Breaker 1 Failure Logic (Y, N)	N
EBFL2	Breaker 2 Failure Logic (Y, N)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E25BK2	Synchronism Check for Breaker 2 (Y, N)	N
E79	Reclosing (Y, Y1, N)	Y
EMANCL	Manual Closing (Y, N)	Y
ELOP	Loss-of-Potential (Y, Y1, N)	Y

Table 10.31 Relay Configuration (Sheet 2 of 2)

Label	Prompt	Default Value
EDEM	Demand Metering (N, THM, ROL)	THM
EHIF	Enable High Impedance Fault Detection (Y, N, T)	N

Make *Table 10.32* settings if Group setting ESOTF := Y.

Table 10.32 Switch-Onto-Fault Scheme

Label	Prompt	Default Value
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	10.000
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	OFF
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	NA

Make *Table 10.33* settings if Group setting ELOAD := Y.

Table 10.33 Load Encroachment

Label	Prompt	Default Value	
		5 A	1 A
ZLF	Forward Load Impedance (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	9.22	46.10
ZLR	Reverse Load Impedance (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	9.22	46.10
PLAF	Forward Load Positive Angle (–90 to +90 degrees)	30.0	30.0
NLAF	Forward Load Negative Angle (–90 to +90 degrees)	–30.0	–30.0
PLAR	Reverse Load Positive Angle (+90 to +270 degrees)	150.0	150.0
NLAR	Reverse Load Negative Angle (+90 to +270 degrees)	210.0	210.0

The number of pickup settings in *Table 10.34* is dependent on Group setting E50P := 1–4. When E50P := N, no settings are made for *Table 10.34* through *Table 10.36*.

Table 10.34 Phase Instantaneous Overcurrent Pickup

Label	Prompt	Default Value 5 A	Default Value 1 A
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	15.00	3.00
50P2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50P3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50P4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF

Make corresponding Level *n* = 1–4 settings in *Table 10.35* and *Table 10.36* for any 50P*n*P settings that are made in *Table 10.34*.

Table 10.35 Phase Definite-Time Overcurrent Time Delay

Label	Prompt	Default Value
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67P2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67P3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
67P4D	Level 4 Time Delay (0.000–16000 cycles)	0.000

Table 10.36 Phase Instantaneous Definite-Time Overcurrent Torque Control[a]

Label	Prompt	Default Value
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
67P2TC	Level 2 Torque Control (SELOGIC Equation)	1
67P3TC	Level 3 Torque Control (SELOGIC Equation)	1
67P4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

The number of pickup settings in *Table 10.37* is dependent on Group setting E50G := 1–4. When E50G := N, no settings are made for *Table 10.37* through *Table 10.39*.

Table 10.37 Residual Ground Instantaneous Overcurrent Pickup

Label	Prompt	Default Value 5 A	Default Value 1 A
50G1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50G2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50G3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50G4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF

Make corresponding Level *n* = 1–4 settings in *Table 10.38* and *Table 10.39* for any 50G*n*P settings that are made in *Table 10.37*.

Table 10.38 Residual Ground Definite-Time Overcurrent Time Delay

Label	Prompt	Default Value
67G1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67G2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67G3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
67G4D	Level 4 Time Delay (0.000–16000 cycles)	0.000

Table 10.39 Residual Ground Instantaneous Definite-Time Overcurrent Torque Control[a]

Label	Prompt	Default Value
67G1TC	Level 1 Torque Control (SELOGIC Equation)	1
67G2TC	Level 2 Torque Control (SELOGIC Equation)	1
67G3TC	Level 3 Torque Control (SELOGIC Equation)	1
67G4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

The number of pickup settings in *Table 10.40* is dependent on Group setting E50Q := 1–4. When E50Q := N, no settings are made for *Table 10.40* through *Table 10.42*.

Table 10.40 Negative-Sequence Instantaneous Overcurrent Pickup

Label	Prompt	Default Value 5 A	Default Value 1 A
50Q1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50Q2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50Q3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50Q4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF

Make corresponding Level *n* = 1–4 settings in *Table 10.41* and *Table 10.42* for any 50Q*n*P settings that are made in *Table 10.40*.

Table 10.41 Negative-Sequence Definite-Time Overcurrent Time Delay

Label	Prompt	Default Value
67Q1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67Q2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67Q3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
67Q4D	Level 4 Time Delay (0.000–16000 cycles)	0.000

Table 10.42 Negative-Sequence Instantaneous Definite-Time Overcurrent Torque Control[a]

Label	Prompt	Default Value
67Q1TC	Level 1 Torque Control (SELOGIC Equation)	1
67Q2TC	Level 2 Torque Control (SELOGIC Equation)	1
67Q3TC	Level 3 Torque Control (SELOGIC Equation)	1
67Q4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

Make *Table 10.43* settings if Group relay configuration setting E51S := 1–6.

Table 10.43 Selectable Operating Quantity Inverse Time Overcurrent Element 1 (Sheet 1 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	IMAXL	IMAXL
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S1C	51S1 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3

Table 10.43 Selectable Operating Quantity Inverse Time Overcurrent Element 1 (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
51S1TD	51S1 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.00	1.00
51S1RS	51S1 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S1TC[b]	51S1 Torque Control (SELOGIC Equation)	1	1

[a] Parameter n = L for line, 1 for BK1, and 2 for BK2. R suffix selects rms filtered magnitudes.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.44* settings if Group setting E51S := 2–6.

Table 10.44 Selectable Operating Quantity Inverse Time Overcurrent Element 2

Label	Prompt	Default Value 5 A	Default Value 1 A
51S2O	51S2 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	3I0L	3I0L
51S2P	51S2 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	1.50	0.30
51S2C	51S2 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S2TD	51S2 Inverse Time Overcurrent Time Dial (0.50–15.00) (0.05–1.00) IEC	1.00	1.00
51S2RS	51S2 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S2TC[b]	51S2 Torque Control (SELOGIC Equation)	PLT01 # GROUND ENABLED	PLT01 # GROUND ENABLED

[a] Parameter n = L for line, 1 for BK1, 2 for BK2. R suffix selects rms filtered magnitudes.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.45* settings if Group setting E51S := 3–6.

Table 10.45 Selectable Operating Quantity Inverse Time Overcurrent Element 3 (Sheet 1 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
51S3O	51S3 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	IMAXL	IMAXL
51S3P	51S3 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S3C	51S3 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3

Table 10.45 Selectable Operating Quantity Inverse Time Overcurrent Element 3 (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
51S3TD	51S3 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.00	1.00
51S3RS	51S3 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S3TC[b]	51S3 Torque Control (SELOGIC Equation)	1	1

[a] Parameter n = L for line, 1 for BK1, 2 for BK2. R suffix selects rms filtered magnitudes.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.46* settings if Group setting E51S := 4–6.

Table 10.46 Selectable Operating Quantity Inverse Time Overcurrent Element 4

Label	Prompt	Default Value 5 A	Default Value 1 A
51S4O	51S4 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	IMAXL	IMAXL
51S4P	51S4 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S4C	51S4 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S4TD	51S4 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.00	1.00
51S4RS	51S4 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S4TC[b]	51S4 Torque Control (SELOGIC Equation)	1	1

[a] Parameter n = L for line, 1 for BK1, 2 for BK2. R suffix selects rms filtered magnitudes.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.47* settings if Group setting E51S := 5 or 6.

Table 10.47 Selectable Operating Quantity Inverse Time Overcurrent Element 5 (Sheet 1 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
51S5O	51S5 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	IMAXL	IMAXL
51S5P	51S5 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S5C	51S5 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3

Table 10.47 Selectable Operating Quantity Inverse Time Overcurrent Element 5 (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
51S5TD	51S5 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.00	1.00
51S5RS	51S5 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S5TC[b]	51S5 Torque Control (SELOGIC Equation)	1	1

[a] Parameter n = L for line, 1 for BK1, 2 for BK2. R suffix selects rms filtered magnitudes.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.48* settings if Group setting E51S := 6.

Table 10.48 Selectable Operating Quantity Inverse Time Overcurrent Element 6

Label	Prompt	Default Value 5 A	Default Value 1 A
51S6O	51S6 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	IMAXL	IMAXL
51S6P	51S6 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S6C	51S6 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S6TD	51S6 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.00	1.00
51S6RS	51S6 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S6TC[b]	51S6 Torque Control (SELOGIC Equation)	1	1

[a] Parameter n = L for line, 1 for BK1, 2 for BK2. R suffix selects rms filtered magnitudes.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.49* settings if Group setting E32 := Y or AUTO, and any of the settings E50P, E50G or E50Q := 3 or 4.

Table 10.49 Level Direction

Label	Prompt	Default Value
DIR3	Level 3 Directional Control (F, R)	R
DIR4	Level 4 Directional Control (F, R)	F

Make *Table 10.50* settings if Group setting E32 := Y. If E32 := AUTO, most of the settings in *Table 10.50* are automatically determined by the relay—only enter the ORDER and E32IV settings.

Table 10.50 Directional Control Element

Label	Prompt	Default Value 5 A	Default Value 1 A
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV	QV
50FP[a]	Forward Directional Overcurrent Pickup (0.25–5 A secondary) 5 A (0.05–1 A secondary) 1 A	0.60	0.12
50RP[a]	Reverse Directional Overcurrent Pickup (0.25–5 A secondary) 5 A (0.05–1 A secondary) 1 A	0.40	0.08
Z2F[a]	Forward Directional Z2 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	1.07	5.35
Z2R[a]	Reverse Directional Z2 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	1.17	5.85
a2[a]	Positive-Sequence Restraint Factor, I2/I1 (0.02–0.50)	0.10	0.10
k2[a]	Zero-Sequence Restraint Factor, I2/I0 (0.10–1.20)	0.20	0.20
Z0F[a]	Forward Directional Z0 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	3.19	15.95
Z0R[a]	Reverse Directional Z0 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	3.29	16.45
a0[a]	Positive-Sequence Restraint Factor, I0/I1 (0.02–0.5)	0.10	0.10
E32IV	Zero-Sequence Voltage and Current Enable (SELOGIC Equation)	1	1

[a] Make setting only when Group setting E32 := Y. Setting automatically calculated when E32 := AUTO.

Table 10.51 Pole Open Detection

Label	Prompt	Default Value
EPO	Pole Open Detection (52, V)	52
27PO	Undervoltage Pole Open Threshold (1–200 V)	40
3POD	Three Pole Open Dropout Delay (0.000–60 cycles)	0.500

Make *Table 10.52* and *Table 10.53* settings if Group setting ECOMM := POTT or DCUB1 or DCUB2.

Table 10.52 POTT Trip Scheme

Label	Prompt	Default Value
Z3RBD	Zone 3 Reverse Block Time Delay (0.000–16000 cycles)	5.000
EBLKD	Echo Block Time Delay (OFF, 0.000–16000 cycles)	10.000
ETDPU	Echo Time Delay Pickup (OFF, 0.000–16000 cycles)	2.000
EDURD	Echo Duration Time Delay (0.000–16000 cycles)	4.000
EWFC	Weak Infeed Trip (Y, N)	N
27PPW[a]	Weak Infeed Phase-to-Phase Undervoltage Pickup (1.0–300 V secondary)	80.0
59NW[a]	Weak Infeed Zero-Sequence Overvoltage Pickup (1.0–200 V secondary)	5.0
PT1	General Permissive Trip Received (SELOGIC Equation)	NA

[a] Make setting when EWFC := Y.

Make *Table 10.53* settings if Group setting ECOMM := DCUB1 or DCUB2.

Table 10.53 DCUB Trip Scheme

Label	Prompt	Default Value
GARD1D	Guard Present Security Delay (0.000–16000 cycles)	120.000
UBDURD	DCUB Disabling Time Delay (0.000–16000 cycles)	180.000
UBEND	DCUB Duration Time Delay (0.000–16000 cycles)	20.000
PT2[a]	Channel 2 Permissive Trip Received (SELOGIC Equation)	NA
LOG1	Channel 1 Loss-of-Guard (SELOGIC Equation)	NA
LOG2[a]	Channel 2 Loss-of-Guard (SELOGIC Equation)	NA

[a] Make setting when ECOMM := DCUB2.

Make *Table 10.54* settings if Group setting ECOMM := DCB.

Table 10.54 DCB Trip Scheme

Label	Prompt	Default Value
Z3XPU	Zone 3 Reverse Pickup Time Delay (0.000–16000 cycles)	1.000
Z3XD	Zone 3 Reverse Dropout Delay (0.000–16000 cycles)	6.000
BTXD	Block Trip Receive Extension Time (0.000–16000 cycles)	1.000
67SD	Level 2 Overcurrent Short Delay (0.000–16000 cycles)	2.000
BT	Block Trip Received (SELOGIC Equation)	NA

Make *Table 10.55* settings if Group settings EBFL1 := Y or EBFL2 := Y.

Table 10.55 Breaker 1 Failure Logic (and Breaker 2 Failure Logic[a])

Label	Prompt	Default Value 5 A	Default Value 1 A
50FP1	Phase Fault Current Pickup—BK1 (0.50–50 A secondary) 5 A (0.10–10 A secondary) 1 A	6.00	1.20
BFPU1	Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000	3.000
BFI3P1	Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)	1.500	1.500
BFISP1	Breaker Fail Initiate Seal-in Delay—BK1 (0.000–1000 cycles)	2.000	2.000
ENCBF1	No Current/Residual Current Logic—BK1 (Y, N)	N	N
50RP1	Residual Current Pickup—BK1 (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	1.00	0.20
NPU1	No Current Breaker Failure Delay—BK1 (0.000–6000 cycles)	12.000	12.000
BFIN1	No Current Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA
ELCBF1	Load Current Breaker Failure Logic—BK1 (Y, N)	N	N
50LP1	Phase Load Current Pickup—BK (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	0.50	0.10
LCPU1	Load Pickup Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000
BFILC1	Breaker Failure Load Current Initiate—BK1 (SELOGIC Equation)	NA	NA
EFOBF1	Flashover Breaker Failure Logic—BK1 (Y, N)	N	N
50FO1	Flashover Current Pickup—BK1 (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	0.50	0.10
FOPU1	Flashover Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000
BLKFOA1	Block A-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA
BLKFOB1	Block B-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA
BLKFOC1	Block C-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA
BFTR1	Breaker Failure Trip—BK1 (SELOGIC Equation)	NA	NA
BFULTR1	Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)	NA	NA

[a] Replace 1 with 2 in the setting label.

Make *Table 10.56* settings if Group setting E25BK1 := Y or E25BK2 := Y.

Table 10.56 Synchronism Check Element Reference

Label	Prompt	Default Value
SYNCP	Synchronism Reference (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
25VL	Voltage Window Low Threshold (20.0–200 V secondary)	55.0
25VH	Voltage Window High Threshold (20.0–200 V secondary)	70.0

Make *Table 10.57* settings if Group setting E25BK1 := Y.

Table 10.57 Breaker 1 Synchronism Check

Label	Prompt	Default Value
SYNCS1	Synchronism Source 1 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAZ
KS1M	Synchronism Source 1 Ratio Factor (0.10–3)	1.00
KS1A	Synchronism Source 1 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
25SFBK1	Maximum Slip Frequency—BK1 (OFF, 0.005–0.5 Hz)	0.050
ANG1BK1	Maximum Angle Difference 1—BK1 (3.0–80 degrees)	10.0
ANG2BK1	Maximum Angle Difference 2—BK1 (3.0–80 degrees)	10.0
TCLSBK1	Breaker 1 Close Time (1.00–30 cycles)[a]	8.00
BSYNBK1	Block Synchronism Check—BK1 (SELOGIC Equation)	NA

[a] Adjust setting TCLSBK1 in 0.25-cycle steps.

Make *Table 10.58* settings if Group setting E25BK2 := Y.

Table 10.58 Breaker 2 Synchronism Check (Sheet 1 of 2)

Label	Prompt	Default Value
SYNCS2	Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBZ
KS2M	Synchronism Source 2 Ratio Factor (0.10–3)	1.00
KS2A	Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
ALTS2	Alternative Synchronism Source 2 (SELOGIC Equation)	NA
ASYNCS2	Alternative Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCZ
AKS2M	Alternative Synchronism Source 2 Ratio Factor (0.10–3)	1.00
AKS2A	Alternative Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
25SFBK2	Maximum Slip Frequency—BK2 (OFF, 0.005–0.5 Hz)	0.050

Table 10.58 Breaker 2 Synchronism Check (Sheet 2 of 2)

Label	Prompt	Default Value
ANG1BK2	Maximum Angle Difference 1—BK2 (3.0–80 degrees)	10.0
ANG2BK2	Maximum Angle Difference 2—BK2 (3.0–80 degrees)	10.0
TCLSBK2	Breaker 2 Close Time (1.00–30 cycles)[a]	8.00
BSYNBK2	Block Synchronism Check—BK2 (SELOGIC Equation)	NA

[a] Adjust setting TCLSBK2 in 0.25-cycle steps.

Make some or all of the *Table 10.59* settings if Group settings E79 := Y or Y1 or EMANCL := Y. The number of settings also depends on the Global setting NUMBK := 1 or 2.

Table 10.59 Recloser and Manual Closing[a] (Sheet 1 of 2)

Label	Prompt	Default Value
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	1
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	PLT02 AND PLT04
E3PR2	Three-Pole Reclose Enable—BK2 (SELOGIC Equation)	PLT02 AND PLT04
TBBKD	Time Between Breakers for Automatic Reclose (1–999999 cycles)	300
BKCFD	Breaker Close Failure Delay (OFF, 1–999999 cycles)	300
SLBK1	Lead Breaker = Breaker 1 (SELOGIC Equation)	1
SLBK2	Lead Breaker = Breaker 2 (SELOGIC Equation)	NA
FBKCEN	Follower Breaker Closing Enable (SELOGIC Equation)	1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 OR TRIP
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2 OR TRIP
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	NOT (PLT02 AND PLT04) AND (3PT OR NOT 52AA1)
79BRCT	Block Reclaim Timer (SELOGIC Equation)	3PT
BK1MCL	Breaker 1 Manual Close (SELOGIC Equation)	
	8 pushbuttons	(CC1 OR PB7_PUL) AND PLT04
	12 pushbuttons	(CC1 OR PB11PUL) AND PLT04
	12 pushbuttons and auxiliary TRIP/CLOSE pushbuttons	CC1 AND PLT04
BK2MCL	Breaker 2 Manual Close (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–999999 cycles)	300

Table 10.59 Recloser and Manual Closing[a] (Sheet 2 of 2)

Label	Prompt	Default Value
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–999999 cycles)	60
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–999999 cycles)	60

[a] Adjust all timers in 1-cycle steps.

Make some or all of the *Table 10.60* settings if Group settings E79 := Y or Y1 or N3PSHOT := 1, 2, 3, or 4.

Table 10.60 Three-Pole Reclose Settings[a]

Label	Prompt	Default Value
3POISC	Three-Pole Open Interval Supervision (SELOGIC Equaltion)[b]	1
3POISD	Three-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1
3POID1	Three-Pole Open Interval 1 Delay (1–999999 cycles)	300
3POID2	Three-Pole Open Interval 2 Delay (1–999999 cycles)	300
3POID3	Three-Pole Open Interval 3 Delay (1–999999 cycles)	300
3POID4	Three-Pole Open Interval 4 Delay (1–999999 cycles)	300
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA
3PFOID	Three-Pole Fast Open Interval Delay (1–999999 cycles)	60
3PRCD	Three-Pole Reclaim Time Delay (1–999999 cycles)	900
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT AND NOT (Z2PT OR Z2GT OR Z3PT OR Z3GT OR SOTFT)
3PRIH	Three-Pole Line Open Failure Delay (OFF, 1–99999)	15
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3P1CLS	Three-Pole BK 1 Reclose Supervision (SELOGIC Equation)[b]	PLT02
3P2CLS	Three-Pole BK 2 Reclose Supervision (SELOGIC Equation)[b]	PLT02

[a] Adjust all timers in 1-cycle steps.
[b] These settings cannot be set to NA or to logical 0.

Make *Table 10.61* settings if Group settings E79 := Y or Y1 or EMANCL := Y.

Table 10.61 Voltage Elements

Label	Prompt	Default Value
EVCK	Reclosing Voltage Check (Y, N)	N
27LP	Dead Line Voltage (1.0–200 V secondary)	14.0
59LP	Live Line Voltage (1.0–200 V secondary)	53.0
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	14.0
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	53.0
27BK2P	Breaker 2 Dead Busbar Voltage (1.0–200 V secondary)	14.0
59BK2P	Breaker 2 Live Busbar Voltage (1.0–200 V secondary)	53.0

Make *Table 10.62* settings if Group setting EDEM := THM or ROL.

Table 10.62 Demand Metering

Label	Prompt	Default Value 5 A	Default Value 1 A
DMTC	Demand Metering Time Constant (5, 10, . . . , 300 minutes)	15	15
PDEMP	Phase Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF
GDEMP	Residual Ground Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF
QDEMP	Negative-Sequence Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF

Table 10.63 Trip Logic (Sheet 1 of 2)

Label	Prompt	Default Value
TR	Trip (SELOGIC Equation)	51S1T OR 51S2T
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	NA
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	50P1
BK1MTR	Breaker 1 Manual Trip—BK1 (SELOGIC Equation)	
	8 pushbuttons	OC1 OR PB8_PUL
	12 pushbuttons	OC1 OR PB12PUL
	12 pushbuttons and auxiliary TRIP/CLOSE pushbuttons	OC1
BK2MTR	Breaker 2 Manual Trip—BK2 (SELOGIC Equation)	NA
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip—BK1 (SELOGIC Equation)	NOT 52AA1

Table 10.63 Trip Logic (Sheet 2 of 2)

Label	Prompt	Default Value
ULMTR2	Unlatch Manual Trip—BK2 (SELOGIC Equation)	NA
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	12.000
ER	Event Report Trigger Equation (SELOGIC Equation)	R_TRIG 51S1 OR R_TRIG 51S2

Make *Table 10.64* settings if Group setting EHIF := Y or T.

Table 10.64 High-Impedance Fault (HIF) Detection

Label	Prompt	Default Value
HIFMODE	HIF Detection Sensitivity (SELOGIC Equation)	0
HIFER	HIF Event Report Ext. Trigger (SELOGIC Equation)	0

Table 10.65 50G High-Z (HIZ) Fault Detection

Label	Prompt	Default Value
50GHIZP	50G HIZ Overcurrent Pickup (OFF,0.25–100 amps,sec)	OFF
NPUD0	50G HIZ Element Pickup/Dropout Counts (1–1000)	10
TPUD0	NPUDO Time Window (0.01–20 seconds)	2.00
NHIZ	HIZ Counts [1 HIZ count = NPUDO counts] (1–1000)	100
THIZ	NHIZ Time Window (1.00–200 seconds)	60.00
NHIZR	HIZ Counts Reporting Threshold (1–1000)	95
HIZRST	HIZ Alarm Reset (SELOGIC Equation)	0

Protection Free-Form SELOGIC Control Equations

Protection free-form SELOGIC control equations are in classes 1 through 6 corresponding to settings Groups 1 through Group 6 (see *Section 3: SELOGIC Control Equations*).

Table 10.66 and *Table 10.67* only show the factory default protection free-form SELOGIC control equations. Up to 250 lines of free-form equations may be entered in each of six settings groups, although the actual maximum capacity may be less. See *SELOGIC Control Equation Capacity on page R.3.10* for more information.

NOTE: See corresponding command descriptions SET L on page R.9.48 and SHO L on page R.9.52 to set or show the free-form Protection SELOGIC control equations.

Table 10.66 Protection Free-Form SELOGIC Control Equations (Sheet 1 of 2)

Label	Default Value (SEL-451)
PLT01S	PB1_PUL AND NOT PLT01 # GROUND ENABLED
PLT01R	PB1_PUL AND PLT01
PLT02S	PB2_PUL AND NOT PLT02 # RECLOSE ENABLED
PLT02R	PB2_PUL AND PLT02 OR NOT PLT04 # HOT LINE TAG DISABLES RECLOSE
PLT03S	PB3_PUL AND NOT PLT03 # REMOTE ENABLED

NOTE: See corresponding command descriptions SET L on page R.9.48 and SHO L on page R.9.52 to set or show the free-form Protection SELOGIC control equations.

Table 10.66 Protection Free-Form SELOGIC Control Equations (Sheet 2 of 2)

Label	Default Value (SEL-451)
PLT03R	PB3_PUL AND PLT03
PLT04S	PB5_PUL AND NOT PLT04
PLT04R	PB5_PUL AND PLT04 # HOT LINE TAG (WHEN DEASSERTED)
PLT05S	PB6_PUL AND NOT PLT05 # AUX
PLT05R	PB6_PUL AND PLT05
PSV01	51S1 OR 51S2 OR 50P1
PCT01PU	3.000
PCT01DO	0.000
PCT01IN	PSV01 # FOR INST TARGET LED

Table 10.67 Protection Free-Form SELOGIC Control Equations

Label	Default Value (SEL-451-4)
PLT01S	PB4_PUL AND NOT PLT01 # LOCAL
PLT01R	PB4_PUL AND PLT01
PLT02S	PB6_PUL AND NOT PLT02 # RECLOSE ENABLED
PLT02R	PB6_PUL AND PLT02 OR NOT PLT04 # HOT LINE TAG DISABLES RECLOSE
PLT03S	PB3_PUL AND NOT PLT03 # TEST MODE
PLT03R	PB3_PUL AND PLT03
PLT04S	PB5_PUL AND NOT PLT04
PLT04R	PB5_PUL AND PLT04 # HOT LINE TAG (WHEN DEASSERTED)
PSV01	51S1 OR 51S2 OR 50P1
PCT01PU	3.000
PCT01DO	0.000
PCT01IN	PSV01 # FOR INST TARGET LED

Automation Free-Form SELOGIC Control Equations

Automation free-form SELOGIC control equations are in blocks 1 through 10. (see *Section 3: SELOGIC Control Equations*).

NOTE: See corresponding command descriptions SET A on page R.9.46 and SHO A on page R.9.51 to set or show the Automation settings.

The SEL-451 does not contain any automation free-form SELOGIC settings in the factory default settings.

The SEL-451 has a capacity of 100 lines of automation free-form SELOGIC control equations in each of 10 automation setting blocks. See *SELOGIC Control Equation Capacity on page R.3.10* for more information.

Output Settings

Table 10.68 Output Settings Categories

Settings	Reference
Main Board	*Table 10.69*
Interface Board #1	*Table 10.71*
Interface Board #2	*Table 10.72*
Communications Card Outputs	*Table 10.73*
MIRRORED BITS Transmit Equations	*Table 10.74*

NOTE: See corresponding command descriptions SET O on page R.9.48 and SHO O on page R.9.53 to set or show the Output settings.

Table 10.69 Main Board

Label	Prompt	Default Value (SEL-451)
OUT101		T3P1 # BREAKER 1 TRIP
OUT102		T3P1 # EXTRA BREAKER 1 TRIP
OUT103		BK1CL # BREAKER 1 CLOSE
OUT104		NA
OUT105		NA
OUT106		NA
OUT107		NA
OUT108		NOT (SALARM OR HALARM)

Table 10.70 Main Board

Label	Prompt	Default Value (SEL-451-4)
OUT101		T3P1 AND NOT PLT03 # BREAKER 1 TRIP
OUT102		T3P1 AND NOT PLT03 # EXTRA BREAKER 1 TRIP
OUT103		BK1CL AND NOT PLT03 # BREAKER 1 CLOSE
OUT104		NA
OUT105		NA
OUT106		NA
OUT107		PLT03 # RELAY TEST MODE
OUT108		NOT (SALARM OR HALARM)

Make *Table 10.71* settings if interface board #1 is present.

Table 10.71 Interface Board #1

Label	Prompt	Default Value
OUT201		NA
•	•	•
•	•	•
•	•	•
OUT216		NA

Make *Table 10.72* settings if interface board #2 is present.

Table 10.72 Interface Board #2

Label	Prompt	Default Value
OUT301		NA
•	•	•
•	•	•
•	•	•
OUT316		NA

Make *Table 10.73* settings if a communication card is present.

Table 10.73 Communications Card Outputs

Label	Prompt	Default Value
CCOUT01		NA
•	•	•
•	•	•
•	•	•
CCOUT32		NA

Table 10.74 Mirrored Bits Transmit Equations

Label	Prompt	Default Value
TMB1A		NA
•	•	•
•	•	•
•	•	•
TMB8A		NA
TMB1B		NA
•	•	•
•	•	•
•	•	•
TMB8B		NA

Front-Panel Settings

NOTE: See corresponding command descriptions SET F on page R.9.47 and SHO F on page R.9.51 to set or show the Front-panel settings.

Table 10.75 Front-Panel Settings Categories

Settings	Reference
Front-Panel Settings	*Table 10.76*
Selectable Screens for the Front Panel	*Table 10.77*
Selectable Operator Pushbuttons	*Table 10.78*
Front-Panel Event Display	*Table 10.79*
Local Control and Aliases	*Table 10.82*
Local Bits SELogic	*Table 10.83*
Display Points and Aliases	
Boolean Display Points	*Table 10.80*
Analog Display Points	*Table 10.81*

Table 10.76 Front-Panel Settings (Sheet 1 of 5)

Label	Prompt	Default Value
FP_TO	Front Panel Display Time-Out (OFF,1–60 min)	15
EN_LEDC	Enable LED Asserted Color (R,G)	G
TR_LEDC	Trip LED Asserted Color (R,G) Pushbutton LED 1	R
PB1_LED	Pushbutton LED 1 (SELOGIC Equation)	PLT01 #GROUND ENABLED (SEL-451) PB1 #SER EVENTS (SEL-451-4)
PB1_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB2_LED	Pushbutton LED 2 (SELOGIC Equation)	PLT02 #RECLOSE ENABLED (SEL-451) PB2 #BAY DISPLAY (SEL-451-4)
PB2_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB3_LED	Pushbutton LED 3 (SELOGIC Equation)	0 # REMOTE ENABLED (SEL-451) PLT03 #TEST MODE (SEL-451-4)
PB3_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB4_LED	Pushbutton LED 4 (SELOGIC Equation)	NOT SG1 #ALT SETTINGS (SEL-451) LOCAL #LOCAL CONTROL (SEL-451-4)
PB4_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB5_LED	Pushbutton LED 5 (SELOGIC Equation)	NOT PLT04 #HOT LINE TAG
PB5_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB6_LED	Pushbutton LED 6 (SELOGIC Equation)	0 #AUX (SEL-451, 8 Pushbuttons) PB6 #DISPLAY POINTS (SEL-451, 12 Pushbuttons) PLT02 #RECLOSE ENABLE (SEL-451-4)
PB6_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB7_LED	Pushbutton LED 7 (SELOGIC Equation)	52ACL1 #BREAKER CLOSED (SEL-451, SEL-451-4, 8 Pushbuttons) PB7 #SER EVENTS (SEL-451, 12 Pushbuttons) PB7 #DISPLAY POINTS (SEL-451-4, 12 Pushbuttons)
PB7_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB8_LED	Pushbutton LED 8 (SELOGIC Equation)	NOT 52ACL1 #BREAKER OPEN (SEL-451, SEL-451-4, 8 Pushbuttons) PB8 #EVENT SUMMARY (SEL-451, SEL-451-4, 12 Pushbuttons)

Table 10.76 Front-Panel Settings (Sheet 2 of 5)

Label	Prompt	Default Value
PB8_COL	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB9_LED[a]	Pushbutton LED 9 (SELOGIC Equation)	0 #AUX
PB9_COL[a]	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB10LED[a]	Pushbutton LED 10 (SELOGIC Equation)	0 #AUX
PB10COL[a]	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB11LED[a]	Pushbutton LED 11 (SELOGIC Equation)	52ACL1 #BREAKER CLOSED (SEL-451, SEL-451-4) 0 #AUX (SEL-451, SEL-451-4, Auxiliary TRIP/CLOSE Pushbuttons)
PB11COL[a]	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
PB12LED[a]	Pushbutton LED 12 (SELOGIC Equation)	NOT 52ACL1 #BREAKER OPEN (SEL-451, SEL-451-4) 0 #AUX (SEL-451, SEL-451-4, Auxiliary TRIP/CLOSE Pushbuttons)
PB12COL[a]	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)	AO
T1_LED	Target LED 1 (SELOGIC Equation)	PSV01 AND NOT PCT01Q # INST
T1LEDL	Target LED 1 Latch (Y, N)	Y
T1LEDA	Target LED 1 Alias (8 characters)	INST
T1LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T2_LED	Target LED 2 (SELOGIC Equation)	51S1T OR 51S2T # TIME
T2LEDL	Target LED 2 Latch (Y, N)	Y
T2LEDA	Target LED 2 Alias (8 characters)	TIME
T2LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T3_LED	Target LED 3 (SELOGIC Equation)	COMPRM # COMM
T3LEDL	Target LED 3 Latch (Y, N)	Y
T3LEDA	Target LED 3 Alias (8 characters)	COMM
T3LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T4_LED	Target LED 4 (SELOGIC Equation)	SOTFT # SOTF
T4LEDL	Target LED 4 Latch (Y, N)	Y
T4LEDA	Target LED 4 Alias (8 characters)	SOTF
T4LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO

Table 10.76 Front-Panel Settings (Sheet 3 of 5)

Label	Prompt	Default Value
T5_LED	Target LED 5 (SELOGIC Equation)	0 # NEG-SEQ
T5LEDL	Target LED 5 Latch (Y, N)	Y
T5LEDA	Target LED 5 Alias (8 characters)	NEG_SEQ
T5LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T6_LED	Target LED 6 (SELOGIC Equation)	BK1RS # 79 RESET
T6LEDL	Target LED 6 Latch (Y, N)	N
T6LEDA	Target LED 6 Alias (8 characters)	79_RESET
T6LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T7_LED	Target LED 7 (SELOGIC Equation)	79CY3 # 79 CYCLE
T7LEDL	Target LED 7 Latch (Y, N)	N
T7LEDA	Target LED 7 Alias (8 characters)	79_CYCLE
T7LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T8_LED	Target LED 8 (SELOGIC Equation)	BK1LO # 79 LOCKOUT
T8LEDL	Target LED 8 Latch (Y, N)	N
T8LEDA	Target LED 8 Alias (8 characters)	79_LO
T8LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T9_LED	Target LED 9 (SELOGIC Equation)	PHASE_A
T9LEDL	Target LED 9 Latch (Y, N)	Y
T9LEDA	Target LED 9 Alias (8 characters)	A_FAULT
T9LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T10_LED	Target LED 10 (SELOGIC Equation)	PHASE_B
T10LEDL	Target LED 10 Latch (Y, N)	Y
T10LEDA	Target LED 10 Alias (8 characters)	B_FAULT
T10LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T11_LED	Target LED 11 (SELOGIC Equation)	PHASE_C
T11LEDL	Target LED 11 Latch (Y, N)	Y
T11LEDA	Target LED 11 Alias (8 characters)	C_FAULT
T11LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T12_LED	Target LED 12 (SELOGIC Equation)	GROUND
T12LEDL	Target LED 12 Latch (Y, N)	Y
T12LEDA	Target LED 12 Alias (8 characters)	GROUND

Table 10.76 Front-Panel Settings (Sheet 4 of 5)

Label	Prompt	Default Value
T12LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T13_LED	Target LED 13 (SELOGIC Equation)	LOP
T13LEDL	Target LED 13 Latch (Y, N)	N
T13LEDA	Target LED 13 Alias (8 characters)	LOP
T13LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T14_LED	Target LED 14 (SELOGIC Equation)	VAFIM > 55 # VAY ON
T14LEDL	Target LED 14 Latch (Y, N)	N
T14LEDA	Target LED 14 Alias (8 characters)	VAY_ON
T14LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T15_LED	Target LED 15 (SELOGIC Equation)	VBFIM > 55 # VBY ON
T15LEDL	Target LED 15 Latch (Y, N)	N
T15LEDA	Target LED 15 Alias (8 characters)	VBY_ON
T15LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T16_LED	Target LED 16 (SELOGIC Equation)	VCFIM > 55 # VCY ON
T16LEDL	Target LED 16 Latch (Y, N)	N
T16LEDA	Target LED 16 Alias (8 characters)	VCY_ON
T16LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T17_LED[b]	Target LED 17 (SELOGIC Equation)	VAZM > 55 # VAZ ON
T17LEDL[b]	Target LED 17 Latch (Y, N)	N
T17LEDA[b]	Target LED 17 Alias (8 characters)	VAZ_ON
T17LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T18_LED[b]	Target LED 18 (SELOGIC Equation)	VBZM > 55 # VBZ ON
T18LEDL[b]	Target LED 18 Latch (Y, N)	N
T18LEDA[b]	Target LED 18 Alias (8 characters)	VBZ_ON
T18LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T19_LED[b]	Target LED 19 (SELOGIC Equation)	VCZM > 55 # VCZ ON
T19LEDL[b]	Target LED 19 Latch (Y, N)	N
T19LEDA[b]	Target LED 19 Alias (8 characters)	VCZ_ON
T19LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T20_LED[b]	Target LED 20 (SELOGIC Equation)	BFTRIP1
T20LEDL[b]	Target LED 20 Latch (Y, N)	N

Table 10.76 Front-Panel Settings (Sheet 5 of 5)

Label	Prompt	Default Value
T20LEDA[b]	Target LED 20 Alias (8 characters)	BK1_FAIL
T20LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T21_LED[b]	Target LED 21 (SELOGIC Equation)	B1BCWAL
T21LEDL[b]	Target LED 21 Latch (Y, N)	N
T21LEDA[b]	Target LED 21 Alias (8 characters)	BK1WEAR
T21LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T22_LED[b]	Target LED 22 (SELOGIC Equation)	0 # EXT_TRIP
T22LEDL[b]	Target LED 22 Latch (Y, N)	N
T22LEDA[b]	Target LED 22 Alias (8 characters)	EXT_TRIP
T22LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T23_LED[b]	Target LED 23 (SELOGIC Equation)	51S1 OR 51S2
T23LEDL[b]	Target LED 23 Latch (Y, N)	N
T23LEDA[b]	Target LED 23 Alias (8 characters)	51PICKUP
T23LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO
T24_LED[b]	Target LED 24 (SELOGIC Equation)	TIRIG # IRIG SIGNAL LOCKED
T24LEDL[b]	Target LED 24 Latch (Y, N)	N
T24LEDA[b]	Target LED 24 Alias (8 characters)	IRIG_LCK
T24LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)	RO

[a] PB9–PB12 settings are only available on 12 pushbutton models.
[b] T17–T24 settings are only available on 12 pushbutton models.

Table 10.77 Selectable Screens for the Front Panel (Sheet 1 of 2)

Label	Prompt	Default Value
SCROLD	Front Panel Display Update Rate (OFF, 1–15 secs)[a]	5
RMS_V	RMS Line Voltage Screen (Y, N)	N
RMS_I	RMS Line Current Screen (Y, N)	Y[b]
RMS_VPP	RMS Line Voltage Phase to Phase Screen (Y, N)	N
RMS_W	RMS Active Power Screen (Y, N)	N
FUNDVAR	Fundamental Reactive Power Screen (Y, N)	N
RMS_VA	RMS Apparent Power Screen (Y, N)	N
RMS_PF	RMS Power Factor Screen (Y, N)	N
RMS_BK1	RMS Breaker 1 Currents Screen (Y, N)	N
RMS_BK2	RMS Breaker 2 Currents Screen (Y, N)	N
STA_BAT	Station Battery Screen (Y, N)	N
FUND_VI	Fundamental Voltage and Current Screen (Y, N)	Y[b]

Table 10.77 Selectable Screens for the Front Panel (Sheet 2 of 2)

Label	Prompt	Default Value
FUNDSEQ	Fundamental Sequence Quantities Screen (Y, N)	N
FUND_BK	Fundamental Breaker Currents Screen (Y, N)	N
ONELINE[c]	One Line Bay Control Diagram (Y, N)	Y

[a] Screens will not rotate when SCROLD := OFF; the first screen in the rotation order remains on the screen.
[b] SEL-451-4 shipped from the factory with RMS_I := N and FUND_V1 := N
[c] ONELINE available in the SEL-451-4 and is the first screen in the rotating display

Table 10.78 Selectable Operator Pushbuttons

Label	Prompt	Default Value
PB1_HMI	Pushbutton 1 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF (SEL-451) SER (SEL-451-4)
PB2_HMI	Pushbutton 2 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF (SEL-451) BC (SEL-451-4)
PB3_HMI	Pushbutton 3 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF
PB4_HMI	Pushbutton 4 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF
PB5_HMI	Pushbutton 5 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF
PB6_HMI	Pushbutton 6 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF (SEL-451, 8 Pushbuttons, SEL-451-4) DP (SEL-451, 12 Pushbuttons)
PB7_HMI	Pushbutton 7 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF (SEL-451, SEL-451-4, 8 Pushbuttons) SER (SEL-451, 12 Pushbuttons) DP (SEL-451-4, 12 Pushbuttons)
PB8_HMI	Pushbutton 8 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF (SEL-451, SEL-451-4, 8 Pushbuttons) EVE (SEL-451, SEL-451-4, 12 Pushbuttons)
PB9_HMI[c]	Pushbutton 9 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF
PB10HMI[c]	Pushbutton 10 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF
PB11HMI[c]	Pushbutton 11 HMI Screen (OFF, AP, DP, EVE, SER, BC)[a, b]	OFF
PB12HMI[c]	Pushbutton 12 HMI Screen (OFF, AP, DP, EVE, SER, BC)[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, BC) 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
BC= Bay Control One Line Diagram (BC selection is available in the SEL-451-4)
[c] PB9–PB12 settings are only available on 12 pushbutton models.

Table 10.79 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 10.80 Boolean Display Points and Aliases[a]

Label	Prompt	Default Value
[Relay Word Bit Name]	Name of any element in element store	None
[Alias]	String of ASCII characters except double quotation marks[b]	None
[Set String]	String of ASCII characters except double quotation marks	None
[Clear String]	String of ASCII characters except double quotation marks	None
[Text Size}	S for single, D for double	S

[a] Relay Word Bit Name, "Alias," "Set String," "Clear String", "Text Size."
[b] Total length of Boolean Display Point is 20 characters; 19 characters of ASCII string with 1 character reserved for an "="

Table 10.81 Analog Display Points and User Text and Formatting[a]

Label	Prompt	Default Value
[Analog Quantity Name]	Name of any element in element store	None
[User Text]	String of ASCII characters except double quotation marks and {}[b]	None
[Formatting]	{total width.characters to right of decimal place, scaling factor}[c]	None
[User Text]	String of ASCII characters except double quotation marks and {}	None
[Text Size]	S for single, D for double	S

[a] Analog Quantity Name, "User Text and Formatting", "Text Size."
[b] Total length of Analog Display Point is 20 characters.
[c] See Display Points on page U.5.11 for examples of setting Analog Display Points.

Table 10.82 Local Control and Aliases[a]

Label	Prompt	Default Value
[Local Bit number]	Valid Local Bit number (LB01, for example)	None
[Alias Name]	String up to 20 printable ASCII characters except double quotation marks	None
[Alias for Set State]	String up to 20 printable ASCII characters except double quotation marks	None
[Alias for Clear State]	String up to 20 printable ASCII characters except double quotation marks	None
[Pulse Enable]	Pulse Local Bit (Y, N)	N

[a] Local Bit, Local Name, Local Set State, Local Clear State, Pulse Enable.

Table 10.83 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 10.83 appear if the associated local bit is defined. If no local bits are defined, the whole category is hidden.

Report Settings

NOTE: See corresponding command descriptions SET R on page R.9.49 and SHO R on page R.9.53 to set or show the Report settings.

Table 10.84 Report Settings Categories

Settings	Reference
SER Chatter Criteria	*Table 10.85*
SER Points and Aliases	*Table 10.86*
Event Reporting	*Table 10.87*
Event Reporting Digital Elements	*Table 10.88*
HIF Event Reporting	*Table 10.89*

Table 10.85 SER Chatter Criteria

Label	Prompt	Default Value
ESERDEL	Automatic Removal of Chattering SER Points (Y, N)	N
SRDLCNT[a]	Number of Counts Before Auto-Removal (2–20)	5
SRDLTIM[a]	Time for Auto-Removal (0.1–30 seconds)	1.0

[a] Setting is only available if ESERDEL := Y.

Table 10.86 SER Points and Aliases

Label	Prompt	Default Value[a]
[Relay Word Bit]	Label of any element in element store	None
[Reporting Name]	Alphanumeric string up to 20 characters	None
[Set State Name]	Alphanumeric string up to 20 characters	Asserted
[Clear State Name]	Alphanumeric string up to 20 characters	Deasserted
[HMI Alarm]	Y,N	N

[a] See Figure 10.2 for default values for 8-pushbutton model.

```
=>SHO R<Enter>

SER Chatter Criteria

ESERDEL := N

SER Points and Aliases
(Relay Word Bit, Alias Name, Alias for Set State, Alias for Clear State)

1: T3P1,"Breaker 1 TRIP","Asserted","Deasserted"
2: T3P2,"Breaker 2 TRIP","Asserted","Deasserted"
3: BK1CL,"Breaker 1 CLOSE","Asserted","Deasserted"
4: BK2CL,"Breaker 2 CLOSE","Asserted","Deasserted"
5: 52AA1,"Breaker 1 Status","Closed","Open"
6: 52AA2,"Breaker 2 Status","Closed","Open"
7: BK1CFT,"Breaker 1 Close Fail","Asserted","Deasserted"
8: BK2CFT,"Breaker 2 Close Fail","Asserted","Deasserted"
9: BK1RS,"Breaker 1 Reset","Asserted","Deasserted"
10: BK2RS,"Breaker 2 Reset","Asserted","Deasserted"
11: 79CY3,"Reclose Cycle","Asserted","Deasserted"
12: BK1LO,"Breaker 1 Lockout","Asserted","Deasserted"
13: BK2LO,"Breaker 2 Lockout","Asserted","Deasserted"
14: SOTFT,"SOTF TRIP","Asserted","Deasserted"
15: 3PSHOT0,"Reclose Shot 0","Asserted","Deasserted"
16: 3PSHOT1,"Reclose Shot 1","Asserted","Deasserted"
17: 3PSHOT2,"Reclose Shot 2","Asserted","Deasserted"
18: 3PSHOT3,"Reclose Shot 3","Asserted","Deasserted"
19: 3PSHOT4,"Reclose Shot 4","Asserted","Deasserted"
20: PB7_PUL,"Close Pushbutton","Asserted","Deasserted"
21: PB8_PUL,"Trip Pushbutton","Asserted","Deasserted"
22: OC1,"Open Command 1","Asserted","Deasserted"
23: OC2,"Open Command 2","Asserted","Deasserted"
24: CC1,"Close Command 1","Asserted","Deasserted"
25: CC2,"Close Command 2","Asserted","Deasserted"
26: 51S1T,"51S1T","Asserted","Deasserted"
27: 51S2T,"51S2T","Asserted","Deasserted"
28: 51S1,"51S1","Asserted","Deasserted"
29: 51S2,"51S2","Asserted","Deasserted"
30: 50P1,"50P1","Asserted","Deasserted"

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Figure 10.2 Extract From the Report Default Settings Showing SER Settings

Table 10.87 Event Reporting (Sheet 1 of 2)

Label	Prompt	Default Value
SRATE	Sample Rate of Event Report (1, 2, 4, 8 kHz)	2
LER	Length of Event Report (0.25–2.00 seconds); SRATE := 8	0.50
PRE	Length of Pre-Fault (0.05–1.95 seconds); SRATE := 8	0.10
LER	Length of Event Report (0.25–3.00 seconds); SRATE := 4	0.50
PRE	Length of Pre-Fault (0.05–2.95 seconds); SRATE := 4	0.10

Table 10.87 Event Reporting (Sheet 2 of 2)

Label	Prompt	Default Value
LER	Length of Event Report (0.25–4.00 seconds); SRATE := 2	0.50
PRE	Length of Pre-Fault (0.05–3.95 seconds); SRATE := 2	0.10
LER	Length of Event Report (0.25–5.00 seconds); SRATE := 1	0.50
PRE	Length of Pre-Fault (0.05–4.95 seconds); SRATE := 1	0.10

Table 10.88 Event Reporting Digital Elements[a]

Label	Prompt	Default Value
[Relay Word Bit]	Name of any Relay Word bit, or OFF	Relay Word bits[b]

[a] 800 Relay Word bits maximum from 100 Rows maximum.
[b] See ACSELERATOR QuickSet **Report > Event Report Digitals** in the **Relay Editor Settings** tree view. The rows containing the following elements are always included as part of the 100 rows: 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, FSA, FSB, FSC, 67P1, 67P2, 67P3, 67P4, 67Q1, 67Q2, 67Q3, 67Q4, 51S1, 51S2, 51S3, 51S4, 51S5, 51S6, 67G1, 67G2, 67G3, 67G4, RMBnA, TMBnA, RMBnB, TMBnB, ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, TRIP, T3P1, T3P2, 52ϕCL1, 52ϕCL2, BK1CL, BK2CL (n = 1–8, ϕ = A,B,C). For row descriptions, see Appendix A: Relay Word Bits.

Table 10.89 HIF Event Reporting

Label	Prompt	Default Value
HIFLER	Length of HIF Event Report (2,5,10,20,40 minutes)	10

Port Settings

NOTE: See corresponding command descriptions SET P on page R.9.49 and SHO P on page R.9.53 to set or show the Port settings.

Table 10.90 Port Settings Categories

Settings	Reference
Protocol Selection	See *Table 10.91*.
Communications Settings	See *Table 10.92*.
SEL Protocol Settings	See *Table 10.93*.
Synchronized Phasor Measurement Settings	See *Table 10.15*
DNP3 Protocol (Serial) Settings	See *Table 10.94*.
MIRRORED BITS Protocol Settings	See *Table 10.95*.
RTD Protocol Settings	See *Table 10.96*.
Ethernet Settings	See *Ethernet Network Operation Settings on page R.4.5*.
FTP Settings	See *FTP on page R.4.7*.
Telnet Settings	See *Telnet on page R.4.9*.
Network Host Names	See *Network Address Resolution on page R.4.7*
IEC 61850 Settings	See *Section 8: IEC 61850 Communications in the Reference Manual*.

Table 10.91 Protocol Selection

Label	Prompt	Default Value
EPORT[a]	Enable Port (Y, N)	Y
MAXACC[a]	Maximum Access Level (1, B, P, A, 0, 2, C)	C
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	SEL

[a] Not available in SEL-451-1.

Make *Table 10.92* settings if preceding setting PROTO ≠ RTD.

Table 10.92 DNP3 Serial Port Protocol Settings

Label	Prompt	Default Value
MBT[a]	Using Pulsar 9600 modem? (Y, N)	N
SPEED[b]	Data Speed (300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, SYNC[c])	9600
DATABIT[d]	Data Bits (7, 8 bits)	8
PARITY[d]	Parity (Odd, Even, None)	N
STOPBIT[e]	Stop Bits (1, 2 bits)	1
RTSCTS[f]	Enable Hardware Handshaking (Y, N)	N

[a] For PROTO :=MBA or MBB only.
[b] For PROTO := MBA or MBB, 57600 not available.
[c] SYNC option only available for PROTO := MBA or MBB, on rear-panel serial ports.
[d] For PROTO := SEL only.
[e] For PROTO := SEL, MBA, MBB, or PMU only.
[f] For PROTO := SEL or PMU only.

Make *Table 10.93* settings if Port setting PROTO := SEL, DNP, or PMU.

Table 10.93 SEL Protocol Settings

Label	Prompt	Default Value
TIMEOUT[a]	Port Time-Out (OFF, 1–60 minutes)	5
AUTO[b]	Send Auto-Messages to Port (Y, N)	Y
FASTOP[c]	Enable Fast Operate Messages (Y, N)	N
TERTIM1[a]	Initial Delay-Disconnect Sequence (0–600 seconds)	1
TERSTRN[a]	Termination String-Disconnect Sequence (9 characters maximum)[d]	"\005"
TERTIM2[a]	Final Delay-Disconnect Sequence (0–600 seconds)	0

[a] Not required for PROTO := PMU.
[b] Not required for PROTO := DNP or PMU.
[c] Not required for PROTO := DNP.
[d] TERSTRN set at \005 is <Ctrl+E>.

Make *Table 10.94* settings if Port setting PROTO := DNP.

Table 10.94 DNP3 Serial Protocol Settings (Sheet 1 of 2)

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
ECLASSV	Class for Virtual Terminal Data (OFF, 1–3)	OFF
TIMERQ	Time-Set Request Interval (I, M, 1–32767 minutes)	I

NOTE: In SEL-451 firmware version R104, Port Synchronized Phasor Measurement settings PMADDR and PMDATA were removed. The new Synchronized Phasor Measurement Settings are contained in Global Settings in Table 10.4 and Table 10.15. See Section 7: Synchrophasors for details.

Table 10.94 DNP3 Serial Protocol Settings (Sheet 2 of 2)

Label	Prompt	Default Value
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
MINDIST[a]	Minimum Fault Location to Capture (OFF, -10000–10000)	OFF
MAXDIST[a]	Maximum Fault Location to Capture (OFF, -10000–10000)	OFF
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] MAXDIST must be greater than MINDIST.

Make *Table 10.95* settings if Port setting PROTO := MBA or MBB.

Table 10.95 Mirrored Bits Protocol Settings (Sheet 1 of 2)

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

Table 10.95 MIRRORED BITS Protocol Settings (Sheet 2 of 2)

Label	Prompt	Default Value
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)	LIAFM
MBANA2	Selection for Analog Channel 2 (analog label)	LIBFM
MBANA3	Selection for Analog Channel 3 (analog label)	LICFM
MBANA4	Selection for Analog Channel 4 (analog label)	VAFM
MBANA5	Selection for Analog Channel 5 (analog label)	VBFM
MBANA6	Selection for Analog Channel 6 (analog label)	VCFM
MBANA7	Selection for Analog Channel 7 (analog label)	VABRMS
MBNUMVT	Number of Virtual Terminal Channels (OFF, 0–7)	OFF

Make *Table 10.96* settings if Port setting PROTO := RTD.

Table 10.96 RTD Protocol Settings

Label	Prompt	Default Value
RTDNUM	RTD Number of Inputs (0–12)	12
RTD*nn*TY[a]	RTD *n* Type (NA, PT100, NI100, NI120, CU10)[b]	PT100

[a] Where nn = 01 to the number of RTD inputs enabled in the RTDNUM setting.
[b] NA designates an input that is not connected to an RTD device.

DNP3 Settings—Serial Port

NOTE: See corresponding command descriptions SET D on page R.9.47 and SHO D on page R.9.51 to set or show the DNP3 settings.

Table 10.97 Settings Categories

Settings	Reference
DNP Reference Map Selection	*Table 10.98*
DNP3 Object Default Map Enables	*Table 10.99*
Binary Input Map	*Table 10.100*
Binary Output Map	*Table 10.101*
Counter Map	*Table 10.102*
Analog Input Map	*Table 10.103*
Analog Output Map	*Table 10.104*

Table 10.98 DNP Reference Map Selection

Label	Prompt	Default Value
MAPSEL	Reference Map Selection (B, E)	B

Table 10.99 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

Make *Table 10.100* settings if preceding setting DNPBID := N.

Table 10.100 Binary Input Map[a]

Label	Prompt	Default Value
BI_MAP*n*	Index Number (Valid binary input index number)	

[a] Parameter n indicates the index number for row 1 to 400; see Configurable Data Mapping on page R.6.10.

Make *Table 10.101* settings if preceding setting DNPBOD := N.

Table 10.101 Binary Output Map[a]

Label	Prompt	Default Value
BO_MAP*n*	Index Number (Valid binary output index number)	

[a] Parameter n indicates the index number for row 1 to 70; see Configurable Data Mapping on page R.6.10.

Make *Table 10.102* settings if preceding setting DNPCOD := N.

Table 10.102 Counter Map[a, b]

Label	Prompt	Default Value
CO_MAP*n*	Index Number (Valid counter index number)	
CO_DBD*n*	Deadband (1–32767)	(ANADB*x* port setting)

[a] Parameter n indicates the index number for row 1 to 10; see Configurable Data Mapping on page R.6.10.
[b] Parameter x is A, V, M representing currents, voltages, and miscellaneous, respectively.

Make *Table 10.103* settings if preceding setting DNPAID := N.

Table 10.103 Analog Input Map[a, b]

Label	Prompt	Default Value
AI_MAP*n*	Index Number (Valid analog input index number)	
AI_SCA*n*	Scale Factor (0.001–1000.000)	
AI_DBD*n*	Deadband (1–32767)	

[a] Parameter n indicates the index number for row 1 to 200; see Configurable Data Mapping on page R.6.10.
[b] Parameter x is A, V, M representing currents, voltages, and miscellaneous, respectively.

Make *Table 10.104* settings if preceding setting DNPAOD := N.

Table 10.104 Analog Output Map[a]

Label	Prompt	Default Value
AO_MAP*n*	Index Number (Valid analog output index number)	

[a] Parameter n indicates the index number for row 1 or 2; see Configurable Data Mapping on page R.6.10.

Bay Settings (SEL-451-4 Relay)

NOTE: See corresponding command descriptions SET B on page R.9.47 and SHO B on page R.9.51 to set or show the Bay settings.

NOTE: Bay control settings with pixel ranges are displayed in proportional fonts. With proportional fonts, "W" requires more pixel width than "I". For this reason, the setting ranges for labels that support proportional fonts are specified in number of pixels and a range of characters. The relay checks the string entering and rejects the setting if it is over the allowed pixel width (see *Figure 5.53 on page A.5.50*).

NOTE: Settings in the Bay Control that accept characters as input allow ASCII character decimal 24 to ASCII character decimal 127.

Table 10.105 Bay Control Settings Categories

Settings	Reference
General One-Line Settings	*Table 10.106*
Busbar Information	*Table 10.107*
Breaker Information	*Table 10.108*
Disconnect Information	*Table 10.109*
One-Line Analog Display	*Table 10.110*
Control Section	*Table 10.111*

Table 10.106 General One-Line Settings

Label	Prompt	Default Value
MIMIC	One-line Screen Number (1–100)	1
BAYNAME[a]	Bay Name (20 characters)[b]	BAY 1
BAYLAB*n*[c]	Bay Label *n* (*n* = 1–9) (35 pixels[d], 5–8 characters)[b, e]	LABEL*n*

[a] BAYNAME setting will be uppercased.
[b] BAYNAME, BAYLAB1, and BAYLAB2 settings must contain at least one character.
[c] Each of the one-line diagrams in the SEL-451-4 has a predefined number of Bay Labels. The number of Bay Label settings (1–9) in Table 10.106 is dependant on the MIMIC setting. Refer to Section 5: Bay Control in the Applications Handbook for the number of Bay Label settings associated with each one-line diagram.
[d] Number of pixels per character can be determined in *Figure 5.53 on page A.5.50*.
[e] BAYLAB1 and BAYLAB2 settings are only available in one-line diagrams 14, 17, 18, and 23.

Table 10.107 Busbar Information

Label	Prompt	Default Value
BUSNAM*n*[a]	Busbar *n* Name (*n* = 1–9) (40 pixels, 6–10 characters)[b, c]	BUS *n*

[a] Each of the one-line diagrams in the SEL-451-4 have a predefined number of Busbar Names. The number of Busbar Name settings (1–9) in Table 10.107 is dependant on the MIMIC setting. Refer to Section 5: Bay Control in the Applications Handbook for the number of Busbar Name settings associated with each one-line diagram.
[b] BUSNAM1, BUSNAM2, and BUSNAM3 settings must contain at least one character.
[c] Duplicate bus bar names are not allowed. If a duplicate name is entered, the `Duplicate Busbar Name` error message is displayed and the set routine returns to the first duplicate busbar name setting.

Table 10.108 Breaker Information[a] (Sheet 1 of 2)

Label	Prompt	Default Value
BKRNAM1	Breaker 1 Name (25 pixels, 4–6 characters)[b, c]	BK1
52CLSM1	Breaker 1 Close Status (SELOGIC equation)	52ACL1
52ALM1	Breaker 1 Alarm Status (SELOGIC equation)	52AAL1
BKRNAM2	Breaker 2 Name (25 pixels, 4–6 characters)[b, c]	BK2
52CLSM2	Breaker 2 Close Status (SELOGIC equation)	NA
52ALM2	Breaker 2 Alarm Status (SELOGIC equation)	NA
BKRNAM3	Breaker 3 Name (25 pixels, 4–6 characters)[b, c]	BK3

Table 10.108 Breaker Information[a] (Sheet 2 of 2)

Label	Prompt	Default Value
52CLSM3	Breaker 3 Close Status (SELOGIC equation)	NA
52ALM3	Breaker 3 Alarm Status (SELOGIC equation)	NA

[a] Each of the one-line diagrams in the SEL-451-4 has a predefined number of Breakers. The number of Breaker associated settings (1-3) in Table 10.108 is dependant on the MIMIC setting. Refer to Section 5: Bay Control in the Applications Handbook for the number of Breaker associated settings associated with each one-line diagram.
[b] BKRNAM1, BKRNAM2, and BKRNAM3 settings must contain at least one character.
[c] Duplicate breaker names are not allowed. If a duplicate name is entered, the `Duplicate Breaker Name` error message is displayed and the set routine returns to the first duplicate breaker name setting.

Table 10.109 Disconnect Information

Label	Prompt	Default Value
DISNAM1	Disconnect 1 Name (25 pixels, 4–6 characters)[a, b]	SW1
89AM1[c]	Disconnect 1 N/O Contact (SELOGIC equation)	IN103
89BM1[c]	Disconnect 1 N/C Contact (SELOGIC equation)	IN104
89ALP1	Disconnect 1 Alarm Pickup Delay (1–99999 cyc)	260
89CCON1	Disconnect 1 Remote Close Control (SELOGIC equation)	89CC1
89OCON1	Disconnect 1 Remote Open Control (SELOGIC equation)	89OC1
89CSIT1	Disconnect 1 Close Seal-in Time (1–99999 cyc)	280
89OSIT1	Disconnect 1 Open Seal-in Time (1–99999 cyc)	280
DISNAM*n*	Disconnect *n* (*n* = 2–10) Name (25 pixels, 4–6 characters)[a, b]	SW*n*
89AM*n*[c]	Disconnect *n* (*n* = 2–10) N/O Contact (SELOGIC equation)	1
89BM*n*[c]	Disconnect *n* (*n* = 2–10) N/C Contact (SELOGIC equation)	0
89ALP*n*	Disconnect *n* (*n* = 2–10) Alarm Pickup Delay (1–99999 cyc)	260
89CCON*n*	Disconnect *n* (*n* = 2–10) Remote Close Control (SELOGIC equation)	NA
89OCON*n*	Disconnect *n* (*n* = 2–10) Remote Open Control (SELOGIC equation)	NA
89CSIT*n*	Disconnect *n* (*n* = 2–10) Close Seal-in Time (1–99999 cyc)	280
89OSIT*n*	Disconnect *n* (*n* = 2–10) Open Seal-in Time (1–99999 cyc)	280

[a] DISNAM1, DISNAM2, DISNAM3, DISNAM4, and DISNAM5 settings must contain at least one character.
[b] Duplicate disconnect names are not allowed. If a duplicate name is entered, the `Duplicate Disconnect Name` error message is displayed and the set routine returns to the first duplicate disconnect name setting.
[c] Both of the corresponding 89AM1–5 and 89BM1–5 settings are required for correct disconnect switch and alarm logic operation.

NOTE: Each of the one-line diagrams in the SEL-451-4 has a predefined number of Disconnect Switches. The number of Disconnect Switches associated settings (1-10) in Table 10.109 is dependant on the MIMIC setting. Refer to Section 5: Bay Control in the Applications Handbook for the number of Disconnect Switch associated settings associated with each one-line diagram.

NOTE: Each of the one-line diagrams in the SEL-451-4 has a predefined number of Analog Displays. The number of Analog Display settings (1–6) in Table 10.110 is dependant on the MIMIC setting. Refer to Section 5: Bay Control in the Applications Handbook for the number of Analog Quantity settings provided with each one-line diagram.

Table 10.110 One-Line 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
[Pre-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
[Post-text]	String of ASCII characters except double quotation marks and { }	None

[a] Analog Quantity Name, "User Text and Formatting."
[b] The SEL-451 has no default values programmed for these settings.
[c] Total length (pre and Post text length + Formatting Width) of One-Line Analog Display is 50 pixels or 8 to 12 characters.
[d] See Display Points on page U.5.11 for examples of setting Analog Display Points.

Table 10.111 Control Selection

Label	Prompt	Default Value
LOCAL	Local Control (SELOGIC equation)	PLT01[a]

[a] The protection free-form default settings in the SEL-451-4 that control the state of PLT01 are below:
1. PLT01S := PB4_PUL AND NOT PLT01 # LOCAL
2. PLT01R := PB4_PUL AND PLT01

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Appendix A

Relay Word Bits

This section contains a table of the Relay Word bits available within the SEL-451 Relay. For information on using Relay Word bits in protection and automation, see the *Applications Handbook*.

Alphabetic

Use this appendix as a reference for Relay Word bit labels in this manual and as a resource for elements you use in SELOGIC® control equation relay settings. *Table A.1* lists the Relay Word bits in alphabetic order; *Table A.2* through *Table A.59* list every Relay Word bit row and the bits contained within each row.

Table A.1 Alphabetic List of Relay Word Bits (Sheet 1 of 21)

Name	Description	Row
*	Reserved	
25A1BK1	Circuit Breaker 1 voltages within Synchronism Angle 1	34
25A1BK2	Circuit Breaker 2 voltages within Synchronism Angle 1	36
25A2BK1	Circuit Breaker 1 voltages within Synchronism Angle 2	35
25A2BK2	Circuit Breaker 2 voltages within Synchronism Angle 2	36
25ENBK1	Circuit Breaker 1 synchronism-check element enable	34
25ENBK2	Circuit Breaker 2 synchronism-check element enable	36
25W1BK1	Circuit Breaker 1 Angle 1 within Window 1	34
25W1BK2	Circuit Breaker 2 Angle 1 within Window 1	36
25W2BK1	Circuit Breaker 1 Angle 2 within Window 2	34
25W2BK2	Circuit Breaker 2 Angle 2 within Window 2	36
27APO	A-phase undervoltage, pole open	74
27BPO	B-phase undervoltage, pole open	74
27CPO	C-phase undervoltage, pole open	75
32GF	Forward ground directional element	22
32GR	Reverse ground directional element	22
32IE	32I internal enable	21
32QE	32Q internal enable	21
32QF	Forward negative-sequence overcurrent directional declaration	20
32QGE	32QG internal enable	21
32QR	Reverse negative-sequence overcurrent directional declaration	20
32VE	32V internal enable	21

Table A.1 Alphabetic List of Relay Word Bits (Sheet 2 of 21)

Name	Description	Row
3P1CLS	Three-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)	41
3P2CLS	Three-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)	41
3PARC	Three-pole reclose initiate qualified	38
3PH_A	A-Phase Above 3-Phase Event Level	322
3PH_B	B-Phase Above 3-Phase Event Level	322
3PH_C	C-Phase Above 3-Phase Event Level	322
3PH_CLR	3-Phase Events Cleared	322
3PH_EVE	3-Phase Event Detection	323
3PLSHT	Three-pole reclose last shot	39
3PO	All three poles open	74
3POBK1	Three-pole open Circuit Breaker 1	38
3POBK2	Three-pole open Circuit Breaker 2	39
3POI	Three-pole open interval timing	46
3POISC	Three-pole open supervision condition	46
3POLINE	Three-pole open line	39
3PRCIP	Three-pole reclaim in progress	44
3PRI	Three-pole reclose initiation (SELOGIC control equation)	38
3PSHOT0	Three-pole shot counter =0	45
3PSHOT1	Three-pole shot counter =1	45
3PSHOT2	Three-pole shot counter =2	45
3PSHOT3	Three-pole shot counter =3	45
3PSHOT4	Three-pole shot counter =4	45
3PT	Three-pole trip (follows TRIP)	51
50FA1	Circuit Breaker 1 A-phase current threshold exceeded	62
50FA2	Circuit Breaker 2 A-phase current threshold exceeded	68
50FB1	Circuit Breaker 1 B-phase current threshold exceeded	62
50FB2	Circuit Breaker 2 B-phase current threshold exceeded	68
50FC1	Circuit Breaker 1 C-phase current threshold exceeded	62
50FC2	Circuit Breaker 2 C-phase current threshold exceeded	68
50FOA1	Circuit Breaker 1 A-phase flashover current threshold exceeded	65
50FOA2	Circuit Breaker 2 A-phase flashover current threshold exceeded	71
50FOB1	Circuit Breaker 1 B-phase flashover current threshold exceeded	65
50FOB2	Circuit Breaker 2 B-phase flashover current threshold exceeded	71
50FOC1	Circuit Breaker 1 C-phase flashover current threshold exceeded	65
50FOC2	Circuit Breaker 2 C-phase flashover current threshold exceeded	71
50G1	Level 1 residual overcurrent element	24

Table A.1 Alphabetic List of Relay Word Bits (Sheet 3 of 21)

Name	Description	Row
50G2	Level 2 residual overcurrent element	24
50G3	Level 3 residual overcurrent element	24
50G4	Level 4 residual overcurrent element	24
50GF	Forward zero-sequence supervisory current element	21
50GR	Reverse zero-sequence supervisory current element	21
50GHIZ	Ground HIZ instantaneous overcurrent pickup	313
50GHIZA	Ground HIZ Alarm	313
50LCA1	Circuit Breaker 1 A-phase load current threshold exceeded	64
50LCA2	Circuit Breaker 2 A-phase load current threshold exceeded	70
50LCB1	Circuit Breaker 1 B-phase load current threshold exceeded	64
50LCB2	Circuit Breaker 2 B-phase load current threshold exceeded	70
50LCC1	Circuit Breaker 1 C-phase load current threshold exceeded	64
50LCC2	Circuit Breaker 2 C-phase load current threshold exceeded	70
50P1	Level 1 phase overcurrent element	23
50P2	Level 2 phase overcurrent element	23
50P3	Level 3 phase overcurrent element	23
50P4	Level 4 phase overcurrent element	23
50Q1	Level 1 negative-sequence overcurrent element	26
50Q2	Level 2 negative-sequence overcurrent element	26
50Q3	Level 3 negative-sequence overcurrent element	26
50Q4	Level 4 negative-sequence overcurrent element	26
50QF	Forward negative-sequence supervisory current element	21
50QR	Reverse negative-sequence supervisory current element	21
50R1	Circuit Breaker 1 residual current threshold exceeded	64
50R2	Circuit Breaker 2 residual current threshold exceeded	70
51S1	Inverse-Time Overcurrent Element 1 pickup	28
51S1R	Inverse-Time Overcurrent Element 1 reset	28
51S1T	Inverse-Time Overcurrent Element 1 timed out	28
51S1TC	Inverse-Time Overcurrent Element 1 torque control	28
51S2	Inverse-Time Overcurrent Element 2 pickup	28
51S2R	Inverse-Time Overcurrent Element 2 reset	28
51S2T	Inverse-Time Overcurrent Element 2 timed out	28
51S2TC	Inverse-Time Overcurrent Element 2 torque control	28
51S3	Inverse-Time Overcurrent Element 3 pickup	29
51S3R	Inverse-Time Overcurrent Element 3 reset	29
51S3T	Inverse-Time Overcurrent Element 3 timed out	29
51S3TC	Inverse-Time Overcurrent Element 3 torque control	29
51S4	Inverse-Time Overcurrent Element 4 pickup	29
51S4R	Inverse-Time Overcurrent Element 4 reset	29
51S4T	Inverse-Time Overcurrent Element 4 timed out	29
51S4TC	Inverse-Time Overcurrent Element 4 torque control	29

Table A.1 Alphabetic List of Relay Word Bits (Sheet 4 of 21)

Name	Description	Row
51S5	Inverse-Time Overcurrent Element 5 pickup	30
51S5R	Inverse-Time Overcurrent Element 5 reset	30
51S5T	Inverse-Time Overcurrent Element 5 timed out	30
51S5TC	Inverse-Time Overcurrent Element 5 torque control	30
51S6	Inverse-Time Overcurrent Element 6 pickup	30
51S6R	Inverse-Time Overcurrent Element 6 reset	30
51S6T	Inverse-Time Overcurrent Element 6 timed out	30
51S6TC	Inverse-Time Overcurrent Element 6 torque control	30
52AA1	Circuit Breaker 1, status	76
52AA2	Circuit Breaker 2, status	78
52AAL1	Circuit Breaker 1, alarm	76
52AAL2	Circuit Breaker 2, alarm	77
52AB1	Circuit Breaker 1, status (follows 52AA1)	76
52AB2	Circuit Breaker 2, status (follows 52AA2)	78
52AC1	Circuit Breaker 1, status (follows 52AA1)	77
52AC2	Circuit Breaker 2, status (follows 52AA2)	78
52ACL1	Circuit Breaker 1, closed	76
52ACL2	Circuit Breaker 2, closed	77
52ALM1[a]	Breaker 1 Alarm (SELOGIC Equation)	290
52ALM2[a]	Breaker 2 Alarm (SELOGIC Equation)	290
52ALM3[a]	Breaker 3 Alarm (SELOGIC Equation)	290
52CLSM1[a]	Breaker 1 Closed (SELOGIC Equation)	290
52CLSM2[a]	Breaker 2 Closed (SELOGIC Equation)	290
52CLSM3[a]	Breaker 3 Closed (SELOGIC Equation)	290
59VP	VP within “healthy voltage” window	34
59VS1	VS1 within “healthy voltage” window	34
59VS2	VS2 within “healthy voltage” window	36
67G1	Level 1 residual directional overcurrent element	25
67G1T	Level 1 residual delayed directional overcurrent element	25
67G2	Level 2 residual directional overcurrent element	25
67G2T	Level 2 residual delayed directional overcurrent element	25
67G3	Level 3 residual directional overcurrent element	25
67G3T	Level 3 residual delayed directional overcurrent element	25
67G4	Level 4 residual directional overcurrent element	25
67G4T	Level 4 residual delayed directional overcurrent element	25
67P1	Level 1 phase directional overcurrent element	23
67P1T	Level 1 phase-delayed directional overcurrent element	24
67P2	Level 2 phase directional overcurrent element	23
67P2T	Level 2 phase-delayed directional overcurrent element	24
67P3	Level 3 phase directional overcurrent element	23
67P3T	Level 3 phase-delayed directional overcurrent element	24

Table A.1 Alphabetic List of Relay Word Bits (Sheet 5 of 21)

Name	Description	Row
67P4	Level 4 phase directional overcurrent element	23
67P4T	Level 4 phase-delayed directional overcurrent element	24
67Q1	Level 1 negative-sequence directional overcurrent element	26
67Q1T	Level 1 negative sequence delayed directional overcurrent element	27
67Q2	Level 2 negative-sequence directional overcurrent element	26
67Q2T	Level 2 negative-sequence delayed directional overcurrent element	27
67Q3	Level 3 negative-sequence directional overcurrent element	26
67Q3T	Level 3 negative-sequence delayed directional overcurrent element	27
67Q4	Level 4 negative-sequence directional overcurrent element	26
67Q4T	Level 4 negative-sequence delayed directional overcurrent element	27
67QG2S	Level 2 directional overcurrent short delay element	56
79CY3	Relay in three-pole reclose cycle state	39
79STRT	Relay in start state	46
89AL[a]	Any Disconnect Alarm	291
89AL1[a]	Disconnect 1 Alarm	291
89AL2[a]	Disconnect 2 Alarm	292
89AL3[a]	Disconnect 3 Alarm	293
89AL4[a]	Disconnect 4 Alarm	294
89AL5[a]	Disconnect 5 Alarm	295
89AL6[a]	Disconnect 6 Alarm	324
89AL7[a]	Disconnect 7 Alarm	325
89AL8[a]	Disconnect 8 Alarm	326
89AL9[a]	Disconnect 9 Alarm	327
89AL10[a]	Disconnect 10 Alarm	328
89AM1[a]	Disconnect 1 N/O Auxiliary Contact (SELOGIC Equation)	291
89AM2[a]	Disconnect 2 N/O Auxiliary Contact (SELOGIC Equation)	292
89AM3[a]	Disconnect 3 N/O Auxiliary Contact (SELOGIC Equation)	293
89AM4[a]	Disconnect 4 N/O Auxiliary Contact (SELOGIC Equation)	294
89AM5[a]	Disconnect 5 N/O Auxiliary Contact (SELOGIC Equation)	295
89AM6[a]	Disconnect 6 N/O Auxiliary Contact (SELOGIC Equation)	324
89AM7[a]	Disconnect 7N/O Auxiliary Contact (SELOGIC Equation)	325
89AM8[a]	Disconnect 8 N/O Auxiliary Contact (SELOGIC Equation)	326
89AM9[a]	Disconnect 9 N/O Auxiliary Contact (SELOGIC Equation)	327
89AM10[a]	Disconnect 10 N/O Auxiliary Contact (SELOGIC Equation)	328
89BM1[a]	Disconnect 1 N/C Auxiliary Contact (SELOGIC Equation)	291
89BM2[a]	Disconnect 2 N/C Auxiliary Contact (SELOGIC Equation)	292
89BM3[a]	Disconnect 3 N/C Auxiliary Contact (SELOGIC Equation)	293
89BM4[a]	Disconnect 4 N/C Auxiliary Contact (SELOGIC Equation)	294

Table A.1 Alphabetic List of Relay Word Bits (Sheet 6 of 21)

Name	Description	Row
89BM5[a]	Disconnect 5 N/C Auxiliary Contact (SELOGIC Equation)	295
89BM6[a]	Disconnect 6 N/C Auxiliary Contact (SELOGIC Equation)	324
89BM7[a]	Disconnect 7 N/C Auxiliary Contact (SELOGIC Equation)	325
89BM38	Disconnect 8 N/C Auxiliary Contact (SELOGIC Equation)	326
89BM9[a]	Disconnect 9 N/C Auxiliary Contact (SELOGIC Equation)	327
89BM10[a]	Disconnect 10 N/C Auxiliary Contact (SELOGIC Equation)	328
89CC1[a]	ASCII Close Disconnect 1 Command	297
89CC2[a]	ASCII Close Disconnect 2 Command	299
89CC3[a]	ASCII Close Disconnect 3 Command	301
89CC4[a]	ASCII Close Disconnect 4 Command	303
89CC5[a]	ASCII Close Disconnect 5 Command	305
89CC6[a]	ASCII Close Disconnect 6 Command	330
89CC7[a]	ASCII Close Disconnect 7 Command	332
89CC8[a]	ASCII Close Disconnect 8 Command	334
89CC9[a]	ASCII Close Disconnect 9 Command	336
89CC10[a]	ASCII Close Disconnect 10 Command	338
89CCM1[a]	Mimic Disconnect 1 Close Control	297
89CCM2[a]	Mimic Disconnect 2 Close Control	299
89CCM3[a]	Mimic Disconnect 3 Close Control	301
89CCM4[a]	Mimic Disconnect 4 Close Control	303
89CCM5[a]	Mimic Disconnect 5 Close Control	305
89CCM6[a]	Mimic Disconnect 6 Close Control	330
89CCM7[a]	Mimic Disconnect 7 Close Control	332
89CCM8[a]	Mimic Disconnect 8 Close Control	334
89CCM9[a]	Mimic Disconnect 9 Close Control	336
89CCM10[a]	Mimic Disconnect 10 Close Control	338
89CCMD1[a]	Close Command from Disconnect 1 Control Screen	298
89CCMD2[a]	Close Command from Disconnect 2 Control Screen	300
89CCMD3[a]	Close Command from Disconnect 3 Control Screen	302
89CCMD4[a]	Close Command from Disconnect 4 Control Screen	304
89CCMD5[a]	Close Command from Disconnect 5 Control Screen	306
89CCD6[a]	Close Command from Disconnect 6 Control Screen	331
89CCMD7[a]	Close Command from Disconnect 7 Control Screen	333
89CCMD8[a]	Close Command from Disconnect 8 Control Screen	335
89CCMD9[a]	Close Command from Disconnect 9 Control Screen	337
89CCD10[a]	Close Command from Disconnect 10 Control Screen	339
89CCON1[a]	Close Disconnect 1 (SELOGIC Equation)	297
89CCON2[a]	Close Disconnect 2 (SELOGIC Equation)	299
89CCON3[a]	Close Disconnect 3 (SELOGIC Equation)	301
89CCON4[a]	Close Disconnect 4 (SELOGIC Equation)	303

Table A.1 Alphabetic List of Relay Word Bits (Sheet 7 of 21)

Name	Description	Row
89CCON5[a]	Close Disconnect 5 (SELOGIC Equation)	305
89CCON6[a]	Close Disconnect 6 (SELOGIC Equation)	330
89CCON7[a]	Close Disconnect 7 (SELOGIC Equation)	332
89CCON8[a]	Close Disconnect 8 (SELOGIC Equation)	334
89CCON9[a]	Close Disconnect 9 (SELOGIC Equation)	336
89CCN10[a]	Close Disconnect 10 (SELOGIC Equation)	338
89CL1[a]	Disconnect 1 Closed	291
89CL2[a]	Disconnect 2 Closed	292
89CL3[a]	Disconnect 3 Closed	303
89CL4[a]	Disconnect 4 Closed	294
89CL5[a]	Disconnect 5 Closed	295
89CL6[a]	Disconnect 6 Closed	324
89CL7[a]	Disconnect 7 Closed	325
89CL8[a]	Disconnect 8 Closed	326
89CL9[a]	Disconnect 9 Closed	327
89CL10[a]	Disconnect 10 Closed	328
89CLBZ1[a]	Disconnect 1 Buszone Protection	296
89CLBZ2[a]	Disconnect 2 Buszone Protection	296
89CLBZ3[a]	Disconnect 3 Buszone Protection	296
89CLBZ4[a]	Disconnect 4 Buszone Protection	296
89CLBZ5[a]	Disconnect 5 Buszone Protection	296
89CLBZ6[a]	Disconnect 6 Buszone Protection	329
89CLBZ7[a]	Disconnect 7 Buszone Protection	329
89CLBZ8[a]	Disconnect 8 Buszone Protection	329
89CLBZ9[a]	Disconnect 9 Buszone Protection	329
89CLB10[a]	Disconnect 10 Buszone Protection	329
89CLS1[a]	Disconnect Close 1 Output	297
89CLS2[a]	Disconnect Close 2 Output	299
89CLS3[a]	Disconnect Close 3 Output	301
89CLS4[a]	Disconnect Close 4 Output	303
89CLS5[a]	Disconnect Close 5 Output	305
89CLS6[a]	Disconnect Close 6 Output	330
89CLS7[a]	Disconnect Close 7 Output	332
89CLS8[a]	Disconnect Close 8 Output	334
89CLS9[a]	Disconnect Close 9 Output	336
89CLS10[a]	Disconnect Close 10 Output	338
89OC1[a]	ASCII Open Disconnect 1 Command	297
89OC2[a]	ASCII Open Disconnect 2 Command	299
89OC3[a]	ASCII Open Disconnect 3 Command	301
89OC4[a]	ASCII Open Disconnect 4 Command	303
89OC5[a]	ASCII Open Disconnect 5 Command	305

Table A.1 Alphabetic List of Relay Word Bits (Sheet 8 of 21)

Name	Description	Row
89OC6[a]	ASCII Open Disconnect 6 Command	330
89OC7[a]	ASCII Open Disconnect 7 Command	332
89OC8[a]	ASCII Open Disconnect 8 Command	334
89OC9[a]	ASCII Open Disconnect 9 Command	336
89OC10[a]	ASCII Open Disconnect 10 Command	338
89OCM1[a]	Mimic Disconnect 1 Open Control	297
89OCM2[a]	Mimic Disconnect 2 Open Control	299
89OCM3[a]	Mimic Disconnect 3 Open Control	301
89OCM4[a]	Mimic Disconnect 4 Open Control	303
89OCM5[a]	Mimic Disconnect 5 Open Control	305
89OCM6[a]	Mimic Disconnect 6 Open Control	330
89OCM7[a]	Mimic Disconnect 7 Open Control	332
89OCM8[a]	Mimic Disconnect 8 Open Control	334
89OCM9[a]	Mimic Disconnect 9 Open Control	336
89OCM10[a]	Mimic Disconnect 10 Open Control	338
89OCMD1[a]	Open Command from Disconnect 1 Control Screen	298
89OCMD2[a]	Open Command from Disconnect 2 Control Screen	300
89OCMD3[a]	Open Command from Disconnect 3 Control Screen	302
89OCMD4[a]	Open Command from Disconnect 4 Control Screen	304
89OCMD5[a]	Open Command from Disconnect 5 Control Screen	306
89OCMD6[a]	Open Command from Disconnect 6 Control Screen	331
89OCMD7[a]	Open Command from Disconnect 7 Control Screen	333
89OCMD8[a]	Open Command from Disconnect 8 Control Screen	335
89OCMD9[a]	Open Command from Disconnect 9 Control Screen	337
89OCD10[a]	Open Command from Disconnect 10 Control Screen	339
89OCON1[a]	Open Disconnect 1 (SELOGIC Equation)	297
89OCON2[a]	Open Disconnect 2 (SELOGIC Equation)	299
89OCON3[a]	Open Disconnect 3 (SELOGIC Equation)	301
89OCON4[a]	Open Disconnect 4 (SELOGIC Equation)	303
89OCON5[a]	Open Disconnect 5 (SELOGIC Equation)	305
89OCON6[a]	Open Disconnect 6 (SELOGIC Equation)	330
89OCON7[a]	Open Disconnect 7 (SELOGIC Equation)	332
89OCON8[a]	Open Disconnect 8 (SELOGIC Equation)	334
89OCON9[a]	Open Disconnect 9 (SELOGIC Equation)	336
89OCN10[a]	Open Disconnect 10 (SELOGIC Equation)	338
89OIP[a]	Any Disconnect Operation In Progress	292
89OIP1[a]	Disconnect 1 Operation In Progress	291
89OIP2[a]	Disconnect 2 Operation In Progress	292
89OIP3[a]	Disconnect 3 Operation In Progress	293
89OIP4[a]	Disconnect 4 Operation In Progress	294
89OIP5[a]	Disconnect 5 Operation In Progress	295

Table A.1 Alphabetic List of Relay Word Bits (Sheet 9 of 21)

Name	Description	Row
89OIP6[a]	Disconnect 6 Operation In Progress	324
89OIP7[a]	Disconnect 7 Operation In Progress	325
89OIP8[a]	Disconnect 8 Operation In Progress	326
89OIP9[a]	Disconnect 9 Operation In Progress	327
89OIP10[a]	Disconnect 10 Operation In Progress	328
89OPEN1[a]	Disconnect Open 1 Output	297
89OPEN2[a]	Disconnect Open 2 Output	299
89OPEN3[a]	Disconnect Open 3 Output	301
89OPEN4[a]	Disconnect Open 4 Output	303
89OPEN5[a]	Disconnect Open 5 Output	305
89OPEN6[a]	Disconnect Open 6 Output	330
89OPEN7[a]	Disconnect Open 7 Output	332
89OPEN8[a]	Disconnect Open 8 Output	334
89OPEN9[a]	Disconnect Open 9 Output	336
89OPE10[a]	Disconnect Open 10 Output	338
89OPN1[a]	Disconnect 1 Open	291
89OPN2[a]	Disconnect 2 Open	292
89OPN3[a]	Disconnect 3 Open	293
89OPN4[a]	Disconnect 4 Open	294
89OPN5[a]	Disconnect 5 Open	295
89OPN6[a]	Disconnect 6 Open	324
89OPN7[a]	Disconnect 7 Open	325
89OPN8[a]	Disconnect 8 Open	326
89OPN9[a]	Disconnect 9 Open	327
89OPN10[a]	Disconnect 10 Open	328
ACN01Q–ACN32Q	Automation Counter outputs	190–193
ACN01R–ACN32R	Automation Counter resets	194–197
AFRTEXA	Automation SELOGIC control equation first execution after Automation Settings Change	200
AFRTEXP	Automation SELOGIC control equation first execution after Protection Settings Change, Group Switch, or Source Switch Selection	200
ALT01–ALT32	Automation Latches	178–181
ALTI	Alternate current source (SELOGIC control equation)	265
ALTS2	Alternate synchronism source for Circuit Breaker 2	265
ALTV	Alternate voltage source (SELOGIC control equation)	265
ANOKA	Analog transfer OK on MIRRORED BITS communications Channel A	237
ANOKB	Analog transfer OK on MIRRORED BITS communications Channel B	238

Table A.1 Alphabetic List of Relay Word Bits (Sheet 10 of 21)

Name	Description	Row
AST01Q–AST32Q	Automation Sequencing Timer outputs	182–185
AST01R–AST32R	Automation Sequencing Timer resets	186–189
ASV001–ASV256	Automation SELOGIC control equation Variables	146–177
AUNRLBL	Automation SELOGIC control equation unresolved label	200
B1BCWAL	Circuit Breaker 1 contact wear monitor alarm	83
B1BITAL	Circuit Breaker 1 inactivity time alarm	84
B1ESOAL	Circuit Breaker 1 electrical slow operation alarm	84
B1KAIAL	Circuit Breaker 1 interrupted current alarm	84
B1MRTAL	Circuit Breaker 1 motor running time alarm	84
B1MRTIN	Motor run time contact input—Circuit Breaker 1 (SELOGIC control equation)	83
B1MSOAL	Circuit Breaker 1 mechanical slow operation alarm	84
B1OPHA	Circuit Breaker 1 A-phase open	73
B1OPHB	Circuit Breaker 1 B-phase open	73
B1OPHC	Circuit Breaker 1 C-phase open	73
B2BCWAL	Circuit Breaker 2 contact wear monitor alarm	85
B2BITAL	Circuit Breaker 2 inactivity time alarm	86
B2ESOAL	Circuit Breaker 2 electrical slow operation alarm	86
B2KAIAL	Circuit Breaker 2 interrupted current alarm	86
B2MRTAL	Circuit Breaker 2 motor running time alarm	86
B2MRTIN	Motor run time contact input—Circuit Breaker 2 (SELOGIC control equation)	85
B2MSOAL	Circuit Breaker 2 mechanical slow operation alarm	86
B2OPHA	Circuit Breaker 2 A-phase open	73
B2OPHB	Circuit Breaker 2 B-phase open	73
B2OPHC	Circuit Breaker 2 C-phase open	73
BADPASS	Invalid password attempt alarm	202
BFI3P1	Circuit Breaker 1 three-pole circuit breaker failure initiation	61
BFI3P2	Circuit Breaker 2 three-pole circuit breaker failure initiation	67
BFI3PT1	Circuit Breaker 1 failure extended initiation	61
BFI3PT2	Circuit Breaker 2 failure extended initiation	67
BFILC1	Circuit Breaker 1 load current circuit breaker failure initiation	64
BFILC2	Circuit Breaker 2 load current circuit breaker failure initiation	70
BFIN1	Circuit Breaker 1 no current circuit breaker failure initiation	64
BFIN2	Circuit Breaker 2 no current circuit breaker failure initiation	70

Table A.1 Alphabetic List of Relay Word Bits (Sheet 11 of 21)

Name	Description	Row
BFTR1	Circuit breaker failure trip—Circuit Breaker 1 (SELOGIC control equation)	66
BFTR2	Circuit breaker failure trip—Circuit Breaker 2 (SELOGIC control equation)	72
BFTRIP1	Circuit Breaker 1 failure trip output asserted	66
BFTRIP2	Circuit Breaker 2 failure trip output asserted	72
BFULTR1	Circuit breaker failure unlatch trip—Circuit Breaker 1 (SELOGIC control equation)	66
BFULTR2	Circuit breaker failure unlatch trip—Circuit Breaker 2 (SELOGIC control equation)	72
BK1BFT	Indicates Circuit Breaker 1 breaker failure trip	232
BK1CFT	Circuit Breaker 1 close failure delay timed out	42
BK1CL	Circuit Breaker 1 close command	40
BK1CLSS	Circuit Breaker 1 in close supervision state	42
BK1CLST	Circuit Breaker 1 close supervision timer timed out	42
BK1EXT	Circuit Breaker 1 closed externally	46
BK1LO	Circuit Breaker 1 in lockout state	39
BK1RCIP	Circuit Breaker 1 reclaim in progress (lockout state)	44
BK1RS	Circuit Breaker 1 in ready state	39
BK2BFT	Indicates Circuit Breaker 2 breaker failure trip	232
BK2CFT	Circuit Breaker 2 close failure delay timed out	42
BK2CL	Circuit Breaker 2 close command	40
BK2CLSS	Circuit Breaker 2 in close supervision state	42
BK2CLST	Circuit Breaker 2 close supervision timer timed out	42
BK2EXT	Circuit Breaker 2 closed externally	46
BK2LO	Circuit Breaker 2 in lockout state	40
BK2RCIP	Circuit Breaker 2 reclaim in progress (lockout state)	44
BK2RS	Circuit Breaker 2 in ready state	39
BLKFOA1	Circuit Breaker 1 block A-phase flashover detection	65
BLKFOA2	Circuit Breaker 2 block A-phase flashover detection	71
BLKFOB1	Circuit Breaker 1 block B-phase flashover detection	65
BLKFOB2	Circuit Breaker 2 block B-phase flashover detection	71
BLKFOC1	Circuit Breaker 1 block C-phase flashover detection	65
BLKFOC2	Circuit Breaker 2 block C-phase flashover detection	71
BM1CLSA	Circuit breaker monitor close—Circuit Breaker 1 (SELOGIC control equation)	83
BM1CLSB	Circuit breaker monitor close—Circuit Breaker 1 (follows BM1CLSA)	83
BM1CLSC	Circuit breaker monitor C-phase close—Circuit Breaker 1 (follows BM1CLSA)	83
BM1TRPA	Circuit breaker monitor trip—Circuit Breaker 1 (SELOGIC control equation)	83
BM1TRPB	Circuit breaker monitor trip—Circuit Breaker 1 (follows BM1TRPA)	83

Table A.1 Alphabetic List of Relay Word Bits (Sheet 12 of 21)

Name	Description	Row
BM1TRPC	Circuit breaker monitor trip—Circuit Breaker 1 (follows BM1TRPA)	83
BM2CLSA	Circuit breaker monitor close—Circuit Breaker 2 (SELOGIC control equation)	85
BM2CLSB	Circuit breaker monitor close—Circuit Breaker 2 (follows BM2CLA)	85
BM2CLSC	Circuit breaker monitor close—Circuit Breaker 2 (follows BM2CLA)	85
BM2TRPA	Circuit breaker monitor trip—Circuit Breaker 2 (SELOGIC control equation)	85
BM2TRPB	Circuit breaker monitor trip—Circuit Breaker 2 (follows BM2TRPA)	85
BM2TRPC	Circuit breaker monitor trip—Circuit Breaker 2 (follows BM2TRPA)	85
BSYNBK1	Block synchronism check for Circuit Breaker 1	35
BSYNBK2	Block synchronism check for Circuit Breaker 2	37
BTX	Block extension picked up	56
CBADA	Unavailability threshold exceeded for MIRRORED BITS communications Channel A	237
CBADB	Unavailability threshold exceeded for MIRRORED BITS communications Channel B	238
CC1	Circuit Breaker 1 close command	91
CC2	Circuit Breaker 2 close command	91
CCALARM	Communications card status alarm	202
CCOK	Indicates connected SEL-2702 is operating normally	202
CCIN001–CCIN128	Communications Card Input Points	240–255
CCOUT01–CCOUT32	Communications Card Output Points	256–259
CCSTA01–CCSTA16	Communications Card Status Word	260–261
CCSTA17–CCSTA32	Communications Card Self-Test Status Word	262–263
CHIZ0	50G HIZ counter CHIZ reset	313
CHSG	Settings Group Change	100
COMPRM	Communications-assisted trip permission	49
CPUDO0	50G HIZ counter CPUDO reset	313
DC1F	DC Monitor 1 fail alarm	89
DC1G	DC Monitor 1 ground fault alarm	89
DC1R	DC Monitor 1 alarm for ac ripple	89
DC1W	DC Monitor 1 warning alarm	89
DC2F	DC Monitor 2 fail alarm	89
DC2G	DC Monitor 2 ground fault alarm	89
DC2R	DC Monitor 2 alarm for ac ripple	89
DC2W	DC Monitor 2 warning alarm	89

Table A.1 Alphabetic List of Relay Word Bits (Sheet 13 of 21)

Name	Description	Row
DDNA	A-Phase Tuning Threshold Decrease	321
DDNB	B-Phase Tuning Threshold Decrease	321
DDNC	C-Phase Tuning Threshold Decrease	321
DDNG	Residual Tuning Threshold Decrease	321
DELAY	Local current and voltage source delay logic	265
DFAULT	Disables maximum/minimum metering and demand metering when SELOGIC control equation FAULT asserts	48
DIA_DIS	A-Phase Large Difference Current Disturbance	319
DIB_DIS	B-Phase Large Difference Current Disturbance	319
DIC_DIS	C-Phase Large Difference Current Disturbance	319
DIG_DIS	Residual Large Difference Current Disturbance	319
DL2CLRA	A-Phase Decision Logic Clear	320
DL2CLRB	B-Phase Decision Logic Clear	320
DL2CLRC	C-Phase Decision Logic Clear	320
DL2CLRG	Residual Decision Logic Clear	320
DLDB1	Dead Line Dead Bus 1	43
DLDB2	Dead Line Dead Bus 2	43
DLLB1	Dead Line Live Bus 1	43
DLLB2	Dead Line Live Bus 2	43
DOKA	Normal MIRRORED BITS communications Channel A status	237
DOKB	Normal MIRRORED BITS communications Channel B status	238
DST	Daylight Savings Time	278
DSTP	Daylight Savings Time Pending	278
DSTRT	Directional start element picked up	56
DUPA	A-Phase Tuning Threshold Increase	321
DUPB	B-Phase Tuning Threshold Increase	321
DUPC	C-Phase Tuning Threshold Increase	321
DUPG	Residual Tuning Threshold Increase	321
DVA_DIS	A-Phase Difference Voltage Disturbance	319
DVB_DIS	B-Phase Difference Voltage Disturbance	319
DVC_DIS	C-Phase Difference Voltage Disturbance	319
DVG_DIS	Residual Difference Voltage Disturbance	319
EAFSRC	Alternate frequency source (SELOGIC control equation)	48
ECTT	Echo conversion to trip signal	54
EKEY	Echo received permissive trip signal	54
EN	Relay Enabled	0
ER	Event report trigger equation (SELOGIC control equation)	48
EVELOCK	Lock DNP Events	274
F32I	Forward current polarized zero-sequence directional element	22

Table A.1 Alphabetic List of Relay Word Bits (Sheet 14 of 21)

Name	Description	Row
F32P	Forward phase directional declaration	20
F32Q	Forward negative-sequence phase directional declaration	20
F32QG	Forward negative-sequence ground directional element	22
F32V	Forward voltage polarized zero-sequence directional element	22
FAST1	fs1 > fp	35
FAST2	fs2 > fp	37
FBF1	Circuit Breaker 1 circuit breaker failure	63
FBF2	Circuit Breaker 2 circuit breaker failure	69
FBFA1	Circuit Breaker 1 A-phase circuit breaker failure	63
FBFA2	Circuit Breaker 2 A-phase circuit breaker failure	69
FBFB1	Circuit Breaker 1 B-phase circuit breaker failure	63
FBFB2	Circuit Breaker 2 B-phase circuit breaker failure	69
FBFC1	Circuit Breaker 1 C-phase circuit breaker failure	63
FBFC2	Circuit Breaker 2 C-phase circuit breaker failure	69
FIDEN	Fault identification logic enabled	47
FOA1	Circuit Breaker 1 A-phase flashover detected	65
FOA2	Circuit Breaker 2 A-phase flashover detected	71
FOB1	Circuit Breaker 1 B-phase flashover detected	65
FOB2	Circuit Breaker 2 B-phase flashover detected	71
FOBF1	Circuit Breaker 1 flashover detected	66
FOBF2	Circuit Breaker 2 flashover detected	72
FOC1	Circuit Breaker 1 C-phase flashover detected	66
FOC2	Circuit Breaker 2 C-phase flashover detected	72
FOLBK0	No follower circuit breaker	40
FOLBK1	Follower circuit breaker = Circuit Breaker 1	40
FOLBK2	Follower circuit breaker = Circuit Breaker 2	41
FREQOK	Assert if relay is estimating frequency	217
FRZCLRA	A-Phase Averager Freeze and Trending Clear Condition	320
FRZCLRB	B-Phase Averager Freeze and Trending Clear Condition	320
FRZCLRC	C-Phase Averager Freeze and Trending Clear Condition	320
FRZCLRG	Residual Averager Freeze and Trending Clear Condition	320
FSA	A-phase sector fault (AG or BCG fault)	47
FSB	B-phase sector fault (BG or CAG fault)	48
FSC	C-phase sector fault (CG or ABG fault)	48
FSERP1	Fast SER enabled for Serial Port 1	264
FSERP2	Fast SER enabled for Serial Port 2	264
FSERP3	Fast SER enabled for Serial Port 3	264
FSERPF	Fast SER enabled for Serial Port F	264
GDEM	Zero-sequence demand current picked up	90
GROUND	Indicates a ground fault	232

Table A.1 Alphabetic List of Relay Word Bits (Sheet 15 of 21)

Name	Description	Row
HALARM	Hardware alarm	202
HIA1_A	A-Phase HIF Alarm	316
HIA1_B	B-Phase HIF Alarm	316
HIA1_C	C-Phase HIF Alarm	316
HIA1_G	Residual Current HIF Alarm	316
HIA2_A	A-Phase HIF Alarm	316
HIA2_B	B-Phase HIF Alarm	316
HIA2_C	C-Phase HIF Alarm	316
HIA2_G	Residual Current HIF Alarm	316
HIF1_A	A-Phase HIF Detection	317
HIF1_B	B-Phase HIF Detection	317
HIF1_C	C-Phase HIF Detection	317
HIF1_G	Residual Current HIF Detection	317
HIF2_A	A-Phase HIF Detection	317
HIF2_B	B-Phase HIF Detection	317
HIF2_C	C-Phase HIF Detection	317
HIF2_G	Residual Current HIF Detection	317
HIFER	HIF Event Report External Trigger SELOGIC setting	323
HIFMODE	HIF Detection Sensitivity SELOGIC setting	323
HIFREC	HIF event report triggered and is being collected	323
HIZ170	50G HIZ Fault Detection logic state	312
HIZ171	50G HIZ Fault Detection logic state	312
HIZ172	50G HIZ Fault Detection logic state	312
HIZ173	50G HIZ Fault Detection logic state	312
HIZ174	50G HIZ Fault Detection logic state	312
HIZ175	50G HIZ Fault Detection logic state	312
HIZ180	50G HIZ Fault Detection logic state	312
HIZ181	50G HIZ Fault Detection logic state	312
HIZ190	50G HIZ Fault Detection logic state	313
HIZ191	50G HIZ Fault Detection logic state	313
HIZ192	50G HIZ Fault Detection logic state	313
HIZRST	HIZ Alarm Reset SELOGIC setting	313
ILOP	Internal loss-of-potential from ELOP setting	47
IN101–IN107	Main Board Inputs	104
IN201–IN224	First Optional I/O Board Inputs (if installed)	109–111
IN301–IN324	Second Optional I/O Board Inputs (if installed)	112–114
ITUNE_A	A-Phase Initial Tuning	318
ITUNE_B	B-Phase Initial Tuning	318
ITUNE_C	C-Phase Initial Tuning	318

Table A.1 Alphabetic List of Relay Word Bits (Sheet 16 of 21)

Name	Description	Row
ITUNE_G	Residual Initial Tuning	318
KEY	Transmit permissive trip signal	54
LB01–LB32	Local Bits	92–95
LB_DP01–LB_DP32	Local Bit Status Display (SELOGIC Equation)	286–289
LB_SP01–LB_SP32	Local Bit Supervision (SELOGIC Equation)	282–285
LBOKA	Normal MIRRORED BITS communications Channel A status while in loopback mode	237
LBOKB	Normal MIRRORED BITS communications Channel B status while in loopback mode	238
LCBF1	Circuit Breaker 1 load current circuit breaker failure	64
LCBF2	Circuit Breaker 2 load current circuit breaker failure	70
LEADBK0	No lead circuit breaker	40
LEADBK1	Lead circuit breaker = Circuit Breaker 1	40
LEADBK2	Lead circuit breaker = Circuit Breaker 2	40
LLDB1	Live Line Dead Bus 1	43
LLDB2	Live Line Dead Bus 2	43
LOADTE	Load TECORR Factor (SELOGIC Equation). When a rising-edge is detected (greater than one cycle), the accumulated time-error value TE is loaded with the TECORR factor (preload value).	280
LOCAL[a]	Local Front Panel Control (SELOGIC Equation)	293
LOP	Loss-of-potential detected	47
LOPHA	Line A-phase open	73
LOPHB	Line B-phase open	73
LOPHC	Line C-phase open	74
LPSEC	Direction of the upcoming leap second. During the time that LPSECP is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.	278
LPSECP	Leap second pending (asserts for up to one minute prior to leap second, deasserted when the change is to occur, at “00”)	278
LRA	Load Reduction in A-Phase	322
LRB	Load Reduction in B-Phase	322
LRC	Load Reduction in C-Phase	322
LR3	3-phase Load Reduction Event	322
MATHERR	SELOGIC control equation math error	198
NBF1	Circuit Breaker 1 no current circuit breaker failure	64
NBF2	Circuit Breaker 2 no current circuit breaker failure	70
NBK0	No circuit breakers active in reclose scheme	41
NBK1	One circuit breaker active in reclose scheme	41
NBK2	Two circuit breakers active in reclose scheme	41
NSTRT	Non-directional start element picked up	56

Table A.1 Alphabetic List of Relay Word Bits (Sheet 17 of 21)

Name	Description	Row
NTUNE_A	A-Phase Normal Tuning	318
NTUNE_B	B-Phase Normal Tuning	318
NTUNE_C	C-Phase Normal Tuning	318
NTUNE_G	Residual Normal Tuning	318
OC1	Circuit Breaker 1 open command	91
OC2	Circuit Breaker 2 open command	91
OUT101–OUT108	Main Board Outputs	222
OUT201–OUT216	Optional I/O Board 1 Outputs (if installed)	223–224
OUT301–OUT316	Optional I/O Board 2 Outputs (if installed)	225–226
PB1–PB8	Pushbuttons	227
PB9–PB12	Pushbuttons	309
PB1_LED–PB8_LED	Pushbutton LEDs	229
PB9_LED–PB12LED	Pushbutton LEDs	310
PB1_PUL–PB8_PUL	Pushbutton pulse inputs (on for one processing interval when button is pushed)	228
PB9_PUL–PB12PUL	Pushbutton pulse inputs (on for one processing interval when button is pushed)	311
PB_CLSE	Auxiliary CLOSE Pushbutton	309
PB_TRIP	Auxiliary TRIP Pushbutton	309
PCN01Q–PCN32Q	Protection Counter outputs	138–141
PCN01R–PCN32R	Protection Counter resets	142–145
PCT01Q–PCT32Q	Protection Conditioning Timer outputs	124–127
PDEM	Phase current demand picked up	90
PFRTEX	Protection SELOGIC control equation first execution	198
PHASE_A	Indicates an A-phase fault	232
PHASE_B	Indicates a B-phase fault	232
PHASE_C	Indicates a C-phase fault	232
PLDTE	Asserts for approximately 1.5 cycles when the **TEC** command is used to load a new time-error correction factor (preload value) into the TECORR analog quantity.	280
PLT01–PLT32	Protection Latches	124–127
PMDOK	Assert if data acquisition system is operating correctly	221
PMTRIG	Trigger (SELOGIC control equation)	272
PST01Q–PST32Q	Protection Sequencing Timer outputs	130–133
PST01R–PST32R	Protection Sequencing Timer resets	134–137

Table A.1 Alphabetic List of Relay Word Bits (Sheet 18 of 21)

Name	Description	Row
PSV01–PSV64	Protection SELOGIC Control Equation Variables	116–123
PT	Permissive trip received	54
PTRX	Permissive trip received Channel 1 and Channel 2	56
PTRX1	Permissive trip received Channel 1	55
PTRX2	Permissive trip received Channel 2	55
PUNRLBL	Protection SELOGIC control equation unresolved label	198
QDEM	Negative-sequence demand current picked up	90
R32I	Reverse current polarized zero-sequence directional element	22
R32P	Reverse phase directional declaration	20
R32Q	Reverse negative-sequence phase directional declaration	20
R32QG	Reverse negative-sequence ground directional element	22
R32V	Reverse voltage polarized zero-sequence directional element	22
RB01–RB32	Remote Bits	96–99
RBADA	Outage too long on MIRRORED BITS communications Channel A	237
RBADB	Outage too long on MIRRORED BITS communications Channel B	238
RMB1A–RMB8A	Channel A Receive MIRRORED BITS 1–8	233
RMB1B–RMB8B	Channel B Receive MIRRORED BITS 1–8	235
ROKA	Normal MIRRORED BITS communications Channel A status while not in loopback mode	237
ROKB	Normal MIRRORED BITS communications Channel B status while not in loopback mode	238
RST_79C	Reset recloser shot count accumulators (SELOGIC control equation)	44
RST_BAT	Reset battery monitoring (SELOGIC control equation)	231
RST_BK1	Reset Circuit Breaker 1 monitor	230
RST_BK2	Reset Circuit Breaker 2 monitor	230
RST_DEM	Reset demand metering	230
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC control equation)	231
RST_ENE	Reset energy metering data	230
RST_PDM	Reset peak demand metering	230
RSTFLOC	Reset fault locator (SELOGIC control equation)	231
RSTMMB1	Reset max/min Circuit Breaker 1 (SELOGIC control equation)	230
RSTMMB2	Reset max/min Circuit Breaker 2 (SELOGIC control equation)	230
RSTMML	Reset max/min line (SELOGIC control equation)	230
RSTTRGT	Target reset (SELOGIC control equation)	232

Table A.1 Alphabetic List of Relay Word Bits (Sheet 19 of 21)

Name	Description	Row
RT1	Circuit Breaker 1 retrip	63
RT2	Circuit Breaker 2 retrip	69
RTD01ST–RTD08ST	RTD Status for Channels 1–8	87
RTD09ST–RTD12ST	RTD Status for Channels 9–12	88
RTDCOMF	RTD Communication Failure	88
RTDFL	RTD device Failure	88
RTDIN	State of RTD contact input	88
RXPRM	Receiver trip permission	49
SALARM	Software alarm	202
SFBK1	5 mHz ≤ Circuit Breaker 1 slip frequency < 25 SFBK1	34
SFBK2	5 mHz ≤ Circuit Breaker 2 slip frequency < 25 SFBK2	36
SFZBK1	Circuit Breaker 1 slip frequency less than 5 mHz	34
SFZBK2	Circuit Breaker 2 slip frequency less than 5 mHz	36
SG1	Settings Group 1 active	100
SG2	Settings Group 2 active	100
SG3	Settings Group 3 active	100
SG4	Settings Group 4 active	100
SG5	Settings Group 5 active	100
SG6	Settings Group 6 active	100
SLOW1	fs1 < fp	35
SLOW2	fs2 < fp	37
SOTFE	Switch-onto-fault enable	47
SOTFT	Switch-onto-fault trip	49
STALLTE	Stall Time-Error Calculation (SELOGIC Equation). When asserted, the time-error calculation is stalled or frozen.	280
STOP	Stop element picked up	56
T3P1	Three-pole trip, breaker 1	53
T3P2	Three-pole trip, breaker 2	53
TBBK	Time between circuit breakers timing	46
TESTDB	Communications card database test bit	239
TESTDNP	DNP test bit	239
TESTFM	Fast meter test bit	239
TESTPUL	Pulse test bit	239
TIRIG	Assert while time is based on IRIG for both mark and value	221
TLED_1–TLED_8	Target LED1–8	1
TLED_9–TLED_16	Target LED 9–16	2
TLED_17–TLED_24	Target LED 17–24	308

Table A.1 Alphabetic List of Relay Word Bits (Sheet 20 of 21)

Name	Description	Row
TMB1A–TMB8A	Channel A Transmit MIRRORED BITS 1–8	234
TMB1B–TMB8B	Channel B Transmit MIRRORED BITS 1–8	236
TQUAL1	Time quality, binary, add 1 when asserted[b]	278
TQUAL2	Time quality, binary, add 2 when asserted[c]	278
TQUAL4	Time quality, binary, add 4 when asserted[c]	278
TQUAL8	Time quality, binary, add 8 when asserted[c]	278
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)	272
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)	272
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)	272
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)	272
TRGTR	Reset all active target relay words	232
TRIP	Trip	51
TRIPLED	Trip LED	0
TRPRM	Trip permission	49
TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements	221
TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized	221
TUPDH	Assert if update source is high-accuracy time source	221
TUTC1	Offset hours from UTC time, binary, add 1 if asserted	277
TUTC2	Offset hours from UTC time, binary, add 2 if asserted	277
TUTC4	Offset hours from UTC time, binary, add 4 if asserted	277
TUTC8	Offset hours from UTC time, binary, add 8 if asserted	277
TUTCH	Offset half-hour from UTC time, binary, add 0.5 is asserted	277
TUTCS	Offset hours sign from UTC time, subtract the URC offset if TUTCS is asserted, add otherwise	277
UBB	Block permissive trip received 1 or 2	55
UBB1	Blocks permissive trip Receiver 1	55
UBB2	Blocks permissive trip Receiver 2	55
ULCL1	Unlatch closing for Circuit Breaker 1 (SELOGIC control equation)	42
ULCL2	Unlatch closing for Circuit Breaker 2 (SELOGIC control equation)	42
ULMTR1	Circuit Breaker 1 unlatch manual trip	52
ULMTR2	Circuit Breaker 2 unlatch manual trip	52
ULTR	Unlatch all protection trips	52
ULTRA	Unlatch Trip	53
VPOLV	Polarizing voltage valid	15
WFC	Weak infeed condition detected	55
YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted[c]	276

Table A.1 Alphabetic List of Relay Word Bits (Sheet 21 of 21)

Name	Description	Row
YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted[c]	276
YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted[c]	276
YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted[c]	276
YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted[c]	276
YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted[c]	276
YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted[c]	276
YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted[c]	276
Z3RB	Current reversal guard asserted	54
Z3XT	Current reversal guard timer picked up	56
ZLIN	Load-encroachment “load out” element	47
ZLOAD	ZLOUT or ZLIN element picked up	47
ZLOUT	Load-encroachment “load in” element	47

[a] SEL-451-4 Relay Word Bits.
[b] See IRIG-B on page U.4.73.
[c] The SEL-451 does not use the year information obtained from IRIG-B to set the internal clock year value.

Row List

Table A.2 Relay Word Bits: Enable and Target LEDs (Sheet 1 of 2)

Row	Name	Description
0	EN	Relay Enabled
0	TRIPLED	Trip LED
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
1	TLED_1	Target LED 1
1	TLED_2	Target LED 2
1	TLED_3	Target LED 3
1	TLED_4	Target LED 4
1	TLED_5	Target LED 5
1	TLED_6	Target LED 6
1	TLED_7	Target LED 7

Table A.2 Relay Word Bits: Enable and Target LEDs (Sheet 2 of 2)

Row	Name	Description
1	TLED_8	Target LED 8
2	TLED_9	Target LED 9
2	TLED_10	Target LED 10
2	TLED_11	Target LED 11
2	TLED_12	Target LED 12
2	TLED_13	Target LED 13
2	TLED_14	Target LED 14
2	TLED_15	Target LED 15
2	TLED_16	Target LED 16

Table A.3 Relay Word Bits: Directional Elements (Sheet 1 of 2)

Row	Name	Description
3-14	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	VPOLV	Polarizing voltage valid
15	*	Reserved
15	*	Reserved
16–19	*	Reserved
20	F32P	Forward phase directional declaration
20	R32P	Reverse phase directional declaration
20	F32Q	Forward negative-sequence phase directional declaration
20	R32Q	Reverse negative-sequence phase directional declaration
20	32QF	Forward negative-sequence overcurrent directional declaration
20	32QR	Reverse negative-sequence overcurrent directional declaration
20	*	Reserved
20	*	Reserved
21	50QF	Forward negative-sequence supervisory current element
21	50QR	Reverse negative-sequence supervisory current element
21	50GF	Forward zero-sequence supervisory current element
21	50GR	Reverse zero-sequence supervisory current element
21	32QE	32Q internal enable
21	32QGE	32QG internal enable
21	32VE	32V internal enable
21	32IE	32I internal enable
22	F32I	Forward current polarized zero-sequence directional element

Table A.3 Relay Word Bits: Directional Elements (Sheet 2 of 2)

Row	Name	Description
22	R32I	Reverse current polarized zero-sequence directional element
22	F32V	Forward voltage polarized zero-sequence directional element
22	R32V	Reverse voltage polarized zero-sequence directional element
22	F32QG	Forward negative-sequence ground directional element
22	R32QG	Reverse negative-sequence ground directional element
22	32GF	Forward ground directional element
22	32GR	Reverse ground directional element

Table A.4 Relay Word Bits: Overcurrent Elements (Sheet 1 of 2)

Row	Name	Description
23	50P1	Level 1 phase overcurrent element
23	50P2	Level 2 phase overcurrent element
23	50P3	Level 3 phase overcurrent element
23	50P4	Level 4 phase overcurrent element
23	67P1	Level 1 phase directional overcurrent element
23	67P2	Level 2 phase directional overcurrent element
23	67P3	Level 3 phase directional overcurrent element
23	67P4	Level 4 phase directional overcurrent element
24	67P1T	Level 1 phase-delayed directional overcurrent element
24	67P2T	Level 2 phase-delayed directional overcurrent element
24	67P3T	Level 3 phase-delayed directional overcurrent element
24	67P4T	Level 4 phase-delayed directional overcurrent element
24	50G1	Level 1 residual overcurrent element
24	50G2	Level 2 residual overcurrent element
24	50G3	Level 3 residual overcurrent element
24	50G4	Level 4 residual overcurrent element
25	67G1	Level 1 residual directional overcurrent element
25	67G2	Level 2 residual directional overcurrent element
25	67G3	Level 3 residual directional overcurrent element
25	67G4	Level 4 residual directional overcurrent element
25	67G1T	Level 1 residual delayed directional overcurrent element
25	67G2T	Level 2 residual delayed directional overcurrent element
25	67G3T	Level 3 residual delayed directional overcurrent element
25	67G4T	Level 4 residual delayed directional overcurrent element
26	50Q1	Level 1 negative-sequence overcurrent element
26	50Q2	Level 2 negative-sequence overcurrent element
26	50Q3	Level 3 negative-sequence overcurrent element
26	50Q4	Level 4 negative-sequence overcurrent element
26	67Q1	Level 1 negative-sequence directional overcurrent element

Table A.4 Relay Word Bits: Overcurrent Elements (Sheet 2 of 2)

Row	Name	Description
26	67Q2	Level 2 negative-sequence directional overcurrent element
26	67Q3	Level 3 negative-sequence directional overcurrent element
26	67Q4	Level 4 negative-sequence directional overcurrent element
27	67Q1T	Level 1 negative sequence delayed directional overcurrent element
27	67Q2T	Level 2 negative-sequence delayed directional overcurrent element
27	67Q3T	Level 3 negative-sequence delayed directional overcurrent element
27	67Q4T	Level 4 negative-sequence delayed directional overcurrent element
27	*	Reserved
27	*	Reserved
27	*	Reserved
27	*	Reserved
28	51S1	Inverse-Time Overcurrent Element 1 pickup
28	51S1T	Inverse-Time Overcurrent Element 1 timed out
28	51S1R	Inverse-Time Overcurrent Element 1 reset
28	51S1TC	Inverse-Time Overcurrent Element 1 torque control
28	51S2	Inverse-Time Overcurrent Element 2 pickup
28	51S2T	Inverse-Time Overcurrent Element 2 timed out
28	51S2R	Inverse-Time Overcurrent Element 2 reset
28	51S2TC	Inverse-Time Overcurrent Element 2 torque control
29	51S3	Inverse-Time Overcurrent Element 3 pickup
29	51S3T	Inverse-Time Overcurrent Element 3 timed out
29	51S3R	Inverse-Time Overcurrent Element 3 reset
29	51S3TC	Inverse-Time Overcurrent Element 3 torque control
29	51S4	Inverse-Time Overcurrent Element 4 pickup
29	51S4T	Inverse-Time Overcurrent Element 4 timed out
29	51S4R	Inverse-Time Overcurrent Element 4 reset
29	51S4TC	Inverse-Time Overcurrent Element 4 torque control
30	51S5	Inverse-Time Overcurrent Element 5 pickup
30	51S5T	Inverse-Time Overcurrent Element 5 timed out
30	51S5R	Inverse-Time Overcurrent Element 5 reset
30	51S5TC	Inverse-Time Overcurrent Element 5 torque control
30	51S6	Inverse-Time Overcurrent Element 6 pickup
30	51S6T	Inverse-Time Overcurrent Element 6 timed out
30	51S6R	Inverse-Time Overcurrent Element 6 reset
30	51S6TC	Inverse-Time Overcurrent Element 6 torque control
31–33	*	Reserved

Table A.5 Relay Word Bits: Synchronism-Check Elements

Row	Name	Description
34	59VP	VP within “healthy voltage” window
34	59VS1	VS1 within “healthy voltage” window
34	25ENBK1	Circuit Breaker 1 synchronism-check element enable
34	SFZBK1	Circuit Breaker 1 slip frequency less than 5 mHz
34	SFBK1	5 mHz ≤ Circuit Breaker 1 slip frequency < 25 SFBK1
34	25W1BK1	Circuit Breaker 1 Angle 1 within Window 1
34	25W2BK1	Circuit Breaker 1 Angle 2 within Window 2
34	25A1BK1	Circuit Breaker 1 voltages within Synchronism Angle 1
35	25A2BK1	Circuit Breaker 1 voltages within Synchronism Angle 2
35	FAST1	fs1 > fp
35	SLOW1	fs1 < fp
35	BSYNBK1	Block synchronism check for Circuit Breaker 1
35	*	Reserved
35	*	Reserved
35	*	Reserved
35	*	Reserved
36	59VS2	VS2 within “healthy voltage” window
36	25ENBK2	Circuit Breaker 2 synchronism-check element enable
36	SFZBK2	Circuit Breaker 2 slip frequency less than 5 mHz
36	SFBK2	5 mHz ≤ Circuit Breaker 2 slip frequency < 25 SFBK2
36	25W1BK2	Circuit Breaker 2 Angle 1 within Window 1
36	25W2BK2	Circuit Breaker 2 Angle 2 within Window 2
36	25A1BK2	Circuit Breaker 2 voltages within Synchronism Angle 1
36	25A2BK2	Circuit Breaker 2 voltages within Synchronism Angle 2
37	FAST2	fs2 > fp
37	SLOW2	fs2 < fp
37	BSYNBK2	Block synchronism check for Circuit Breaker 2
37	*	Reserved
37	*	Reserved
37	*	Reserved
37	*	Reserved
37	*	Reserved

Table A.6 Relay Word Bits: Reclosing Elements (Sheet 1 of 3)

Row	Name	Description
38	*	Reserved
38	*	Reserved
38	*	Reserved
38	*	Reserved
38	*	Reserved
38	3PRI	Three-pole reclose initiation (SELOGIC control equation)

Table A.6 Relay Word Bits: Reclosing Elements (Sheet 2 of 3)

Row	Name	Description
38	3PARC	Three-pole reclose initiate qualified
38	3POBK1	Three-pole open Circuit Breaker 1
39	3POBK2	Three-pole open Circuit Breaker 2
39	3POLINE	Three-pole open line
39	3PLSHT	Three-pole reclose last shot
39	BK1RS	Circuit Breaker 1 in ready state
39	BK2RS	Circuit Breaker 2 in ready state
39	*	Reserved
39	79CY3	Relay in three-pole reclose cycle state
39	BK1LO	Circuit Breaker 1 in lockout state
40	BK2LO	Circuit Breaker 2 in lockout state
40	BK1CL	Circuit Breaker 1 close command
40	BK2CL	Circuit Breaker 2 close command
40	LEADBK0	No lead circuit breaker
40	LEADBK1	Lead circuit breaker = Circuit Breaker 1
40	LEADBK2	Lead circuit breaker = Circuit Breaker 2
40	FOLBK0	No follower circuit breaker
40	FOLBK1	Follower circuit breaker = Circuit Breaker 1
41	FOLBK2	Follower circuit breaker = Circuit Breaker 2
41	NBK0	No circuit breakers active in reclose scheme
41	NBK1	One circuit breaker active in reclose scheme
41	NBK2	Two circuit breakers active in reclose scheme
41	*	Reserved
41	*	Reserved
41	3P1CLS	Three-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)
41	3P2CLS	Three-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)
42	BK1CFT	Circuit Breaker 1 close failure delay timed out
42	BK2CFT	Circuit Breaker 2 close failure delay timed out
42	BK1CLSS	Circuit Breaker 1 in close supervision state
42	BK2CLSS	Circuit Breaker 2 in close supervision state
42	BK1CLST	Circuit Breaker 1 close supervision timer timed out
42	BK2CLST	Circuit Breaker 2 close supervision timer timed out
42	ULCL1	Unlatch closing for Circuit Breaker 1 (SELOGIC control equation)
42	ULCL2	Unlatch closing for Circuit Breaker 2 (SELOGIC control equation)
43	LLDB1	Live Line Dead Bus 1
43	LLDB2	Live Line Dead Bus 2
43	DLLB1	Dead Line Live Bus 1
43	DLLB2	Dead Line Live Bus 2

Table A.6 Relay Word Bits: Reclosing Elements (Sheet 3 of 3)

Row	Name	Description
43	DLDB1	Dead Line Dead Bus 1
43	DLDB2	Dead Line Dead Bus 2
43	*	Reserved
43	*	Reserved
44	*	Reserved
44	BK1RCIP	Circuit Breaker 1 reclaim in progress (lockout state)
44	BK2RCIP	Circuit Breaker 2 reclaim in progress (lockout state)
44	*	Reserved
44	3PRCIP	Three-pole reclaim in progress
44	*	Reserved
44	*	Reserved
44	RST_79C	Reset recloser shot count accumulators (SELOGIC control equation)
45	*	Reserved
45	*	Reserved
45	*	Reserved
45	3PSHOT0	Three-pole shot counter =0
45	3PSHOT1	Three-pole shot counter =1
45	3PSHOT2	Three-pole shot counter =2
45	3PSHOT3	Three-pole shot counter =3
45	3PSHOT4	Three-pole shot counter =4
46	3POISC	Three-pole open supervision condition
46	3POI	Three-pole open interval timing
46	79STRT	Relay in start state
46	TBBK	Time between circuit breakers timing
46	BK1EXT	Circuit Breaker 1 closed externally
46	BK2EXT	Circuit Breaker 2 closed externally
46	*	Reserved
46	*	Reserved

Table A.7 Relay Word Bits: Miscellaneous Elements (Sheet 1 of 2)

Row	Name	Description
47	SOTFE	Switch-onto-fault enable
47	ILOP	Internal loss-of-potential from ELOP setting
47	LOP	Loss-of-potential detected
47	ZLOAD	ZLOUT or ZLIN element picked up
47	ZLIN	Load-encroachment “load out” element
47	ZLOUT	Load-encroachment “load in” element
47	FIDEN	Fault identification logic enabled
47	FSA	A-phase sector fault (AG or BCG fault)
48	FSB	B-phase sector fault (BG or CAG fault)

Table A.7 Relay Word Bits: Miscellaneous Elements (Sheet 2 of 2)

Row	Name	Description
48	FSC	C-phase sector fault (CG or ABG fault)
48	DFAULT	Disables maximum/minimum metering and demand metering when SELOGIC control equation FAULT asserts
48	ER	Event report trigger equation (SELOGIC control equation)
48	EAFSRC	Alternate frequency source (SELOGIC control equation)
48	*	Reserved
48	*	Reserved
48	*	Reserved

Table A.8 Relay Word Bits: Trip Logic Elements (Sheet 1 of 2)

Row	Name	Description
49	RXPRM	Receiver trip permission
49	COMPRM	Communications-assisted trip permission
49	TRPRM	Trip permission
49	*	Reserved
49	SOTFT	Switch-onto-fault trip
49	*	Reserved
49	*	Reserved
49	*	Reserved
50	*	Reserved
50	*	Reserved
50	*	Reserved
50	*	Reserved
50	*	Reserved
50	*	Reserved
50	*	Reserved
50	*	Reserved
51	*	Reserved
51	*	Reserved
51	*	Reserved
51	TRIP	Trip
51	3PT	Three-pole trip (follows TRIP)
51	*	Reserved
51	*	Reserved
51	*	Reserved
52	*	Reserved
52	*	Reserved
52	*	Reserved
52	*	Reserved
52	*	Reserved
52	ULTR	Unlatch all protection trips

Table A.8 Relay Word Bits: Trip Logic Elements (Sheet 2 of 2)

Row	Name	Description
52	ULMTR1	Circuit Breaker 1 unlatch manual trip
52	ULMTR2	Circuit Breaker 2 unlatch manual trip
53	ULTRA	Unlatch Trip
53	*	Reserved
53	*	Reserved
53	*	Reserved
53	*	Reserved
53	*	Reserved
53	T3P1	Three-pole trip, breaker 1
53	T3P2	Three-pole trip, breaker 2

Table A.9 Relay Word Bits: Pilot Tripping Elements

Row	Name	Description
54	PT	Permissive trip received
54	Z3RB	Current reversal guard asserted
54	KEY	Transmit permissive trip signal
54	EKEY	Echo received permissive trip signal
54	ECTT	Echo conversion to trip signal
54	*	Reserved
54	*	Reserved
54	*	Reserved
55	WFC	Weak infeed condition detected
55	*	Reserved
55	*	Reserved
55	UBB1	Blocks permissive trip Receiver 1
55	PTRX1	Permissive trip received Channel 1
55	UBB2	Blocks permissive trip Receiver 2
55	PTRX2	Permissive trip received Channel 2
55	UBB	Block permissive trip received 1 or 2
56	PTRX	Permissive trip received Channel 1 and Channel 2
56	Z3XT	Current reversal guard timer picked up
56	*	Reserved
56	67QG2S	Level 2 directional overcurrent short delay element
56	DSTRT	Directional start element picked up
56	NSTRT	Non-directional start element picked up
56	STOP	Stop element picked up
56	BTX	Block extension picked up
57–60	*	Reserved

Table A.10 Relay Word Bits: Circuit Breaker 1 Failure Elements (Sheet 1 of 2)

Row	Name	Description
61	BFI3P1	Circuit Breaker 1 three-pole circuit breaker failure initiation
61	*	Reserved
61	*	Reserved
61	*	Reserved
61	BFI3PT1	Circuit Breaker 1 failure extended initiation
61	*	Reserved
61	*	Reserved
61	*	Reserved
62	50FA1	Circuit Breaker 1 A-phase current threshold exceeded
62	50FB1	Circuit Breaker 1 B-phase current threshold exceeded
62	50FC1	Circuit Breaker 1 C-phase current threshold exceeded
62	*	Reserved
62	*	Reserved
62	*	Reserved
62	*	Reserved
62	*	Reserved
63	*	Reserved
63	*	Reserved
63	*	Reserved
63	RT1	Circuit Breaker 1 retrip
63	FBFA1	Circuit Breaker 1 A-phase circuit breaker failure
63	FBFB1	Circuit Breaker 1 B-phase circuit breaker failure
63	FBFC1	Circuit Breaker 1 C-phase circuit breaker failure
63	FBF1	Circuit Breaker 1 circuit breaker failure
64	50R1	Circuit Breaker 1 residual current threshold exceeded
64	BFIN1	Circuit Breaker 1 no current circuit breaker failure initiation
64	NBF1	Circuit Breaker 1 no current circuit breaker failure
64	50LCA1	Circuit Breaker 1 A-phase load current threshold exceeded
64	50LCB1	Circuit Breaker 1 B-phase load current threshold exceeded
64	50LCC1	Circuit Breaker 1 C-phase load current threshold exceeded
64	BFILC1	Circuit Breaker 1 load current circuit breaker failure initiation
64	LCBF1	Circuit Breaker 1 load current circuit breaker failure
65	50FOA1	Circuit Breaker 1 A-phase flashover current threshold exceeded
65	50FOB1	Circuit Breaker 1 B-phase flashover current threshold exceeded
65	50FOC1	Circuit Breaker 1 C-phase flashover current threshold exceeded

Table A.10 Relay Word Bits: Circuit Breaker 1 Failure Elements (Sheet 2 of 2)

Row	Name	Description
65	BLKFOA1	Circuit Breaker 1 block A-phase flashover detection
65	BLKFOB1	Circuit Breaker 1 block B-phase flashover detection
65	BLKFOC1	Circuit Breaker 1 block C-phase flashover detection
65	FOA1	Circuit Breaker 1 A-phase flashover detected
65	FOB1	Circuit Breaker 1 B-phase flashover detected
66	FOC1	Circuit Breaker 1 C-phase flashover detected
66	FOBF1	Circuit Breaker 1 flashover detected
66	BFTRIP1	Circuit Breaker 1 failure trip output asserted
66	BFTR1	Circuit breaker failure trip—Circuit Breaker 1 (SELOGIC control equation)
66	BFULTR1	Circuit breaker failure unlatch trip—Circuit Breaker 1 (SELOGIC control equation)
66	*	Reserved
66	*	Reserved
66	*	Reserved

Table A.11 Relay Word Bits: Circuit Breaker 2 Failure Elements (Sheet 1 of 2)

Row	Name	Description
67	BFI3P2	Circuit Breaker 2 three-pole circuit breaker failure initiation
67	*	Reserved
67	*	Reserved
67	*	Reserved
67	BFI3PT2	Circuit Breaker 2 failure extended initiation
67	*	Reserved
67	*	Reserved
67	*	Reserved
68	50FA2	Circuit Breaker 2 A-phase current threshold exceeded
68	50FB2	Circuit Breaker 2 B-phase current threshold exceeded
68	50FC2	Circuit Breaker 2 C-phase current threshold exceeded
68	*	Reserved
68	*	Reserved
68	*	Reserved
68	*	Reserved
68	*	Reserved
69	*	Reserved
69	*	Reserved
69	*	Reserved
69	RT2	Circuit Breaker 2 retrip
69	FBFA2	Circuit Breaker 2 A-phase circuit breaker failure
69	FBFB2	Circuit Breaker 2 B-phase circuit breaker failure
69	FBFC2	Circuit Breaker 2 C-phase circuit breaker failure

Table A.11 Relay Word Bits: Circuit Breaker 2 Failure Elements (Sheet 2 of 2)

Row	Name	Description
69	FBF2	Circuit Breaker 2 circuit breaker failure
70	50R2	Circuit Breaker 2 residual current threshold exceeded
70	BFIN2	Circuit Breaker 2 no current circuit breaker failure initiation
70	NBF2	Circuit Breaker 2 no current circuit breaker failure
70	50LCA2	Circuit Breaker 2 A-phase load current threshold exceeded
70	50LCB2	Circuit Breaker 2 B-phase load current threshold exceeded
70	50LCC2	Circuit Breaker 2 C-phase load current threshold exceeded
70	BFILC2	Circuit Breaker 2 load current circuit breaker failure initiation
70	LCBF2	Circuit Breaker 2 load current circuit breaker failure
71	50FOA2	Circuit Breaker 2 A-phase flashover current threshold exceeded
71	50FOB2	Circuit Breaker 2 B-phase flashover current threshold exceeded
71	50FOC2	Circuit Breaker 2 C-phase flashover current threshold exceeded
71	BLKFOA2	Circuit Breaker 2 block A-phase flashover detection
71	BLKFOB2	Circuit Breaker 2 block B-phase flashover detection
71	BLKFOC2	Circuit Breaker 2 block C-phase flashover detection
71	FOA2	Circuit Breaker 2 A-phase flashover detected
71	FOB2	Circuit Breaker 2 B-phase flashover detected
72	FOC2	Circuit Breaker 2 C-phase flashover detected
72	FOBF2	Circuit Breaker 2 flashover detected
72	BFTRIP2	Circuit Breaker 2 failure trip output asserted
72	BFTR2	Circuit breaker failure trip—Circuit Breaker 2 (SELOGIC control equation)
72	BFULTR2	Circuit breaker failure unlatch trip—Circuit Breaker 2 (SELOGIC control equation)
72	*	Reserved
72	*	Reserved
72	*	Reserved

Table A.12 Relay Word Bits: Circuit Breaker Status and Open Phase Detector (Sheet 1 of 3)

Row	Name	Description
73	B1OPHA	Circuit Breaker 1 A-phase open
73	B1OPHB	Circuit Breaker 1 B-phase open
73	B1OPHC	Circuit Breaker 1 C-phase open
73	B2OPHA	Circuit Breaker 2 A-phase open
73	B2OPHB	Circuit Breaker 2 B-phase open
73	B2OPHC	Circuit Breaker 2 C-phase open

Table A.12 Relay Word Bits: Circuit Breaker Status and Open Phase Detector (Sheet 2 of 3)

Row	Name	Description
73	LOPHA	Line A-phase open
73	LOPHB	Line B-phase open
74	LOPHC	Line C-phase open
74	*	Reserved
74	*	Reserved
74	*	Reserved
74	*	Reserved
74	3PO	All three poles open
74	27APO	A-phase undervoltage, pole open
74	27BPO	B-phase undervoltage, pole open
75	27CPO	C-phase undervoltage, pole open
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
76	52ACL1	Circuit Breaker 1, closed
76	*	Reserved
76	*	Reserved
76	52AAL1	Circuit Breaker 1, alarm
76	*	Reserved
76	*	Reserved
76	52AA1	Circuit Breaker 1, status
76	52AB1	Circuit Breaker 1, status (follows 52AA1)
77	52AC1	Circuit Breaker 1, status (follows 52AA1)
77	*	Reserved
77	52ACL2	Circuit Breaker 2, closed
77	*	Reserved
77	*	Reserved
77	52AAL2	Circuit Breaker 2, alarm
77	*	Reserved
77	*	Reserved
78	52AA2	Circuit Breaker 2, status
78	52AB2	Circuit Breaker 2, status (follows 52AA2)
78	52AC2	Circuit Breaker 2, status (follows 52AA2)
78	*	Reserved
78	*	Reserved
78	*	Reserved

Table A.12 Relay Word Bits: Circuit Breaker Status and Open Phase Detector (Sheet 3 of 3)

Row	Name	Description
78	*	Reserved
78	*	Reserved
79–82	*	Reserved

Table A.13 Relay Word Bits: Circuit Breaker Monitor (Sheet 1 of 2)

Row	Name	Description
83	BM1TRPA	Circuit breaker monitor trip—Circuit Breaker 1 (SELOGIC control equation)
83	BM1TRPB	Circuit breaker monitor trip—Circuit Breaker 1 (follows BM1TRPA)
83	BM1TRPC	Circuit breaker monitor trip—Circuit Breaker 1 (follows BM1TRPA)
83	BM1CLSA	Circuit breaker monitor close—Circuit Breaker 1 (SELOGIC control equation)
83	BM1CLSB	Circuit breaker monitor close—Circuit Breaker 1 (follows BM1CLSA)
83	BM1CLSC	Circuit breaker monitor close—Circuit Breaker 1 (follows BM1CLSA)
83	B1BCWAL	Circuit Breaker 1 contact wear monitor alarm
83	B1MRTIN	Motor run time contact input—Circuit Breaker 1 (SELOGIC control equation)
84	*	Reserved
84	B1MSOAL	Circuit Breaker 1 mechanical slow operation alarm
84	B1ESOAL	Circuit Breaker 1 electrical slow operation alarm
84	*	Reserved
84	*	Reserved
84	B1BITAL	Circuit Breaker 1 inactivity time alarm
84	B1MRTAL	Circuit Breaker 1 motor running time alarm
84	B1KAIAL	Circuit Breaker 1 interrupted current alarm
85	BM2TRPA	Circuit breaker monitor trip—Circuit Breaker 2 (SELOGIC control equation)
85	BM2TRPB	Circuit breaker monitor trip—Circuit Breaker 2 (follows BM2TRPA)
85	BM2TRPC	Circuit breaker monitor trip—Circuit Breaker 2 (follows BM2TRPA)
85	BM2CLSA	Circuit breaker monitor close—Circuit Breaker 2 (SELOGIC control equation)
85	BM2CLSB	Circuit breaker monitor close—Circuit Breaker 2 (follows BM2CLSA)
85	BM2CLSC	Circuit breaker monitor close—Circuit Breaker 2 (follows BM2CLSA)
85	B2BCWAL	Circuit Breaker 2 contact wear monitor alarm
85	B2MRTIN	Motor run time contact input—Circuit Breaker 2 (SELOGIC control equation)
86	*	Reserved

Table A.13 Relay Word Bits: Circuit Breaker Monitor (Sheet 2 of 2)

Row	Name	Description
86	B2MSOAL	Circuit Breaker 2 mechanical slow operation alarm
86	B2ESOAL	Circuit Breaker 2 electrical slow operation alarm
86	*	Reserved
86	*	Reserved
86	B2BITAL	Circuit Breaker 2 inactivity time alarm
86	B2MRTAL	Circuit Breaker 2 motor running time alarm
86	B2KAIAL	Circuit Breaker 2 interrupted current alarm

Table A.14 Relay Word Bits: RTD Status

Row	Name	Description
87	RTD08ST	RTD Status for Channel 8
87	RTD07ST	RTD Status for Channel 7
87	RTD06ST	RTD Status for Channel 6
87	RTD05ST	RTD Status for Channel 5
87	RTD04ST	RTD Status for Channel 4
87	RTD03ST	RTD Status for Channel 3
87	RTD02ST	RTD Status for Channel 2
87	RTD01ST	RTD Status for Channel 1
88	RTDIN	State of RTD contact input
88	RTDCOMF	RTD Communication Failure
88	RTDFL	RTD device Failure
88	*	Reserved
88	RTD12ST	RTD Status for Channel 12
88	RTD11ST	RTD Status for Channel 11
88	RTD10ST	RTD Status for Channel 10
88	RTD09ST	RTD Status for Channel 9

Table A.15 Relay Word Bits: DC Supply Monitor

Row	Name	Description
89	DC1F	DC Monitor 1 fail alarm
89	DC1W	DC Monitor 1 warning alarm
89	DC1G	DC Monitor 1 ground fault alarm
89	DC1R	DC Monitor 1 alarm for ac ripple
89	DC2F	DC Monitor 2 fail alarm
89	DC2W	DC Monitor 2 warning alarm
89	DC2G	DC Monitor 2 ground fault alarm
89	DC2R	DC Monitor 2 alarm for ac ripple

Table A.16 Relay Word Bits: Metering Elements

Row	Name	Description
90	PDEM	Phase current demand picked up
90	QDEM	Negative-sequence demand current picked up
90	GDEM	Zero-sequence demand current picked up
90	*	Reserved
90	*	Reserved
90	*	Reserved
90	*	Reserved
90	*	Reserved

Table A.17 Relay Word Bits: Open and Close Command

Row	Name	Description
91	CC2	Circuit Breaker 2 close command
91	OC2	Circuit Breaker 2 open command
91	CC1	Circuit Breaker 1 close command
91	OC1	Circuit Breaker 1 open command
91	*	Reserved
91	*	Reserved
91	*	Reserved
91	*	Reserved

Table A.18 Relay Word Bits: Local Bits (Sheet 1 of 2)

Row	Name	Description
92	LB08	Local Bit 8
92	LB07	Local Bit 7
92	LB06	Local Bit 6
92	LB05	Local Bit 5
92	LB04	Local Bit 4
92	LB03	Local Bit 3
92	LB02	Local Bit 2
92	LB01	Local Bit 1
93	LB16	Local Bit 16
93	LB15	Local Bit 15
93	LB14	Local Bit 14
93	LB13	Local Bit 13
93	LB12	Local Bit 12
93	LB11	Local Bit 11
93	LB10	Local Bit 10
93	LB09	Local Bit 9
94	LB24	Local Bit 24
94	LB23	Local Bit 23
94	LB22	Local Bit 22

Table A.18 Relay Word Bits: Local Bits (Sheet 2 of 2)

Row	Name	Description
94	LB21	Local Bit 21
94	LB20	Local Bit 20
94	LB19	Local Bit 19
94	LB18	Local Bit 18
94	LB17	Local Bit 17
95	LB32	Local Bit 32
95	LB31	Local Bit 31
95	LB30	Local Bit 30
95	LB29	Local Bit 29
95	LB28	Local Bit 28
95	LB27	Local Bit 27
95	LB26	Local Bit 26
95	LB25	Local Bit 25

Table A.19 Relay Word Bits: Remote Bits (Sheet 1 of 2)

Row	Name	Description
96	RB25	Remote Bit 25
96	RB26	Remote Bit 26
96	RB27	Remote Bit 27
96	RB28	Remote Bit 28
96	RB29	Remote Bit 29
96	RB30	Remote Bit 30
96	RB31	Remote Bit 31
96	RB32	Remote Bit 32
97	RB17	Remote Bit 17
97	RB18	Remote Bit 18
97	RB19	Remote Bit 19
97	RB20	Remote Bit 20
97	RB21	Remote Bit 21
97	RB22	Remote Bit 22
97	RB23	Remote Bit 23
97	RB24	Remote Bit 24
98	RB09	Remote Bit 9
98	RB10	Remote Bit 10
98	RB11	Remote Bit 11
98	RB12	Remote Bit 12
98	RB13	Remote Bit 13
98	RB14	Remote Bit 14
98	RB15	Remote Bit 15
98	RB16	Remote Bit 16
99	RB01	Remote Bit 1

Table A.19 Relay Word Bits: Remote Bits (Sheet 2 of 2)

Row	Name	Description
99	RB02	Remote Bit 2
99	RB03	Remote Bit 3
99	RB04	Remote Bit 4
99	RB05	Remote Bit 5
99	RB06	Remote Bit 6
99	RB07	Remote Bit 7
99	RB08	Remote Bit 8

Table A.20 Relay Word Bits: Active Protection Settings Group

Row	Name	Description
100	SG6	Settings Group 6 active
100	SG5	Settings Group 5 active
100	SG4	Settings Group 4 active
100	SG3	Settings Group 3 active
100	SG2	Settings Group 2 active
100	SG1	Settings Group 1 active
100	CHSG	Settings Group Change
100	*	Reserved
101–103	*	Reserved

Table A.21 Relay Word Bits: Input Elements (Sheet 1 of 3)

Row	Name	Description
104	*	Reserved
104	IN107	Main Board Input 7
104	IN106	Main Board Input 6
104	IN105	Main Board Input 5
104	IN104	Main Board Input 4
104	IN103	Main Board Input 3
104	IN102	Main Board Input 2
104	IN101	Main Board Input 1
105	IN208	First Optional I/O Board Input 8 (if installed)
105	IN207	First Optional I/O Board Input 7 (if installed)
105	IN206	First Optional I/O Board Input 6 (if installed)
105	IN205	First Optional I/O Board Input 5 (if installed)
105	IN204	First Optional I/O Board Input 4 (if installed)
105	IN203	First Optional I/O Board Input 3 (if installed)
105	IN202	First Optional I/O Board Input 2 (if installed)
105	IN201	First Optional I/O Board Input 1 (if installed)
106	IN216	First Optional I/O Board Input 16 (if installed)
106	IN215	First Optional I/O Board Input 15 (if installed)

Table A.21 Relay Word Bits: Input Elements (Sheet 2 of 3)

Row	Name	Description
106	IN214	First Optional I/O Board Input 14 (if installed)
106	IN213	First Optional I/O Board Input 13 (if installed)
106	IN212	First Optional I/O Board Input 12 (if installed)
106	IN211	First Optional I/O Board Input 11 (if installed)
106	IN210	First Optional I/O Board Input 10 (if installed)
106	IN209	First Optional I/O Board Input 9 (if installed)
107	IN224	First Optional I/O Board Input 24 (if installed)
107	IN223	First Optional I/O Board Input 23 (if installed)
107	IN222	First Optional I/O Board Input 22 (if installed)
107	IN221	First Optional I/O Board Input 21 (if installed)
107	IN220	First Optional I/O Board Input 20 (if installed)
107	IN219	First Optional I/O Board Input 19 (if installed)
107	IN218	First Optional I/O Board Input 18 (if installed)
107	IN217	First Optional I/O Board Input 17 (if installed)
108	IN308	Second Optional I/O Board Input 8 (if installed)
108	IN307	Second Optional I/O Board Input 7 (if installed)
108	IN306	Second Optional I/O Board Input 6 (if installed)
108	IN305	Second Optional I/O Board Input 5 (if installed)
108	IN304	Second Optional I/O Board Input 4 (if installed)
108	IN303	Second Optional I/O Board Input 3 (if installed)
108	IN302	Second Optional I/O Board Input 2 (if installed)
108	IN301	Second Optional I/O Board Input 1 (if installed)
109	IN316	Second Optional I/O Board Input 16 (if installed)
109	IN315	Second Optional I/O Board Input 15 (if installed)
109	IN314	Second Optional I/O Board Input 14 (if installed)
109	IN313	Second Optional I/O Board Input 13 (if installed)
109	IN312	Second Optional I/O Board Input 12 (if installed)
109	IN311	Second Optional I/O Board Input 11 (if installed)
109	IN310	Second Optional I/O Board Input 10 (if installed)
109	IN309	Second Optional I/O Board Input 9 (if installed)
110	IN324	Second Optional I/O Board Input 24 (if installed)
110	IN323	Second Optional I/O Board Input 23 (if installed)
110	IN322	Second Optional I/O Board Input 22 (if installed)
110	IN321	Second Optional I/O Board Input 21 (if installed)
110	IN320	Second Optional I/O Board Input 20 (if installed)
110	IN319	Second Optional I/O Board Input 19 (if installed)
110	IN318	Second Optional I/O Board Input 18 (if installed)
110	IN317	Second Optional I/O Board Input 17 (if installed)
111	*	Reserved
111	*	Reserved
111	*	Reserved

Table A.21 Relay Word Bits: Input Elements (Sheet 3 of 3)

Row	Name	Description
111	*	Reserved
111	*	Reserved
111	*	Reserved
111	*	Reserved
111	*	Reserved

Table A.22 Relay Word Bits: Protection Variables (Sheet 1 of 2)

Row	Name	Description
112	PSV08	Protection SELOGIC Variable 8
112	PSV07	Protection SELOGIC Variable 7
112	PSV06	Protection SELOGIC Variable 6
112	PSV05	Protection SELOGIC Variable 5
112	PSV04	Protection SELOGIC Variable 4
112	PSV03	Protection SELOGIC Variable 3
112	PSV02	Protection SELOGIC Variable 2
112	PSV01	Protection SELOGIC Variable 1
113	PSV16	Protection SELOGIC Variable 16
113	PSV15	Protection SELOGIC Variable 15
113	PSV14	Protection SELOGIC Variable 14
113	PSV13	Protection SELOGIC Variable 13
113	PSV12	Protection SELOGIC Variable 12
113	PSV11	Protection SELOGIC Variable 11
113	PSV10	Protection SELOGIC Variable 10
113	PSV09	Protection SELOGIC Variable 9
114	PSV24	Protection SELOGIC Variable 24
114	PSV23	Protection SELOGIC Variable 23
114	PSV22	Protection SELOGIC Variable 22
114	PSV21	Protection SELOGIC Variable 21
114	PSV20	Protection SELOGIC Variable 20
114	PSV19	Protection SELOGIC Variable 19
114	PSV18	Protection SELOGIC Variable 18
114	PSV17	Protection SELOGIC Variable 17
115	PSV32	Protection SELOGIC Variable 32
115	PSV31	Protection SELOGIC Variable 31
115	PSV30	Protection SELOGIC Variable 30
115	PSV29	Protection SELOGIC Variable 29
115	PSV28	Protection SELOGIC Variable 28
115	PSV27	Protection SELOGIC Variable 27
115	PSV26	Protection SELOGIC Variable 26
115	PSV25	Protection SELOGIC Variable 25
116	PSV40	Protection SELOGIC Variable 40

Table A.22 Relay Word Bits: Protection Variables (Sheet 2 of 2)

Row	Name	Description
116	PSV39	Protection SELOGIC Variable 39
116	PSV38	Protection SELOGIC Variable 38
116	PSV37	Protection SELOGIC Variable 37
116	PSV36	Protection SELOGIC Variable 36
116	PSV35	Protection SELOGIC Variable 35
116	PSV34	Protection SELOGIC Variable 34
116	PSV33	Protection SELOGIC Variable 33
117	PSV48	Protection SELOGIC Variable 48
117	PSV47	Protection SELOGIC Variable 47
117	PSV46	Protection SELOGIC Variable 46
117	PSV45	Protection SELOGIC Variable 45
117	PSV44	Protection SELOGIC Variable 44
117	PSV43	Protection SELOGIC Variable 43
117	PSV42	Protection SELOGIC Variable 42
117	PSV41	Protection SELOGIC Variable 41
118	PSV56	Protection SELOGIC Variable 56
118	PSV55	Protection SELOGIC Variable 55
118	PSV54	Protection SELOGIC Variable 54
118	PSV53	Protection SELOGIC Variable 53
118	PSV52	Protection SELOGIC Variable 52
118	PSV51	Protection SELOGIC Variable 51
118	PSV50	Protection SELOGIC Variable 50
118	PSV49	Protection SELOGIC Variable 49
119	PSV64	Protection SELOGIC Variable 64
119	PSV63	Protection SELOGIC Variable 63
119	PSV62	Protection SELOGIC Variable 62
119	PSV61	Protection SELOGIC Variable 61
119	PSV60	Protection SELOGIC Variable 60
119	PSV59	Protection SELOGIC Variable 59
119	PSV58	Protection SELOGIC Variable 58
119	PSV57	Protection SELOGIC Variable 57

Table A.23 Relay Word Bits: Protection Latches (Sheet 1 of 2)

Row	Name	Description
120	PLT08	Protection Latch 8
120	PLT07	Protection Latch 7
120	PLT06	Protection Latch 6
120	PLT05	Protection Latch 5
120	PLT04	Protection Latch 4
120	PLT03	Protection Latch 3
120	PLT02	Protection Latch 2

Table A.23 Relay Word Bits: Protection Latches (Sheet 2 of 2)

Row	Name	Description
120	PLT01	Protection Latch 1
121	PLT16	Protection Latch 16
121	PLT15	Protection Latch 15
121	PLT14	Protection Latch 14
121	PLT13	Protection Latch 13
121	PLT12	Protection Latch 12
121	PLT11	Protection Latch 11
121	PLT10	Protection Latch 10
121	PLT09	Protection Latch 9
122	PLT24	Protection Latch 24
122	PLT23	Protection Latch 23
122	PLT22	Protection Latch 22
122	PLT21	Protection Latch 21
122	PLT20	Protection Latch 20
122	PLT19	Protection Latch 19
122	PLT18	Protection Latch 18
122	PLT17	Protection Latch 17
123	PLT32	Protection Latch 32
123	PLT31	Protection Latch 31
123	PLT30	Protection Latch 30
123	PLT29	Protection Latch 29
123	PLT28	Protection Latch 28
123	PLT27	Protection Latch 27
123	PLT26	Protection Latch 26
123	PLT25	Protection Latch 25

Table A.24 Relay Word Bits: Protection Conditioning Timers (Sheet 1 of 2)

Row	Name	Description
124	PCT08Q	Protection Conditioning Timer 8 output
124	PCT07Q	Protection Conditioning Timer 7 output
124	PCT06Q	Protection Conditioning Timer 6 output
124	PCT05Q	Protection Conditioning Timer 5 output
124	PCT04Q	Protection Conditioning Timer 4 output
124	PCT03Q	Protection Conditioning Timer 3 output
124	PCT02Q	Protection Conditioning Timer 2 output
124	PCT01Q	Protection Conditioning Timer 1 output
125	PCT16Q	Protection Conditioning Timer 16 output
125	PCT15Q	Protection Conditioning Timer 15 output
125	PCT14Q	Protection Conditioning Timer 14 output
125	PCT13Q	Protection Conditioning Timer 13 output
125	PCT12Q	Protection Conditioning Timer 12 output

Table A.24 Relay Word Bits: Protection Conditioning Timers (Sheet 2 of 2)

Row	Name	Description
125	PCT11Q	Protection Conditioning Timer 11 output
125	PCT10Q	Protection Conditioning Timer 10 output
125	PCT09Q	Protection Conditioning Timer 9 output
126	PCT24Q	Protection Conditioning Timer 24 output
126	PCT23Q	Protection Conditioning Timer 23 output
126	PCT22Q	Protection Conditioning Timer 22 output
126	PCT21Q	Protection Conditioning Timer 21 output
126	PCT20Q	Protection Conditioning Timer 20 output
126	PCT19Q	Protection Conditioning Timer 19 output
126	PCT18Q	Protection Conditioning Timer 18 output
126	PCT17Q	Protection Conditioning Timer 17output
127	PCT32Q	Protection Conditioning Timer 32 output
127	PCT31Q	Protection Conditioning Timer 31 output
127	PCT30Q	Protection Conditioning Timer 30 output
127	PCT29Q	Protection Conditioning Timer 29 output
127	PCT28Q	Protection Conditioning Timer 28 output
127	PCT27Q	Protection Conditioning Timer 27 output
127	PCT26Q	Protection Conditioning Timer 26 output
127	PCT25Q	Protection Conditioning Timer 25 output
128	*	Reserved
129	*	Reserved

Table A.25 Relay Word Bits: Protection Sequencing Timers (Sheet 1 of 3)

Row	Name	Description
130	PST08Q	Protection Sequencing Timer 8 output
130	PST07Q	Protection Sequencing Timer 7 output
130	PST06Q	Protection Sequencing Timer 6 output
130	PST05Q	Protection Sequencing Timer 5 output
130	PST04Q	Protection Sequencing Timer 4 output
130	PST03Q	Protection Sequencing Timer 3 output
130	PST02Q	Protection Sequencing Timer 2 output
130	PST01Q	Protection Sequencing Timer 1 output
131	PST16Q	Protection Sequencing Timer 16 output
131	PST15Q	Protection Sequencing Timer 15 output
131	PST14Q	Protection Sequencing Timer 14 output
131	PST13Q	Protection Sequencing Timer 13 output
131	PST12Q	Protection Sequencing Timer 12 output
131	PST11Q	Protection Sequencing Timer 11 output
131	PST10Q	Protection Sequencing Timer 10 output
131	PST09Q	Protection Sequencing Timer 9 output
132	PST24Q	Protection Sequencing Timer 24 output

Table A.25 Relay Word Bits: Protection Sequencing Timers (Sheet 2 of 3)

Row	Name	Description
132	PST23Q	Protection Sequencing Timer 23 output
132	PST22Q	Protection Sequencing Timer 22 output
132	PST21Q	Protection Sequencing Timer 21 output
132	PST20Q	Protection Sequencing Timer 20 output
132	PST19Q	Protection Sequencing Timer 19 output
132	PST18Q	Protection Sequencing Timer 18 output
132	PST17Q	Protection Sequencing Timer 17 output
133	PST32Q	Protection Sequencing Timer 32 output
133	PST31Q	Protection Sequencing Timer 31 output
133	PST30Q	Protection Sequencing Timer 30 output
133	PST29Q	Protection Sequencing Timer 29 output
133	PST28Q	Protection Sequencing Timer 28 output
133	PST27Q	Protection Sequencing Timer 27 output
133	PST26Q	Protection Sequencing Timer 26 output
133	PST25Q	Protection Sequencing Timer 25 output
134	PST08R	Protection Sequencing Timer 8 reset (SELOGIC control equation)
134	PST07R	Protection Sequencing Timer 7 reset (SELOGIC control equation)
134	PST06R	Protection Sequencing Timer 6 reset (SELOGIC control equation)
134	PST05R	Protection Sequencing Timer 5 reset (SELOGIC control equation)
134	PST04R	Protection Sequencing Timer 4 reset (SELOGIC control equation)
134	PST03R	Protection Sequencing Timer 3 reset (SELOGIC control equation)
134	PST02R	Protection Sequencing Timer 2 reset (SELOGIC control equation)
134	PST01R	Protection Sequencing Timer 1 reset (SELOGIC control equation)
135	PST16R	Protection Sequencing Timer 16 reset (SELOGIC control equation)
135	PST15R	Protection Sequencing Timer 15 reset (SELOGIC control equation)
135	PST14R	Protection Sequencing Timer 14 reset (SELOGIC control equation)
135	PST13R	Protection Sequencing Timer 13 reset (SELOGIC control equation)
135	PST12R	Protection Sequencing Timer 12 reset (SELOGIC control equation)
135	PST11R	Protection Sequencing Timer 11 reset (SELOGIC control equation)
135	PST10R	Protection Sequencing Timer 10 reset (SELOGIC control equation)
135	PST09R	Protection Sequencing Timer 9 reset (SELOGIC control equation)

Table A.25 Relay Word Bits: Protection Sequencing Timers (Sheet 3 of 3)

Row	Name	Description
136	PST24R	Protection Sequencing Timer 24 reset (SELOGIC control equation)
136	PST23R	Protection Sequencing Timer 23 reset (SELOGIC control equation)
136	PST22R	Protection Sequencing Timer 22 reset (SELOGIC control equation)
136	PST21R	Protection Sequencing Timer 21 reset (SELOGIC control equation)
136	PST20R	Protection Sequencing Timer 20 reset (SELOGIC control equation)
136	PST19R	Protection Sequencing Timer 19 reset (SELOGIC control equation)
136	PST18R	Protection Sequencing Timer 18 reset (SELOGIC control equation)
136	PST17R	Protection Sequencing Timer 17 reset (SELOGIC control equation)
137	PST32R	Protection Sequencing Timer 32 reset (SELOGIC control equation)
137	PST31R	Protection Sequencing Timer 31 reset (SELOGIC control equation)
137	PST30R	Protection Sequencing Timer 30 reset (SELOGIC control equation)
137	PST29R	Protection Sequencing Timer 29 reset (SELOGIC control equation)
137	PST28R	Protection Sequencing Timer 28 reset (SELOGIC control equation)
137	PST27R	Protection Sequencing Timer 27 reset (SELOGIC control equation)
137	PST26R	Protection Sequencing Timer 26 reset (SELOGIC control equation)
137	PST25R	Protection Sequencing Timer 25 reset (SELOGIC control equation)

Table A.26 Relay Word Bits: Protection Counters (Sheet 1 of 3)

Row	Name	Description
138	PCN08Q	Protection Counter 8 output
138	PCN07Q	Protection Counter 7 output
138	PCN06Q	Protection Counter 6 output
138	PCN05Q	Protection Counter 5 output
138	PCN04Q	Protection Counter 4 output
138	PCN03Q	Protection Counter 3 output
138	PCN02Q	Protection Counter 2 output
138	PCN01Q	Protection Counter 1 output
139	PCN16Q	Protection Counter 16 output
139	PCN15Q	Protection Counter 15 output
139	PCN14Q	Protection Counter 14 output
139	PCN13Q	Protection Counter 13 output

Table A.26 Relay Word Bits: Protection Counters (Sheet 2 of 3)

Row	Name	Description
139	PCN12Q	Protection Counter 12 output
139	PCN11Q	Protection Counter 11 output
139	PCN10Q	Protection Counter 10 output
139	PCN09Q	Protection Counter 9 output
140	PCN24Q	Protection Counter 24 output
140	PCN23Q	Protection Counter 23 output
140	PCN22Q	Protection Counter 22 output
140	PCN21Q	Protection Counter 21 output
140	PCN20Q	Protection Counter 20 output
140	PCN19Q	Protection Counter 19 output
140	PCN18Q	Protection Counter 18 output
140	PCN17Q	Protection Counter 17 output
141	PCN32Q	Protection Counter 32 output
141	PCN31Q	Protection Counter 31 output
141	PCN30Q	Protection Counter 30 output
141	PCN29Q	Protection Counter 29 output
141	PCN28Q	Protection Counter 28 output
141	PCN27Q	Protection Counter 27 output
141	PCN26Q	Protection Counter 26 output
141	PCN25Q	Protection Counter 25 output
142	PCN08R	Protection Counter 8 reset (SELOGIC control equation)
142	PCN07R	Protection Counter 7 reset (SELOGIC control equation)
142	PCN06R	Protection Counter 6 reset (SELOGIC control equation)
142	PCN05R	Protection Counter 5 reset (SELOGIC control equation)
142	PCN04R	Protection Counter 4 reset (SELOGIC control equation)
142	PCN03R	Protection Counter 3 reset (SELOGIC control equation)
142	PCN02R	Protection Counter 2 reset (SELOGIC control equation)
142	PCN01R	Protection Counter 1 reset (SELOGIC control equation)
143	PCN16R	Protection Counter 16 reset (SELOGIC control equation)
143	PCN15R	Protection Counter 15 reset (SELOGIC control equation)
143	PCN14R	Protection Counter 14 reset (SELOGIC control equation)
143	PCN13R	Protection Counter 13 reset (SELOGIC control equation)
143	PCN12R	Protection Counter 12 reset (SELOGIC control equation)
143	PCN11R	Protection Counter 11 reset (SELOGIC control equation)
143	PCN10R	Protection Counter 10 reset (SELOGIC control equation)
143	PCN09R	Protection Counter 9 reset (SELOGIC control equation)
144	PCN24R	Protection Counter 24 reset (SELOGIC control equation)
144	PCN23R	Protection Counter 23 reset (SELOGIC control equation)
144	PCN22R	Protection Counter 22 reset (SELOGIC control equation)
144	PCN21R	Protection Counter 21 reset (SELOGIC control equation)
144	PCN20R	Protection Counter 20 reset (SELOGIC control equation)

Table A.26 Relay Word Bits: Protection Counters (Sheet 3 of 3)

Row	Name	Description
144	PCN19R	Protection Counter 19 reset (SELOGIC control equation)
144	PCN18R	Protection Counter 18 reset (SELOGIC control equation)
144	PCN17R	Protection Counter 17 reset (SELOGIC control equation)
145	PCN32R	Protection Counter 32 reset (SELOGIC control equation)
145	PCN31R	Protection Counter 31 reset (SELOGIC control equation)
145	PCN30R	Protection Counter 30 reset (SELOGIC control equation)
145	PCN29R	Protection Counter 29 reset (SELOGIC control equation)
145	PCN28R	Protection Counter 28 reset (SELOGIC control equation)
145	PCN27R	Protection Counter 27 reset (SELOGIC control equation)
145	PCN26R	Protection Counter 26 reset (SELOGIC control equation)
145	PCN25R	Protection Counter 25 reset (SELOGIC control equation)

Table A.27 Relay Word Bits: Automation Variables (Sheet 1 of 7)

Row	Name	Description
146	ASV008	Automation SELOGIC Variable 8
146	ASV007	Automation SELOGIC Variable 7
146	ASV006	Automation SELOGIC Variable 6
146	ASV005	Automation SELOGIC Variable 5
146	ASV004	Automation SELOGIC Variable 4
146	ASV003	Automation SELOGIC Variable 3
146	ASV002	Automation SELOGIC Variable 2
146	ASV001	Automation SELOGIC Variable 1
147	ASV016	Automation SELOGIC Variable 16
147	ASV015	Automation SELOGIC Variable 15
147	ASV014	Automation SELOGIC Variable 14
147	ASV013	Automation SELOGIC Variable 13
147	ASV012	Automation SELOGIC Variable 12
147	ASV011	Automation SELOGIC Variable 11
147	ASV010	Automation SELOGIC Variable 10
147	ASV009	Automation SELOGIC Variable 9
148	ASV024	Automation SELOGIC Variable 24
148	ASV023	Automation SELOGIC Variable 23
148	ASV022	Automation SELOGIC Variable 22
148	ASV021	Automation SELOGIC Variable 21
148	ASV020	Automation SELOGIC Variable 20
148	ASV019	Automation SELOGIC Variable 19
148	ASV018	Automation SELOGIC Variable 18
148	ASV017	Automation SELOGIC Variable 17
149	ASV032	Automation SELOGIC Variable 32
149	ASV031	Automation SELOGIC Variable 31
149	ASV030	Automation SELOGIC Variable 30

Table A.27 Relay Word Bits: Automation Variables (Sheet 2 of 7)

Row	Name	Description
149	ASV029	Automation SELOGIC Variable 29
149	ASV028	Automation SELOGIC Variable 28
149	ASV027	Automation SELOGIC Variable 27
149	ASV026	Automation SELOGIC Variable 26
149	ASV025	Automation SELOGIC Variable 25
150	ASV040	Automation SELOGIC Variable 40
150	ASV039	Automation SELOGIC Variable 39
150	ASV038	Automation SELOGIC Variable 38
150	ASV037	Automation SELOGIC Variable 37
150	ASV036	Automation SELOGIC Variable 36
150	ASV035	Automation SELOGIC Variable 35
150	ASV034	Automation SELOGIC Variable 34
150	ASV033	Automation SELOGIC Variable 33
151	ASV048	Automation SELOGIC Variable 48
151	ASV047	Automation SELOGIC Variable 47
151	ASV046	Automation SELOGIC Variable 46
151	ASV045	Automation SELOGIC Variable 45
151	ASV044	Automation SELOGIC Variable 44
151	ASV043	Automation SELOGIC Variable 43
151	ASV042	Automation SELOGIC Variable 42
151	ASV041	Automation SELOGIC Variable 41
152	ASV056	Automation SELOGIC Variable 56
152	ASV055	Automation SELOGIC Variable 55
152	ASV054	Automation SELOGIC Variable 54
152	ASV053	Automation SELOGIC Variable 53
152	ASV052	Automation SELOGIC Variable 52
152	ASV051	Automation SELOGIC Variable 51
152	ASV050	Automation SELOGIC Variable 50
152	ASV049	Automation SELOGIC Variable 49
153	ASV064	Automation SELOGIC Variable 64
153	ASV063	Automation SELOGIC Variable 63
153	ASV062	Automation SELOGIC Variable 62
153	ASV061	Automation SELOGIC Variable 61
153	ASV060	Automation SELOGIC Variable 60
153	ASV059	Automation SELOGIC Variable 59
153	ASV058	Automation SELOGIC Variable 58
153	ASV057	Automation SELOGIC Variable 57
154	ASV072	Automation SELOGIC Variable 72
154	ASV071	Automation SELOGIC Variable 71
154	ASV070	Automation SELOGIC Variable 70
154	ASV069	Automation SELOGIC Variable 69

Table A.27 Relay Word Bits: Automation Variables (Sheet 3 of 7)

Row	Name	Description
154	ASV068	Automation SELOGIC Variable 68
154	ASV067	Automation SELOGIC Variable 67
154	ASV066	Automation SELOGIC Variable 66
154	ASV065	Automation SELOGIC Variable 65
155	ASV080	Automation SELOGIC Variable 80
155	ASV079	Automation SELOGIC Variable 79
155	ASV078	Automation SELOGIC Variable 78
155	ASV077	Automation SELOGIC Variable 77
155	ASV076	Automation SELOGIC Variable 76
155	ASV075	Automation SELOGIC Variable 75
155	ASV074	Automation SELOGIC Variable 74
155	ASV073	Automation SELOGIC Variable 73
156	ASV088	Automation SELOGIC Variable 88
156	ASV087	Automation SELOGIC Variable 87
156	ASV086	Automation SELOGIC Variable 86
156	ASV085	Automation SELOGIC Variable 85
156	ASV084	Automation SELOGIC Variable 84
156	ASV083	Automation SELOGIC Variable 83
156	ASV082	Automation SELOGIC Variable 82
156	ASV081	Automation SELOGIC Variable 81
157	ASV096	Automation SELOGIC Variable 96
157	ASV095	Automation SELOGIC Variable 95
157	ASV094	Automation SELOGIC Variable 94
157	ASV093	Automation SELOGIC Variable 93
157	ASV092	Automation SELOGIC Variable 92
157	ASV091	Automation SELOGIC Variable 91
157	ASV090	Automation SELOGIC Variable 90
157	ASV089	Automation SELOGIC Variable 89
158	ASV104	Automation SELOGIC Variable 104
158	ASV103	Automation SELOGIC Variable 103
158	ASV102	Automation SELOGIC Variable 102
158	ASV101	Automation SELOGIC Variable 101
158	ASV100	Automation SELOGIC Variable 100
158	ASV099	Automation SELOGIC Variable 99
158	ASV098	Automation SELOGIC Variable 98
158	ASV097	Automation SELOGIC Variable 97
159	ASV112	Automation SELOGIC Variable 112
159	ASV111	Automation SELOGIC Variable 111
159	ASV110	Automation SELOGIC Variable 110
159	ASV109	Automation SELOGIC Variable 109
159	ASV108	Automation SELOGIC Variable 108

Table A.27 Relay Word Bits: Automation Variables (Sheet 4 of 7)

Row	Name	Description
159	ASV107	Automation SELOGIC Variable 107
159	ASV106	Automation SELOGIC Variable 106
159	ASV105	Automation SELOGIC Variable 105
160	ASV120	Automation SELOGIC Variable 120
160	ASV119	Automation SELOGIC Variable 119
160	ASV118	Automation SELOGIC Variable 118
160	ASV117	Automation SELOGIC Variable 117
160	ASV116	Automation SELOGIC Variable 116
160	ASV115	Automation SELOGIC Variable 115
160	ASV114	Automation SELOGIC Variable 114
160	ASV113	Automation SELOGIC Variable 113
161	ASV128	Automation SELOGIC Variable 128
161	ASV127	Automation SELOGIC Variable 127
161	ASV126	Automation SELOGIC Variable 126
161	ASV125	Automation SELOGIC Variable 125
161	ASV124	Automation SELOGIC Variable 124
161	ASV123	Automation SELOGIC Variable 123
161	ASV122	Automation SELOGIC Variable 122
161	ASV121	Automation SELOGIC Variable 121
162	ASV136	Automation SELOGIC Variable 136
162	ASV135	Automation SELOGIC Variable 135
162	ASV134	Automation SELOGIC Variable 134
162	ASV133	Automation SELOGIC Variable 133
162	ASV132	Automation SELOGIC Variable 132
162	ASV131	Automation SELOGIC Variable 131
162	ASV130	Automation SELOGIC Variable 130
162	ASV129	Automation SELOGIC Variable 129
163	ASV144	Automation SELOGIC Variable 144
163	ASV143	Automation SELOGIC Variable 143
163	ASV142	Automation SELOGIC Variable 142
163	ASV141	Automation SELOGIC Variable 141
163	ASV140	Automation SELOGIC Variable 140
163	ASV139	Automation SELOGIC Variable 139
163	ASV138	Automation SELOGIC Variable 138
163	ASV137	Automation SELOGIC Variable 137
164	ASV152	Automation SELOGIC Variable 152
164	ASV151	Automation SELOGIC Variable 151
164	ASV150	Automation SELOGIC Variable 150
164	ASV149	Automation SELOGIC Variable 149
164	ASV148	Automation SELOGIC Variable 148
164	ASV147	Automation SELOGIC Variable 147

Table A.27 Relay Word Bits: Automation Variables (Sheet 5 of 7)

Row	Name	Description
164	ASV146	Automation SELOGIC Variable 146
164	ASV145	Automation SELOGIC Variable 145
165	ASV160	Automation SELOGIC Variable 160
165	ASV159	Automation SELOGIC Variable 159
165	ASV158	Automation SELOGIC Variable 158
165	ASV157	Automation SELOGIC Variable 157
165	ASV156	Automation SELOGIC Variable 156
165	ASV155	Automation SELOGIC Variable 155
165	ASV154	Automation SELOGIC Variable 154
165	ASV153	Automation SELOGIC Variable 153
166	ASV168	Automation SELOGIC Variable 168
166	ASV167	Automation SELOGIC Variable 167
166	ASV166	Automation SELOGIC Variable 166
166	ASV165	Automation SELOGIC Variable 165
166	ASV164	Automation SELOGIC Variable 164
166	ASV163	Automation SELOGIC Variable 163
166	ASV162	Automation SELOGIC Variable 162
166	ASV161	Automation SELOGIC Variable 161
167	ASV176	Automation SELOGIC Variable 176
167	ASV175	Automation SELOGIC Variable 175
167	ASV174	Automation SELOGIC Variable 174
167	ASV173	Automation SELOGIC Variable 173
167	ASV172	Automation SELOGIC Variable 172
167	ASV171	Automation SELOGIC Variable 171
167	ASV170	Automation SELOGIC Variable 170
167	ASV169	Automation SELOGIC Variable 169
168	ASV184	Automation SELOGIC Variable 184
168	ASV183	Automation SELOGIC Variable 183
168	ASV182	Automation SELOGIC Variable 182
168	ASV181	Automation SELOGIC Variable 181
168	ASV180	Automation SELOGIC Variable 180
168	ASV179	Automation SELOGIC Variable 179
168	ASV178	Automation SELOGIC Variable 178
168	ASV177	Automation SELOGIC Variable 177
169	ASV192	Automation SELOGIC Variable 192
169	ASV191	Automation SELOGIC Variable 191
169	ASV190	Automation SELOGIC Variable 190
169	ASV189	Automation SELOGIC Variable 189
169	ASV188	Automation SELOGIC Variable 188
169	ASV187	Automation SELOGIC Variable 187
169	ASV186	Automation SELOGIC Variable 186

Table A.27 Relay Word Bits: Automation Variables (Sheet 6 of 7)

Row	Name	Description
169	ASV185	Automation SELOGIC Variable 185
170	ASV200	Automation SELOGIC Variable 200
170	ASV199	Automation SELOGIC Variable 199
170	ASV198	Automation SELOGIC Variable 198
170	ASV197	Automation SELOGIC Variable 197
170	ASV196	Automation SELOGIC Variable 196
170	ASV195	Automation SELOGIC Variable 195
170	ASV194	Automation SELOGIC Variable 194
170	ASV193	Automation SELOGIC Variable 193
171	ASV208	Automation SELOGIC Variable 208
171	ASV207	Automation SELOGIC Variable 207
171	ASV206	Automation SELOGIC Variable 206
171	ASV205	Automation SELOGIC Variable 205
171	ASV204	Automation SELOGIC Variable 204
171	ASV203	Automation SELOGIC Variable 203
171	ASV202	Automation SELOGIC Variable 202
171	ASV201	Automation SELOGIC Variable 201
172	ASV216	Automation SELOGIC Variable 216
172	ASV215	Automation SELOGIC Variable 215
172	ASV214	Automation SELOGIC Variable 214
172	ASV213	Automation SELOGIC Variable 213
172	ASV212	Automation SELOGIC Variable 212
172	ASV211	Automation SELOGIC Variable 211
172	ASV210	Automation SELOGIC Variable 210
172	ASV209	Automation SELOGIC Variable 209
173	ASV224	Automation SELOGIC Variable 224
173	ASV223	Automation SELOGIC Variable 223
173	ASV222	Automation SELOGIC Variable 222
173	ASV221	Automation SELOGIC Variable 221
173	ASV220	Automation SELOGIC Variable 220
173	ASV219	Automation SELOGIC Variable 219
173	ASV218	Automation SELOGIC Variable 218
173	ASV217	Automation SELOGIC Variable 217
174	ASV232	Automation SELOGIC Variable 232
174	ASV231	Automation SELOGIC Variable 231
174	ASV230	Automation SELOGIC Variable 230
174	ASV229	Automation SELOGIC Variable 229
174	ASV228	Automation SELOGIC Variable 228
174	ASV227	Automation SELOGIC Variable 227
174	ASV226	Automation SELOGIC Variable 226
174	ASV225	Automation SELOGIC Variable 225

Table A.27 Relay Word Bits: Automation Variables (Sheet 7 of 7)

Row	Name	Description
175	ASV240	Automation SELOGIC Variable 240
175	ASV239	Automation SELOGIC Variable 239
175	ASV238	Automation SELOGIC Variable 238
175	ASV237	Automation SELOGIC Variable 237
175	ASV236	Automation SELOGIC Variable 236
175	ASV235	Automation SELOGIC Variable 235
175	ASV234	Automation SELOGIC Variable 234
175	ASV233	Automation SELOGIC Variable 233
176	ASV248	Automation SELOGIC Variable 248
176	ASV247	Automation SELOGIC Variable 247
176	ASV246	Automation SELOGIC Variable 246
176	ASV245	Automation SELOGIC Variable 245
176	ASV244	Automation SELOGIC Variable 244
176	ASV243	Automation SELOGIC Variable 243
176	ASV242	Automation SELOGIC Variable 242
176	ASV241	Automation SELOGIC Variable 241
177	ASV256	Automation SELOGIC Variable 256
177	ASV255	Automation SELOGIC Variable 255
177	ASV254	Automation SELOGIC Variable 254
177	ASV253	Automation SELOGIC Variable 253
177	ASV252	Automation SELOGIC Variable 252
177	ASV251	Automation SELOGIC Variable 251
177	ASV250	Automation SELOGIC Variable 250
177	ASV249	Automation SELOGIC Variable 249

Table A.28 Relay Word Bits: Automation Latches (Sheet 1 of 2)

Row	Name	Description
178	ALT08	Automation Latch 8
178	ALT07	Automation Latch 7
178	ALT06	Automation Latch 6
178	ALT05	Automation Latch 5
178	ALT04	Automation Latch 4
178	ALT03	Automation Latch 3
178	ALT02	Automation Latch 2
178	ALT01	Automation Latch 1
179	ALT16	Automation Latch 16
179	ALT15	Automation Latch 15
179	ALT14	Automation Latch 14
179	ALT13	Automation Latch 13
179	ALT12	Automation Latch 12
179	ALT11	Automation Latch 11

Table A.28 Relay Word Bits: Automation Latches (Sheet 2 of 2)

Row	Name	Description
179	ALT10	Automation Latch 10
179	ALT09	Automation Latch 9
180	ALT24	Automation Latch 24
180	ALT23	Automation Latch 23
180	ALT22	Automation Latch 22
180	ALT21	Automation Latch 21
180	ALT20	Automation Latch 20
180	ALT19	Automation Latch 19
180	ALT18	Automation Latch 18
180	ALT17	Automation Latch 17
181	ALT32	Automation Latch 32
181	ALT31	Automation Latch 31
181	ALT30	Automation Latch 30
181	ALT29	Automation Latch 29
181	ALT28	Automation Latch 28
181	ALT27	Automation Latch 27
181	ALT26	Automation Latch 26
181	ALT25	Automation Latch 25

Table A.29 Relay Word Bits: Automation Sequencing Timers (Sheet 1 of 3)

Row	Name	Description
182	AST08Q	Automation Sequencing Timer 8 output
182	AST07Q	Automation Sequencing Timer 7 output
182	AST06Q	Automation Sequencing Timer 6 output
182	AST05Q	Automation Sequencing Timer 5 output
182	AST04Q	Automation Sequencing Timer 4 output
182	AST03Q	Automation Sequencing Timer 3 output
182	AST02Q	Automation Sequencing Timer 2 output
182	AST01Q	Automation Sequencing Timer 1 output
183	AST16Q	Automation Sequencing Timer 16 output
183	AST15Q	Automation Sequencing Timer 15 output
183	AST14Q	Automation Sequencing Timer 14 output
183	AST13Q	Automation Sequencing Timer 13 output
183	AST12Q	Automation Sequencing Timer 12 output
183	AST11Q	Automation Sequencing Timer 11 output
183	AST10Q	Automation Sequencing Timer 10 output
183	AST09Q	Automation Sequencing Timer 9 output
184	AST24Q	Automation Sequencing Timer 24 output
184	AST23Q	Automation Sequencing Timer 23 output
184	AST22Q	Automation Sequencing Timer 22 output
184	AST21Q	Automation Sequencing Timer 21 output

Table A.29 Relay Word Bits: Automation Sequencing Timers (Sheet 2 of 3)

Row	Name	Description
184	AST20Q	Automation Sequencing Timer 20 output
184	AST19Q	Automation Sequencing Timer 19 output
184	AST18Q	Automation Sequencing Timer 18 output
184	AST17Q	Automation Sequencing Timer 17 output
185	AST32Q	Automation Sequencing Timer 32 output
185	AST31Q	Automation Sequencing Timer 31 output
185	AST30Q	Automation Sequencing Timer 30 output
185	AST29Q	Automation Sequencing Timer 29 output
185	AST28Q	Automation Sequencing Timer 28 output
185	AST27Q	Automation Sequencing Timer 27 output
185	AST26Q	Automation Sequencing Timer 26 output
185	AST25Q	Automation Sequencing Timer 25 output
186	AST08R	Automation Sequencing Timer 8 reset (SELOGIC control equation)
186	AST07R	Automation Sequencing Timer 7 reset (SELOGIC control equation)
186	AST06R	Automation Sequencing Timer 6 reset (SELOGIC control equation)
186	AST05R	Automation Sequencing Timer 5 reset (SELOGIC control equation)
186	AST04R	Automation Sequencing Timer 4 reset (SELOGIC control equation)
186	AST03R	Automation Sequencing Timer 3 reset (SELOGIC control equation)
186	AST02R	Automation Sequencing Timer 2 reset (SELOGIC control equation)
186	AST01R	Automation Sequencing Timer 1 reset (SELOGIC control equation)
187	AST16R	Automation Sequencing Timer 16 reset (SELOGIC control equation)
187	AST15R	Automation Sequencing Timer 15 reset (SELOGIC control equation)
187	AST14R	Automation Sequencing Timer 14 reset (SELOGIC control equation)
187	AST13R	Automation Sequencing Timer 13 reset (SELOGIC control equation)
187	AST12R	Automation Sequencing Timer 12 reset (SELOGIC control equation)
187	AST11R	Automation Sequencing Timer 11 reset (SELOGIC control equation)
187	AST10R	Automation Sequencing Timer 10 reset (SELOGIC control equation)
187	AST09R	Automation Sequencing Timer 9 reset (SELOGIC control equation)
188	AST24R	Automation Sequencing Timer 24 reset (SELOGIC control equation)

Table A.29 Relay Word Bits: Automation Sequencing Timers (Sheet 3 of 3)

Row	Name	Description
188	AST23R	Automation Sequencing Timer 23 reset (SELOGIC control equation)
188	AST22R	Automation Sequencing Timer 22 reset (SELOGIC control equation)
188	AST21R	Automation Sequencing Timer 21 reset (SELOGIC control equation)
188	AST20R	Automation Sequencing Timer 20 reset (SELOGIC control equation)
188	AST19R	Automation Sequencing Timer 19 reset (SELOGIC control equation)
188	AST18R	Automation Sequencing Timer 18 reset (SELOGIC control equation)
188	AST17R	Automation Sequencing Timer 17 reset (SELOGIC control equation)
189	AST32R	Automation Sequencing Timer 32 reset (SELOGIC control equation)
189	AST31R	Automation Sequencing Timer 31 reset (SELOGIC control equation)
189	AST30R	Automation Sequencing Timer 30 reset (SELOGIC control equation)
189	AST29R	Automation Sequencing Timer 29 reset (SELOGIC control equation)
189	AST28R	Automation Sequencing Timer 28 reset (SELOGIC control equation)
189	AST27R	Automation Sequencing Timer 27 reset (SELOGIC control equation)
189	AST26R	Automation Sequencing Timer 26 reset (SELOGIC control equation)
189	AST25R	Automation Sequencing Timer 25 reset (SELOGIC control equation)

Table A.30 Relay Word Bits: Automation Counters (Sheet 1 of 3)

Row	Name	Description
190	ACN08Q	Automation Counter 8 output
190	ACN07Q	Automation Counter 7 output
190	ACN06Q	Automation Counter 6 output
190	ACN05Q	Automation Counter 5 output
190	ACN04Q	Automation Counter 4 output
190	ACN03Q	Automation Counter 3 output
190	ACN02Q	Automation Counter 2 output
190	ACN01Q	Automation Counter 1 output
191	ACN16Q	Automation Counter 16 output
191	ACN15Q	Automation Counter 15 output
191	ACN14Q	Automation Counter 14 output
191	ACN13Q	Automation Counter 13 output
191	ACN12Q	Automation Counter 12 output

Table A.30 Relay Word Bits: Automation Counters (Sheet 2 of 3)

Row	Name	Description
191	ACN11Q	Automation Counter 11 output
191	ACN10Q	Automation Counter 10 output
191	ACN09Q	Automation Counter 9 output
192	ACN24Q	Automation Counter 24 output
192	ACN23Q	Automation Counter 23 output
192	ACN22Q	Automation Counter 22 output
192	ACN21Q	Automation Counter 21 output
192	ACN20Q	Automation Counter 20 output
192	ACN19Q	Automation Counter 19 output
192	ACN18Q	Automation Counter 18 output
192	ACN17Q	Automation Counter 17 output
193	ACN32Q	Automation Counter 32 output
193	ACN31Q	Automation Counter 31 output
193	ACN30Q	Automation Counter 30 output
193	ACN29Q	Automation Counter 29 output
193	ACN28Q	Automation Counter 28 output
193	ACN27Q	Automation Counter 27 output
193	ACN26Q	Automation Counter 26 output
193	ACN25Q	Automation Counter 25 output
194	ACN08R	Automation Counter 8 reset (SELOGIC control equation)
194	ACN07R	Automation Counter 7 reset (SELOGIC control equation)
194	ACN06R	Automation Counter 6 reset (SELOGIC control equation)
194	ACN05R	Automation Counter 5 reset (SELOGIC control equation)
194	ACN04R	Automation Counter 4 reset (SELOGIC control equation)
194	ACN03R	Automation Counter 3 reset (SELOGIC control equation)
194	ACN02R	Automation Counter 2 reset (SELOGIC control equation)
194	ACN01R	Automation Counter 1 reset (SELOGIC control equation)
195	ACN16R	Automation Counter 16 reset (SELOGIC control equation)
195	ACN15R	Automation Counter 15 reset (SELOGIC control equation)
195	ACN14R	Automation Counter 14 reset (SELOGIC control equation)
195	ACN13R	Automation Counter 13 reset (SELOGIC control equation)
195	ACN12R	Automation Counter 12 reset (SELOGIC control equation)
195	ACN11R	Automation Counter 11 reset (SELOGIC control equation)
195	ACN10R	Automation Counter 10 reset (SELOGIC control equation)
195	ACN09R	Automation Counter 9 reset (SELOGIC control equation)
196	ACN24R	Automation Counter 24 reset (SELOGIC control equation)
196	ACN23R	Automation Counter 23 reset (SELOGIC control equation)
196	ACN22R	Automation Counter 22 reset (SELOGIC control equation)
196	ACN21R	Automation Counter 21 reset (SELOGIC control equation)
196	ACN20R	Automation Counter 20 reset (SELOGIC control equation)
196	ACN19R	Automation Counter 19 reset (SELOGIC control equation)

Table A.30 Relay Word Bits: Automation Counters (Sheet 3 of 3)

Row	Name	Description
196	ACN18R	Automation Counter 18 reset (SELOGIC control equation)
196	ACN17R	Automation Counter 17 reset (SELOGIC control equation)
197	ACN32R	Automation Counter 32 reset (SELOGIC control equation)
197	ACN31R	Automation Counter 31 reset (SELOGIC control equation)
197	ACN30R	Automation Counter 30 reset (SELOGIC control equation)
197	ACN29R	Automation Counter 29 reset (SELOGIC control equation)
197	ACN28R	Automation Counter 28 reset (SELOGIC control equation)
197	ACN27R	Automation Counter 27 reset (SELOGIC control equation)
197	ACN26R	Automation Counter 26 reset (SELOGIC control equation)
197	ACN25R	Automation Counter 25 reset (SELOGIC control equation)

Table A.31 Relay Word Bits: SELOGIC Control Equation Error and Status (Sheet 1 of 2)

Row	Name	Description
198	PUNRLBL	Protection SELOGIC control equation unresolved label
198	PFRTEX	Protection SELOGIC control equation first execution
198	MATHERR	SELOGIC control equation math error
198	*	Reserved
198	*	Reserved
198	*	Reserved
198	*	Reserved
198	*	Reserved
199	*	Reserved
199	*	Reserved
199	*	Reserved
199	*	Reserved
199	*	Reserved
199	*	Reserved
199	*	Reserved
200	AUNRLBL	Automation SELOGIC control equation unresolved label
200	AFRTEXP	Automation SELOGIC control equation first execution after Protection Settings Change, Group Switch, or Source Switch Selection
200	AFRTEXA	Automation SELOGIC control equation first execution after Automation Settings Change
200	*	Reserved
200	*	Reserved
200	*	Reserved
200	*	Reserved
200	*	Reserved
201	*	Reserved

Table A.31 Relay Word Bits: SELOGIC Control Equation Error and Status (Sheet 2 of 2)

Row	Name	Description
201	*	Reserved
201	*	Reserved
201	*	Reserved
201	*	Reserved
201	*	Reserved
201	*	Reserved
201	*	Reserved

Table A.32 Relay Word Bits: Relay Alarms

Row	Name	Description
202	SALARM	Software alarm
202	HALARM	Hardware alarm
202	BADPASS	Invalid password attempt alarm
202	CCALARM	Communications card status alarm
202	CCOK	Indicates connected SEL-2702 is operating normally
202	*	Reserved
202	*	Reserved
202	*	Reserved
202	*	Reserved
203–220	*	Reserved

Table A.33 Relay Word Bits: Time and Date Elements

Row	Name	Description
221	*	Reserved
221	*	Reserved
221	TIRIG	Assert while time is based on IRIG for both mark and value
221	TUPDH	Assert if update source is high-accuracy time source
221	TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized
221	TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements
221	PMDOK	Assert if data acquisition system is operating correctly
221	FREQOK	Assert if relay is estimating frequency

Table A.34 Relay Word Bits: Output Elements

Row	Name	Description
222	OUT108	Main Board Output 8
222	OUT107	Main Board Output 7
222	OUT106	Main Board Output 6
222	OUT105	Main Board Output 5
222	OUT104	Main Board Output 4
222	OUT103	Main Board Output 3
222	OUT102	Main Board Output 2
222	OUT101	Main Board Output 1
223	OUT208	Optional I/O Board 1 Output 8 (if installed)
223	OUT207	Optional I/O Board 1 Output 7 (if installed)
223	OUT206	Optional I/O Board 1 Output 6 (if installed)
223	OUT205	Optional I/O Board 1 Output 5 (if installed)
223	OUT204	Optional I/O Board 1 Output 4 (if installed)
223	OUT203	Optional I/O Board 1 Output 3 (if installed)
223	OUT202	Optional I/O Board 1 Output 2 (if installed)
223	OUT201	Optional I/O Board 1 Output 1 (if installed)
224	OUT216	Optional I/O Board 1 Output 16 (if installed)
224	OUT215	Optional I/O Board 1 Output 15 (if installed)
224	OUT214	Optional I/O Board 1 Output 14 (if installed)
224	OUT213	Optional I/O Board 1 Output 13 (if installed)
224	OUT212	Optional I/O Board 1 Output 12 (if installed)
224	OUT211	Optional I/O Board 1 Output 11 (if installed)
224	OUT210	Optional I/O Board 1 Output 10 (if installed)
224	OUT209	Optional I/O Board 1 Output 9 (if installed)
225	OUT308	Optional I/O Board 2 Output 8 (if installed)
225	OUT307	Optional I/O Board 2 Output 7 (if installed)
225	OUT306	Optional I/O Board 2 Output 6 (if installed)
225	OUT305	Optional I/O Board 2 Output 5 (if installed)
225	OUT304	Optional I/O Board 2 Output 4 (if installed)
225	OUT303	Optional I/O Board 2 Output 3 (if installed)
225	OUT302	Optional I/O Board 2 Output 2 (if installed)
225	OUT301	Optional I/O Board 2 Output 1 (if installed)
226	OUT316	Optional I/O Board 2 Output 16 (if installed)
226	OUT315	Optional I/O Board 2 Output 15 (if installed)
226	OUT314	Optional I/O Board 2 Output 14 (if installed)
226	OUT313	Optional I/O Board 2 Output 13 (if installed)
226	OUT312	Optional I/O Board 2 Output 12 (if installed)
226	OUT311	Optional I/O Board 2 Output 11 (if installed)
226	OUT310	Optional I/O Board 2 Output 10 (if installed)
226	OUT309	Optional I/O Board 2 Output 9 (if installed)

Table A.35 Relay Word Bits: Pushbutton Elements

Row	Name	Description
227	PB1	Pushbutton 1
227	PB2	Pushbutton 2
227	PB3	Pushbutton 3
227	PB4	Pushbutton 4
227	PB5	Pushbutton 5
227	PB6	Pushbutton 6
227	PB7	Pushbutton 7
227	PB8	Pushbutton 8
228	PB1_PUL	Pushbutton 1 pulse (on for one processing interval when button is pushed)
228	PB2_PUL	Pushbutton 2 pulse (on for one processing interval when button is pushed)
228	PB3_PUL	Pushbutton 3 pulse (on for one processing interval when button is pushed)
228	PB4_PUL	Pushbutton 4 pulse (on for one processing interval when button is pushed)
228	PB5_PUL	Pushbutton 5 pulse (on for one processing interval when button is pushed)
228	PB6_PUL	Pushbutton 6 pulse (on for one processing interval when button is pushed)
228	PB7_PUL	Pushbutton 7 pulse (on for one processing interval when button is pushed)
228	PB8_PUL	Pushbutton 8 pulse (on for one processing interval when button is pushed)
229	PB1_LED	Pushbutton 1 LED
229	PB2_LED	Pushbutton 2 LED
229	PB3_LED	Pushbutton 3 LED
229	PB4_LED	Pushbutton 4 LED
229	PB5_LED	Pushbutton 5 LED
229	PB6_LED	Pushbutton 6 LED
229	PB7_LED	Pushbutton 7 LED
229	PB8_LED	Pushbutton 8 LED

Table A.36 Relay Word Bits: Data Reset Bits

Row	Name	Description
230	RST_DEM	Reset demand metering
230	RST_PDM	Reset peak demand metering
230	RST_ENE	Reset energy metering data
230	RSTMML	Reset max/min line (SELOGIC control equation)
230	RSTMMB1	Reset max/min Circuit Breaker 1 (SELOGIC control equation)
230	RSTMMB2	Reset max/min Circuit Breaker 2 (SELOGIC control equation)
230	RST_BK1	Reset Circuit Breaker 1 monitor
230	RST_BK2	Reset Circuit Breaker 2 monitor
231	RST_BAT	Reset battery monitoring (SELOGIC control equation)
231	RSTFLOC	Reset fault locator (SELOGIC control equation)
231	RSTDNPE	Reset DNP Fault Summary Data (SELOGIC control equation)
231	*	Reserved
231	*	Reserved
231	*	Reserved
231	*	Reserved
231	*	Reserved

Table A.37 Relay Word Bits: Target Logic Bits

Row	Name	Description
232	PHASE_A	Indicates an A-phase fault
232	PHASE_B	Indicates a B-phase fault
232	PHASE_C	Indicates a C-phase fault
232	GROUND	Indicates a ground fault
232	BK1BFT	Indicates Circuit Breaker 1 breaker failure trip
232	BK2BFT	Indicates Circuit Breaker 2 breaker failure trip
232	TRGTR	Reset all active target relay words
232	RSTTRGT	Target reset (SELOGIC control equation)

Table A.38 Relay Word Bits: MIRRORED BITS (Sheet 1 of 2)

Row	Name	Description
233	RMB8A	Channel A Receive MIRRORED BIT 8
233	RMB7A	Channel A Receive MIRRORED BIT 7
233	RMB6A	Channel A Receive MIRRORED BIT 6
233	RMB5A	Channel A Receive MIRRORED BIT 5
233	RMB4A	Channel A Receive MIRRORED BIT 4
233	RMB3A	Channel A Receive MIRRORED BIT 3
233	RMB2A	Channel A Receive MIRRORED BIT 2
233	RMB1A	Channel A Receive MIRRORED BIT 1
234	TMB8A	Channel A Transmit MIRRORED BIT 8
234	TMB7A	Channel A Transmit MIRRORED BIT 7
234	TMB6A	Channel A Transmit MIRRORED BIT 6
234	TMB5A	Channel A Transmit MIRRORED BIT 5
234	TMB4A	Channel A Transmit MIRRORED BIT 4
234	TMB3A	Channel A Transmit MIRRORED BIT 3
234	TMB2A	Channel A Transmit MIRRORED BIT 2
234	TMB1A	Channel A Transmit MIRRORED BIT 1
235	RMB8B	Channel B Receive MIRRORED BIT 8
235	RMB7B	Channel B Receive MIRRORED BIT 7
235	RMB6B	Channel B Receive MIRRORED BIT 6
235	RMB5B	Channel B Receive MIRRORED BIT 5
235	RMB4B	Channel B Receive MIRRORED BIT 4
235	RMB3B	Channel B Receive MIRRORED BIT 3
235	RMB2B	Channel B Receive MIRRORED BIT 2
235	RMB1B	Channel B Receive MIRRORED BIT 1
236	TMB8B	Channel B Transmit MIRRORED BIT 8
236	TMB7B	Channel B Transmit MIRRORED BIT 7
236	TMB6B	Channel B Transmit MIRRORED BIT 6
236	TMB5B	Channel B Transmit MIRRORED BIT 5
236	TMB4B	Channel B Transmit MIRRORED BIT 4
236	TMB3B	Channel B Transmit MIRRORED BIT 3
236	TMB2B	Channel B Transmit MIRRORED BIT 2
236	TMB1B	Channel B Transmit MIRRORED BIT 1
237	ROKA	Normal MIRRORED BITS communications Channel A status while not in loopback mode
237	RBADA	Outage too long on MIRRORED BITS communications Channel A
237	CBADA	Unavailability threshold exceeded for MIRRORED BITS communications Channel A
237	LBOKA	Normal MIRRORED BITS communications Channel A status while in loopback mode
237	ANOKA	Analog transfer OK on MIRRORED BITS communications Channel A

Table A.38 Relay Word Bits: MIRRORED BITS (Sheet 2 of 2)

Row	Name	Description
237	DOKA	Normal MIRRORED BITS communications Channel A status
237	*	Reserved
237	*	Reserved
238	ROKB	Normal MIRRORED BITS communications Channel B status while not in loopback mode
238	RBADB	Outage too long on MIRRORED BITS communications Channel B
238	CBADB	Unavailability threshold exceeded for MIRRORED BITS communications Channel B
238	LBOKB	Normal MIRRORED BITS communications Channel B status while in loopback mode
238	ANOKB	Analog transfer OK on MIRRORED BITS communications Channel B
238	DOKB	Normal MIRRORED BITS communications Channel B status
238	*	Reserved
238	*	Reserved

Table A.39 Relay Word Bits: Test Bits

Row	Name	Description
239	TESTDNP	DNP test bit
239	TESTDB	Communications card database test bit
239	TESTFM	Fast meter test bit
239	TESTPUL	Pulse test bit
239	*	Reserved
239	*	Reserved
239	*	Reserved
239	*	Reserved

Table A.40 Relay Word Bits: Communications Card Input Points (Sheet 1 of 4)

Row	Name	Description
240	CCIN121	Communications Card Input Point 121
240	CCIN122	Communications Card Input Point 122
240	CCIN123	Communications Card Input Point 123
240	CCIN124	Communications Card Input Point 124
240	CCIN125	Communications Card Input Point 125
240	CCIN126	Communications Card Input Point 126
240	CCIN127	Communications Card Input Point 127
240	CCIN128	Communications Card Input Point 128
241	CCIN113	Communications Card Input Point 113
241	CCIN114	Communications Card Input Point 114
241	CCIN115	Communications Card Input Point 115
241	CCIN116	Communications Card Input Point 116

Table A.40 Relay Word Bits: Communications Card Input Points
(Sheet 2 of 4)

Row	Name	Description
241	CCIN117	Communications Card Input Point 117
241	CCIN118	Communications Card Input Point 118
241	CCIN119	Communications Card Input Point 119
241	CCIN120	Communications Card Input Point 120
242	CCIN105	Communications Card Input Point 105
242	CCIN106	Communications Card Input Point 106
242	CCIN107	Communications Card Input Point 107
242	CCIN108	Communications Card Input Point 108
242	CCIN109	Communications Card Input Point 109
242	CCIN110	Communications Card Input Point 110
242	CCIN111	Communications Card Input Point 111
242	CCIN112	Communications Card Input Point 112
243	CCIN097	Communications Card Input Point 97
243	CCIN098	Communications Card Input Point 98
243	CCIN099	Communications Card Input Point 99
243	CCIN100	Communications Card Input Point 100
243	CCIN101	Communications Card Input Point 101
243	CCIN102	Communications Card Input Point 102
243	CCIN103	Communications Card Input Point 103
243	CCIN104	Communications Card Input Point 104
244	CCIN089	Communications Card Input Point 89
244	CCIN090	Communications Card Input Point 90
244	CCIN091	Communications Card Input Point 91
244	CCIN092	Communications Card Input Point 92
244	CCIN093	Communications Card Input Point 93
244	CCIN094	Communications Card Input Point 94
244	CCIN095	Communications Card Input Point 95
244	CCIN096	Communications Card Input Point 96
245	CCIN081	Communications Card Input Point 81
245	CCIN082	Communications Card Input Point 82
245	CCIN083	Communications Card Input Point 83
245	CCIN084	Communications Card Input Point 84
245	CCIN085	Communications Card Input Point 85
245	CCIN086	Communications Card Input Point 86
245	CCIN087	Communications Card Input Point 87
245	CCIN088	Communications Card Input Point 88
246	CCIN073	Communications Card Input Point 73
246	CCIN074	Communications Card Input Point 74
246	CCIN075	Communications Card Input Point 75
246	CCIN076	Communications Card Input Point 76

Table A.40 Relay Word Bits: Communications Card Input Points
(Sheet 3 of 4)

Row	Name	Description
246	CCIN077	Communications Card Input Point 77
246	CCIN078	Communications Card Input Point 78
246	CCIN079	Communications Card Input Point 79
246	CCIN080	Communications Card Input Point 80
247	CCIN065	Communications Card Input Point 65
247	CCIN066	Communications Card Input Point 66
247	CCIN067	Communications Card Input Point 67
247	CCIN068	Communications Card Input Point 68
247	CCIN069	Communications Card Input Point 69
247	CCIN070	Communications Card Input Point 70
247	CCIN071	Communications Card Input Point 71
247	CCIN072	Communications Card Input Point 72
248	CCIN057	Communications Card Input Point 57
248	CCIN058	Communications Card Input Point 58
248	CCIN059	Communications Card Input Point 59
248	CCIN060	Communications Card Input Point 60
248	CCIN061	Communications Card Input Point 61
248	CCIN062	Communications Card Input Point 62
248	CCIN063	Communications Card Input Point 63
248	CCIN064	Communications Card Input Point 64
249	CCIN049	Communications Card Input Point 49
249	CCIN050	Communications Card Input Point 50
249	CCIN051	Communications Card Input Point 51
249	CCIN052	Communications Card Input Point 52
249	CCIN053	Communications Card Input Point 53
249	CCIN054	Communications Card Input Point 54
249	CCIN055	Communications Card Input Point 55
249	CCIN056	Communications Card Input Point 56
250	CCIN041	Communications Card Input Point 41
250	CCIN042	Communications Card Input Point 42
250	CCIN043	Communications Card Input Point 43
250	CCIN044	Communications Card Input Point 44
250	CCIN045	Communications Card Input Point 45
250	CCIN046	Communications Card Input Point 46
250	CCIN047	Communications Card Input Point 47
250	CCIN048	Communications Card Input Point 48
251	CCIN033	Communications Card Input Point 33
251	CCIN034	Communications Card Input Point 34
251	CCIN035	Communications Card Input Point 35
251	CCIN036	Communications Card Input Point 36

Table A.40 Relay Word Bits: Communications Card Input Points
(Sheet 4 of 4)

Row	Name	Description
251	CCIN037	Communications Card Input Point 37
251	CCIN038	Communications Card Input Point 38
251	CCIN039	Communications Card Input Point 39
251	CCIN040	Communications Card Input Point 40
252	CCIN025	Communications Card Input Point 25
252	CCIN026	Communications Card Input Point 26
252	CCIN027	Communications Card Input Point 27
252	CCIN028	Communications Card Input Point 28
252	CCIN029	Communications Card Input Point 29
252	CCIN030	Communications Card Input Point 30
252	CCIN031	Communications Card Input Point 31
252	CCIN032	Communications Card Input Point 32
253	CCIN017	Communications Card Input Point 17
253	CCIN018	Communications Card Input Point 18
253	CCIN019	Communications Card Input Point 19
253	CCIN020	Communications Card Input Point 20
253	CCIN021	Communications Card Input Point 21
253	CCIN022	Communications Card Input Point 22
253	CCIN023	Communications Card Input Point 23
253	CCIN024	Communications Card Input Point 24
254	CCIN009	Communications Card Input Point 9
254	CCIN010	Communications Card Input Point 10
254	CCIN011	Communications Card Input Point 11
254	CCIN012	Communications Card Input Point 12
254	CCIN013	Communications Card Input Point 13
254	CCIN014	Communications Card Input Point 14
254	CCIN015	Communications Card Input Point 15
254	CCIN016	Communications Card Input Point 16
255	CCIN001	Communications Card Input Point 1
255	CCIN002	Communications Card Input Point 2
255	CCIN003	Communications Card Input Point 3
255	CCIN004	Communications Card Input Point 4
255	CCIN005	Communications Card Input Point 5
255	CCIN006	Communications Card Input Point 6
255	CCIN007	Communications Card Input Point 7
255	CCIN008	Communications Card Input Point 8

Table A.41 Relay Word Bits: Communications Card Output Points

Row	Name	Description
256	CCOUT25	Communications Card Output Point 25
256	CCOUT26	Communications Card Output Point 26
256	CCOUT27	Communications Card Output Point 27
256	CCOUT28	Communications Card Output Point 28
256	CCOUT29	Communications Card Output Point 29
256	CCOUT30	Communications Card Output Point 30
256	CCOUT31	Communications Card Output Point 31
256	CCOUT32	Communications Card Output Point 32
257	CCOUT17	Communications Card Output Point 17
257	CCOUT18	Communications Card Output Point 18
257	CCOUT19	Communications Card Output Point 19
257	CCOUT20	Communications Card Output Point 20
257	CCOUT21	Communications Card Output Point 21
257	CCOUT22	Communications Card Output Point 22
257	CCOUT23	Communications Card Output Point 23
257	CCOUT24	Communications Card Output Point 24
258	CCOUT09	Communications Card Output Point 9
258	CCOUT10	Communications Card Output Point 10
258	CCOUT11	Communications Card Output Point 11
258	CCOUT12	Communications Card Output Point 12
258	CCOUT13	Communications Card Output Point 13
258	CCOUT14	Communications Card Output Point 14
258	CCOUT15	Communications Card Output Point 15
258	CCOUT16	Communications Card Output Point 16
259	CCOUT01	Communications Card Output Point 1
259	CCOUT02	Communications Card Output Point 2
259	CCOUT03	Communications Card Output Point 3
259	CCOUT04	Communications Card Output Point 4
259	CCOUT05	Communications Card Output Point 5
259	CCOUT06	Communications Card Output Point 6
259	CCOUT07	Communications Card Output Point 7
259	CCOUT08	Communications Card Output Point 8

Table A.42 Relay Word Bits: Communications Card Status Points

Row	Name	Description
260	CCSTA01	Card Status Register Bit 15—Spare
260	CCSTA02	Card Status Register Bit 14—Spare
260	CCSTA03	Card Status Register Bit 13—Spare
260	CCSTA04	Card Status Register Bit 12—Spare
260	CCSTA05	Card Status Register Bit 11—Spare
260	CCSTA06	Card Status Register Bit 10—Spare
260	CCSTA07	Card Status Register Bit 9—Spare
260	CCSTA08	Card Status Register Bit 8—Spare
261	CCSTA09	Card Status Register Bit 7—Low Resource bit
261	CCSTA10	Card Status Register Bit 6—Alarm bit
261	CCSTA11	Card Status Register Bit 5—Settings selection
261	CCSTA12	Card Status Register Bit 4—Running in SELBOOT
261	CCSTA13	Card Status Register Bit 3—Settings error
261	CCSTA14	Card Status Register Bit 2—Network port active
261	CCSTA15	Card Status Register Bit 1—Self-test failure
261	CCSTA16	Card Status Register Bit 0—Alive and initialized
262	CCSTA17	Self Test Failure Bit 15—Spare
262	CCSTA18	Self Test Failure Bit 14—Spare
262	CCSTA19	Self Test Failure Bit 13—SLBT Incompatible
262	CCSTA20	Self Test Failure Bit 12—No Host Response to Interrupt
262	CCSTA21	Self Test Failure Bit 11—Active Ethernet Port
262	CCSTA22	Self Test Failure Bit 10—Host Access Counter Error
262	CCSTA23	Self Test Failure Bit 9—Host Access Counter Warning
262	CCSTA24	Self Test Failure Bit 8—Host Incompatible
263	CCSTA25	Self Test Failure Bit 7—Host Commanded Read/Write Test Results
263	CCSTA26	Self Test Failure Bit 6—Shared Memory Interface Failure
263	CCSTA27	Self Test Failure Bit 5—Configuration
263	CCSTA28	Self Test Failure Bit 4—Executable Storage Block
263	CCSTA29	Self Test Failure Bit 3—Settings Check
263	CCSTA30	Self Test Failure Bit 2—SLBT Code Flash Check
263	CCSTA31	Self Test Failure Bit 1—EXE Code Flash Check
263	CCSTA32	Self Test Failure Bit 0—RAM Check

Table A.43 Relay Word Bits: Fast SER Enable Bits

Row	Bit Name	Description
264	FSERP1	Fast SER enabled for Serial Port 1
264	FSERP2	Fast SER enabled for Serial Port 2
264	FSERP3	Fast SER enabled for Serial Port 3
264	FSERPF	Fast SER enabled for Serial Port F
264	*	Reserved
264	*	Reserved
264	*	Reserved
264	*	Reserved

Table A.44 Relay Word Bits: Source Selection Elements

Row	Bit Name	Description
265	ALTI	Alternate current source (SELOGIC control equation)
265	ALTV	Alternate voltage source (SELOGIC control equation)
265	ALTS2	Alternate synchronism source for Circuit Breaker 2
265	DELAY	Local current and voltage source delay logic
265	*	Reserved
265	*	Reserved
265	*	Reserved
265	*	Reserved
266–271	*	Reserved

Table A.45 Synchrophasor Trigger SELOGIC Equations[a]

Row	Bit Name	Description
272	PMTRIG	Trigger (SELOGIC control equation)
272	TREA4	Trigger Reason Bit 4 (SELOGIC Equation)
272	TREA3	Trigger Reason Bit 3 (SELOGIC Equation)
272	TREA2	Trigger Reason Bit 2 (SELOGIC Equation)
272	TREA1	Trigger Reason Bit 1 (SELOGIC Equation)
272	*	Reserved
272	*	Reserved
272	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved

[a] These bits are sent as part of the IEEE C37.118 format synchrophasor data frame.

Table A.46 DNP Event Mode Control

Row	Bit Name	Description
274	EVELOCK	Lock DNP Events
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved

Table A.47 Time and Synchronization Control Bits[a] (Sheet 1 of 2)

Row	Bit Name	Description
276	YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted[b]
276	YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted[b]
276	YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted[b]
276	YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted[b]
276	YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted[b]
276	YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted[b]
276	YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted[b]
276	YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted[b]
277	*	
277	*	
277	TUTCH	Offset half-hour from UTC time, binary, add 0.5 if asserted
277	TUTC8	Offset hours from UTC time, binary, add 8 if asserted
277	TUTC4	Offset hours from UTC time, binary, add 4 if asserted
277	TUTC2	Offset hours from UTC time, binary, add 2 if asserted
277	TUTC1	Offset hours from UTC time, binary, add 1 if asserted
277	TUTCS	Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise

Table A.47 Time and Synchronization Control Bits[a] (Sheet 2 of 2)

Row	Bit Name	Description
278	DST	Daylight Savings Time
278	DSTP	Daylight Savings Time Pending
278	LPSEC	Direction of the upcoming leap second. During the time that LPSEC is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.
278	LPSECP	Leap second pending
278	TQUAL8	Time quality, binary, add 8 when asserted[c]
278	TQUAL4	Time quality, binary, add 4 when asserted[c]
278	TQUAL2	Time quality, binary, add 2 when asserted[c]
278	TQUAL1	Time quality, binary, add 1 when asserted[c]
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved

[a] These Relay Word bits are valid when an IRIG-B timekeeping source is connected that includes the IEEE C37.118 IRIG-B control bits in the data stream. Otherwise, these Relay Word bits are indeterminate. When the SEL-451 is not connected to an IRIG source, these Relay Word bits are deasserted, except for TQUAL8-TQUAL1, which are asserted.
[b] The SEL-451 does not use the year information obtained from IRIG-B to set the internal clock year value.
[c] See IRIG-B on page U.4.73

Table A.48 Time-Error Calculation (Sheet 1 of 2)

Row	Bit Name	Description
280	LOADTE	Load TECORR Factor (SELOGIC Equation). When a rising-edge is detected, the accumulated time-error value TE is loaded with the TECORR factor (preload value).[a]
280	STALLTE	Stall Time-Error Calculation (SELOGIC Equation). When asserted, the time-error calculation is stalled or frozen.
280	PLDTE	Asserts for approximately 1.5 cycles when the **TEC** command is used to load a new time-error correction factor (preload value) into the TECORR analog quantity.
280	*	Reserved
280	*	Reserved
280	*	Reserved
280	*	Reserved
280	*	Reserved
281	*	Reserved
281	*	Reserved
281	*	Reserved
281	*	Reserved

Table A.48 Time-Error Calculation (Sheet 2 of 2)

Row	Bit Name	Description
281	*	Reserved
281	*	Reserved
281	*	Reserved
281	*	Reserved

[a] The time-error calculation logic runs once per cycle. Condition the LOADTE equation logic expression to assert for at least one cycle to ensure recognition. (Do not use a rising edge operator, R_TRIG, in the LOADTE setting.)

Table A.49 Relay Word Bits: Local Bit Supervision and Status (Sheet 1 of 2)

Row	Bit Name	Description
282	LB_SP08	Local Bit 08 Supervision (SELOGIC Equation)
282	LB_SP07	Local Bit 07 Supervision (SELOGIC Equation)
282	LB_SP06	Local Bit 06 Supervision (SELOGIC Equation)
282	LB_SP05	Local Bit 05 Supervision (SELOGIC Equation)
282	LB_SP04	Local Bit 04 Supervision (SELOGIC Equation)
282	LB_SP03	Local Bit 03 Supervision (SELOGIC Equation)
282	LB_SP02	Local Bit 02 Supervision (SELOGIC Equation)
282	LB_SP01	Local Bit 01 Supervision (SELOGIC Equation)
283	LB_SP16	Local Bit 16 Supervision (SELOGIC Equation)
283	LB_SP15	Local Bit 15 Supervision (SELOGIC Equation)
283	LB_SP14	Local Bit 14 Supervision (SELOGIC Equation)
283	LB_SP13	Local Bit 13 Supervision (SELOGIC Equation)
283	LB_SP12	Local Bit 12 Supervision (SELOGIC Equation)
283	LB_SP11	Local Bit 11 Supervision (SELOGIC Equation)
283	LB_SP10	Local Bit 10 Supervision (SELOGIC Equation)
283	LB_SP09	Local Bit 09 Supervision (SELOGIC Equation)
284	LB_SP24	Local Bit 24 Supervision (SELOGIC Equation)
284	LB_SP23	Local Bit 23 Supervision (SELOGIC Equation)
284	LB_SP22	Local Bit 22 Supervision (SELOGIC Equation)
284	LB_SP21	Local Bit 21 Supervision (SELOGIC Equation)
284	LB_SP20	Local Bit 20 Supervision (SELOGIC Equation)
284	LB_SP19	Local Bit 19 Supervision (SELOGIC Equation)
284	LB_SP18	Local Bit 18 Supervision (SELOGIC Equation)
284	LB_SP17	Local Bit 17 Supervision (SELOGIC Equation)
285	LB_SP32	Local Bit 32 Supervision (SELOGIC Equation)
285	LB_SP31	Local Bit 31 Supervision (SELOGIC Equation)
285	LB_SP30	Local Bit 30 Supervision (SELOGIC Equation)
285	LB_SP29	Local Bit 29 Supervision (SELOGIC Equation)
285	LB_SP28	Local Bit 28 Supervision (SELOGIC Equation)
285	LB_SP27	Local Bit 27 Supervision (SELOGIC Equation)
285	LB_SP26	Local Bit 26 Supervision (SELOGIC Equation)

Table A.49 Relay Word Bits: Local Bit Supervision and Status
(Sheet 2 of 2)

Row	Bit Name	Description
285	LB_SP25	Local Bit 25 Supervision (SELOGIC Equation)
286	LB_DP08	Local Bit 08 Status Display (SELOGIC Equation)
286	LB_DP07	Local Bit 07 Status Display (SELOGIC Equation)
286	LB_DP06	Local Bit 06 Status Display (SELOGIC Equation)
286	LB_DP05	Local Bit 05 Status Display (SELOGIC Equation)
286	LB_DP04	Local Bit 04 Status Display (SELOGIC Equation)
286	LB_DP03	Local Bit 03 Status Display (SELOGIC Equation)
286	LB_DP02	Local Bit 02 Status Display (SELOGIC Equation)
286	LB_DP01	Local Bit 01 Status Display (SELOGIC Equation)
287	LB_DP16	Local Bit 16 Status Display (SELOGIC Equation)
287	LB_DP15	Local Bit 15 Status Display (SELOGIC Equation)
287	LB_DP14	Local Bit 14 Status Display (SELOGIC Equation)
287	LB_DP13	Local Bit 13 Status Display (SELOGIC Equation)
287	LB_DP12	Local Bit 12 Status Display (SELOGIC Equation)
287	LB_DP11	Local Bit 11 Status Display (SELOGIC Equation)
287	LB_DP10	Local Bit 10 Status Display (SELOGIC Equation)
287	LB_DP09	Local Bit 09 Status Display (SELOGIC Equation)
288	LB_DP24	Local Bit 24 Status Display (SELOGIC Equation)
288	LB_DP23	Local Bit 23 Status Display (SELOGIC Equation)
288	LB_DP22	Local Bit 22 Status Display (SELOGIC Equation)
288	LB_DP21	Local Bit 21 Status Display (SELOGIC Equation)
288	LB_DP20	Local Bit 20 Status Display (SELOGIC Equation)
288	LB_DP19	Local Bit 19 Status Display (SELOGIC Equation)
288	LB_DP18	Local Bit 18 Status Display (SELOGIC Equation)
288	LB_DP17	Local Bit 17 Status Display (SELOGIC Equation)
289	LB_DP32	Local Bit 32 Status Display (SELOGIC Equation)
289	LB_DP31	Local Bit 31 Status Display (SELOGIC Equation)
289	LB_DP30	Local Bit 30 Status Display (SELOGIC Equation)
289	LB_DP29	Local Bit 29 Status Display (SELOGIC Equation)
289	LB_DP28	Local Bit 28 Status Display (SELOGIC Equation)
289	LB_DP27	Local Bit 27 Status Display (SELOGIC Equation)
289	LB_DP26	Local Bit 26 Status Display (SELOGIC Equation)
289	LB_DP25	Local Bit 25 Status Display (SELOGIC Equation)

Table A.50 Relay Word Bits: Bay Control—Breaker Status[a]

Row	Bit Name	Description
290	*	Reserved
290	*	Reserved
290	52ALM3	Breaker 3 Alarm (SELOGIC Equation)
290	52ALM2	Breaker 2 Alarm (SELOGIC Equation)
290	52ALM1	Breaker 1 Alarm (SELOGIC Equation)
290	52CLSM3	Breaker 3 Closed (SELOGIC Equation)
290	52CLSM2	Breaker 2 Closed (SELOGIC Equation)
290	52CLSM1	Breaker 1 Closed (SELOGIC Equation)

[a] SEL-451-4 Relay Word Bits

Table A.51 Relay Word Bits: Bay Control—Disconnect Status Indication and Alarms (Disconnects 1-5)[a] (Sheet 1 of 2)

Row	Bit Name	Description
291	89AL	Any Disconnect Alarm
291	*	Reserved
291	89AL1	Disconnect 1 Alarm
291	89OIP1	Disconnect 1 Operation In Progress
291	89OPN1	Disconnect 1 Open
291	89CL1	Disconnect 1 Closed
291	89BM1	Disconnect 1 N/C Auxiliary Contact (SELOGIC Equation)
291	89AM1	Disconnect 1 N/O Auxiliary Contact (SELOGIC Equation)
292	89OIP	Any Disconnect Operation In Progress
292	*	Reserved
292	89AL2	Disconnect 2 Alarm
292	89OIP2	Disconnect 2 Operation In Progress
292	89OPN2	Disconnect 2 Open
292	89CL2	Disconnect 2 Closed
292	89BM2	Disconnect 2 N/C Auxiliary Contact (SELOGIC Equation)
292	89AM2	Disconnect 2 N/O Auxiliary Contact (SELOGIC Equation)
293	LOCAL	Local HMI Control
293	*	Reserved
293	89AL3	Disconnect 3 Alarm
293	89OIP3	Disconnect 3 Operation In Progress
293	89OPN3	Disconnect 3 Open
293	89CL3	Disconnect 3 Closed
293	89BM3	Disconnect 3 N/C Auxiliary Contact (SELOGIC Equation)
293	89AM3	Disconnect 3 N/O Auxiliary Contact (SELOGIC Equation)
294	*	Reserved
294	*	Reserved
294	89AL4	Disconnect 4 Alarm
294	89OIP4	Disconnect 4 Operation In Progress

Table A.51 Relay Word Bits: Bay Control—Disconnect Status Indication and Alarms (Disconnects 1–5)[a] (Sheet 2 of 2)

Row	Bit Name	Description
294	89OPN4	Disconnect 4 Open
294	89CL4	Disconnect 4 Closed
294	89BM4	Disconnect 4 N/C Auxiliary Contact (SELOGIC Equation)
294	89AM4	Disconnect 4 N/O Auxiliary Contact (SELOGIC Equation)
295	*	Reserved
295	*	Reserved
295	89AL5	Disconnect 5 Alarm
295	89OIP5	Disconnect 5 Operation In Progress
295	89OPN5	Disconnect 5 Open
295	89CL5	Disconnect 5 Closed
295	89BM5	Disconnect 5 N/C Auxiliary Contact (SELOGIC Equation)
295	89AM5	Disconnect 5 N/O Auxiliary Contact (SELOGIC Equation)

[a] SEL-451-4 Relay Word Bits

Table A.52 Relay Word Bits: Bay Control—Buszone Disconnect Contacts (Disconnects 1–5)[a]

Row	Bit Name	Description
296	*	Reserved
296	*	Reserved
296	*	Reserved
296	89CLBZ5	Disconnect 5 Buszone Protection
296	89CLBZ4	Disconnect 4 Buszone Protection
296	89CLBZ3	Disconnect 3 Buszone Protection
296	89CLBZ2	Disconnect 2 Buszone Protection
296	89CLBZ1	Disconnect 1 Buszone Protection

[a] SEL-451-4 Relay Word Bits

Table A.53 Relay Word Bits: Bay Control—Disconnect Open/Close (Disconnects 1–5)[a] (Sheet 1 of 3)

Row	Bit Name	Description
297	89CCON1	Close Disconnect 1 (SELOGIC Equation)
297	89OCON1	Open Disconnect 1 (SELOGIC Equation)
297	89CLS1	Disconnect Close 1 Output
297	89OPEN1	Disconnect Open 1 Output
297	89CCM1	Mimic Disconnect 1 Close Control
297	89OCM1	Mimic Disconnect 1 Open Control
297	89CC1	ASCII Close Disconnect 1 Command
297	89OC1	ASCII Open Disconnect 1 Command
298	*	Reserved
298	*	Reserved
298	*	Reserved

Table A.53 Relay Word Bits: Bay Control—Disconnect Open/Close (Disconnects 1–5)[a] (Sheet 2 of 3)

Row	Bit Name	Description
298	*	Reserved
298	*	Reserved
298	*	Reserved
298	89CCMD1	Close Command from Disconnect 1 Control Screen
298	89OCMD1	Open Command from Disconnect 1 Control Screen
299	89CCON2	Close Disconnect 2 (SELOGIC Equation)
299	89OCON2	Open Disconnect 2 (SELOGIC Equation)
299	89CLS2	Disconnect Close 2 Output
299	89OPEN2	Disconnect Open 2 Output
299	89CCM2	Mimic Disconnect 2 Close Control
299	89OCM2	Mimic Disconnect 2 Open Control
299	89CC2	ASCII Close Disconnect 2 Command
299	89OC2	ASCII Open Disconnect 2 Command
300	*	Reserved
300	*	Reserved
300	*	Reserved
300	*	Reserved
300	*	Reserved
300	*	Reserved
300	89CCMD2	Close Command from Disconnect 2 Control Screen
300	89OCMD2	Open Command from Disconnect 2 Control Screen
301	89CCON3	Close Disconnect 3 (SELOGIC Equation)
301	89OCON3	Open Disconnect 3 (SELOGIC Equation)
301	89CLS3	Disconnect Close 3 Output
301	89OPEN3	Disconnect Open 3 Output
301	89CCM3	Mimic Disconnect 3 Close Control
301	89OCM3	Mimic Disconnect 3 Open Control
301	89CC3	ASCII Close Disconnect 3 Command
301	89OC3	ASCII Open Disconnect 3 Command
302	*	Reserved
302	*	Reserved
302	*	Reserved
302	*	Reserved
302	*	Reserved
302	*	Reserved
302	89CCMD3	Close Command from Disconnect 3 Control Screen
302	89OCMD3	Open Command from Disconnect 3 Control Screen
303	89CCON4	Close Disconnect 4 (SELOGIC Equation)
303	89OCON4	Open Disconnect 4 (SELOGIC Equation)
303	89CLS4	Disconnect Close 4 Output

Table A.53 Relay Word Bits: Bay Control—Disconnect Open/Close (Disconnects 1–5)[a] (Sheet 3 of 3)

Row	Bit Name	Description
303	89OPEN4	Disconnect Open 4 Output
303	89CCM4	Mimic Disconnect 4 Close Control
303	89OCM4	Mimic Disconnect 4 Open Control
303	89CC4	ASCII Close Disconnect 4 Command
299	89OC4	ASCII Open Disconnect 4 Command
304	*	Reserved
304	*	Reserved
304	*	Reserved
304	*	Reserved
304	*	Reserved
304	*	Reserved
304	89CCMD4	Close Command from Disconnect 4 Control Screen
304	89OCMD4	Open Command from Disconnect 4 Control Screen
305	89CCON5	Close Disconnect 5 (SELOGIC Equation)
305	89OCON5	Open Disconnect 5 (SELOGIC Equation)
305	89CLS5	Disconnect Close 5 Output
305	89OPEN5	Disconnect Open 5 Output
305	89CCM5	Mimic Disconnect 5 Close Control
305	89OCM5	Mimic Disconnect 5 Open Control
305	89CC5	ASCII Close Disconnect 5 Command
305	89OC5	ASCII Open Disconnect 5 Command
306	*	Reserved
306	*	Reserved
306	*	Reserved
306	*	Reserved
306	*	Reserved
306	*	Reserved
306	89CCMD5	Close Command from Disconnect 5 Control Screen
306	89OCMD5	Open Command from Disconnect 5 Control Screen
307	*	Reserved
307	*	Reserved
307	*	Reserved
307	*	Reserved
307	*	Reserved
307	*	Reserved
307	*	Reserved
307	*	Reserved

[a] SEL-451-4 Relay Word Bits

Table A.54 Pushbuttons, Pushbutton LEDs, Target LEDs for New HMI

Row	Bit Name	Description
308	TLED_17	Target LED 17
308	TLED_18	Target LED 18
308	TLED_19	Target LED 19
308	TLED_20	Target LED 20
308	TLED_21	Target LED 21
308	TLED_22	Target LED 22
308	TLED_23	Target LED 23
308	TLED_24	Target LED 24
309	PB9	Pushbutton 9
309	PB10	Pushbutton 10
309	PB11	Pushbutton 11
309	PB12	Pushbutton 12
309	*	Reserved
309	*	Reserved
309	PB_TRIP	Auxiliary TRIP Pushbutton
309	PB_CLSE	Auxiliary CLOSE Pushbutton
310	PB9_LED	Pushbutton 9 LED
310	PB10LED	Pushbutton 10 LED
310	PB11LED	Pushbutton 11 LED
310	PB12LED	Pushbutton 12 LED
310	*	Reserved
310	*	Reserved
310	*	Reserved
310	*	Reserved
311	PB9_PUL	Pushbutton 9 pulse (on for one processing interval when button is pushed)
311	PB10PUL	Pushbutton 10 pulse (on for one processing interval when button is pushed)
311	PB11PUL	Pushbutton 11 pulse (on for one processing interval when button is pushed)
311	PB12PUL	Pushbutton 12 pulse (on for one processing interval when button is pushed)
311	*	Reserved
311	*	Reserved
311	*	Reserved
311	*	Reserved

Table A.55 50G High-Impedance Fault (50G HIZ) Detection Elements

Row	Bit Name	Description
312	HIZ181	50G HIZ Fault Detection logic state
312	HIZ180	50G HIZ Fault Detection logic state
312	HIZ175	50G HIZ Fault Detection logic state
312	HIZ174	50G HIZ Fault Detection logic state
312	HIZ173	50G HIZ Fault Detection logic state
312	HIZ172	50G HIZ Fault Detection logic state
312	HIZ171	50G HIZ Fault Detection logic state
312	HIZ170	50G HIZ Fault Detection logic state
313	HIZRST	HIZ Alarm Reset SELOGIC setting
313	50GHIZA	Ground HIZ Alarm
313	50GHIZ	Ground HIZ instantaneous overcurrent pickup
313	CHIZ0	50G HIZ counter CHIZ reset
313	CPUDO0	50G HIZ counter CPUDO reset
313	HIZ192	50G HIZ Fault Detection logic state
313	HIZ191	50G HIZ Fault Detection logic state
313	HIZ190	50G HIZ Fault Detection logic state
314–315	*	Reserved

Table A.56 High-Impedance Fault (HIF) Detection Elements (Sheet 1 of 3)

Row	Bit Name	Description
316	HIA1_G	Residual Current HIF Alarm
316	HIA1_C	C-Phase HIF Alarm
316	HIA1_B	B-Phase HIF Alarm
316	HIA1_A	A-Phase HIF Alarm
316	HIA2_G	Residual Current HIF Alarm
316	HIA2_C	C-Phase HIF Alarm
316	HIA2_B	B-Phase HIF Alarm
316	HIA2_A	A-Phase HIF Alarm
317	HIF1_G	Residual Current HIF Detection
317	HIF1_C	C-Phase HIF Detection
317	HIF1_B	B-Phase HIF Detection
317	HIF1_A	A-Phase HIF Detection
317	HIF2_G	Residual Current HIF Detection
317	HIF2_C	C-Phase HIF Detection
317	HIF2_B	B-Phase HIF Detection
317	HIF2_A	A-Phase HIF Detection
318	NTUNE_G	Residual Normal Tuning
318	NTUNE_C	C-Phase Normal Tuning
318	NTUNE_B	B-Phase Normal Tuning
318	NTUNE_A	A-Phase Normal Tuning

Table A.56 High-Impedance Fault (HIF) Detection Elements (Sheet 2 of 3)

Row	Bit Name	Description
318	ITUNE_G	Residual Initial Tuning
318	ITUNE_C	C-Phase Initial Tuning
318	ITUNE_B	B-Phase Initial Tuning
318	ITUNE_A	A-Phase Initial Tuning
319	DIG_DIS	Residual Large Difference Current Disturbance
319	DIC_DIS	C-Phase Large Difference Current Disturbance
319	DIB_DIS	B-Phase Large Difference Current Disturbance
319	DIA_DIS	A-Phase Large Difference Current Disturbance
319	DVG_DIS	Residual Difference Voltage Disturbance
319	DVC_DIS	C-Phase Difference Voltage Disturbance
319	DVB_DIS	B-Phase Difference Voltage Disturbance
319	DVA_DIS	A-Phase Difference Voltage Disturbance
320	DL2CLRG	Residual Decision Logic Clear
320	DL2CLRC	C-Phase Decision Logic Clear
320	DL2CLRB	B-Phase Decision Logic Clear
320	DL2CLRA	A-Phase Decision Logic Clear
320	FRZCLRG	Residual Averager Freeze and Trending Clear Condition
320	FRZCLRC	C-Phase Averager Freeze and Trending Clear Condition
320	FRZCLRB	B-Phase Averager Freeze and Trending Clear Condition
320	FRZCLRA	A-Phase Averager Freeze and Trending Clear Condition
321	DUPG	Residual Tuning Threshold Increase
321	DUPC	C-Phase Tuning Threshold Increase
321	DUPB	B-Phase Tuning Threshold Increase
321	DUPA	A-Phase Tuning Threshold Increase
321	DDNG	Residual Tuning Threshold Decrease
321	DDNC	C-Phase Tuning Threshold Decrease
321	DDNB	B-Phase Tuning Threshold Decrease
321	DDNA	A-Phase Tuning Threshold Decrease
322	3PH_CLR	3-Phase Events Cleared
322	3PH_C	C-Phase Above 3-Phase Event Level
322	3PH_B	B-Phase Above 3-Phase Event Level
322	3PH_A	A-Phase Above 3-Phase Event Level
322	LR3	3-phase Load Reduction Event
322	LRC	Load Reduction in C-Phase
322	LRB	Load Reduction in B-Phase
322	LRA	Load Reduction in A-Phase
323	*	Reserved
323	*	Reserved
323	*	Reserved
323	*	Reserved
323	HIFER	HIF Event Report External Trigger SELOGIC setting

Table A.56 High-Impedance Fault (HIF) Detection Elements (Sheet 3 of 3)

Row	Bit Name	Description
323	HIFMODE	HIF Detection Sensitivity SELOGIC setting
323	HIFREC	HIF event report triggered and is being collected
323	3PH_EVE	3-Phase Event Detection

Table A.57 Relay Word Bits: Bay Control—Disconnect Status Indication and Alarms (Disconnects 6-10)[a] (Sheet 1 of 2)

Row	Bit name	Description
324	89AM6	Disconnect 6 N/O Auxiliary Contact (SELOGIC Equation)
324	89BM6	Disconnect 6 N/C Auxiliary Contact (SELOGIC Equation)
324	89CL6	Disconnect 6 Closed
324	89OPN6	Disconnect 6 Open
324	89OIP6	Disconnect 6 Operation In Progress
324	89AL6	Disconnect 6 Alarm
324	*	Reserved
324	*	Reserved
325	89AM7	Disconnect 7 N/O Auxiliary Contact (SELOGIC Equation)
325	89BM7	Disconnect 7 N/C Auxiliary Contact (SELOGIC Equation)
325	89CL7	Disconnect 7 Closed
325	89OPN7	Disconnect 7 Open
325	89OIP7	Disconnect 7 Operation In Progress
325	89AL7	Disconnect 7 Alarm
325	*	Reserved
325	*	Reserved
326	89AM8	Disconnect 8 N/O Auxiliary Contact (SELOGIC Equation)
326	89BM8	Disconnect 8 N/C Auxiliary Contact (SELOGIC Equation)
326	89CL8	Disconnect 8 Closed
326	89OPN8	Disconnect 8 Open
326	89OIP8	Disconnect 8 Operation In Progress
326	89AL8	Disconnect 8 Alarm
326	*	Reserved
326	*	Reserved
327	89AM9	Disconnect 9 N/O Auxiliary Contact (SELOGIC Equation)
327	89BM9	Disconnect 9 N/C Auxiliary Contact (SELOGIC Equation)
327	89CL9	Disconnect 9 Closed
327	89OPN9	Disconnect 9 Open
327	89OIP9	Disconnect 9 Operation In Progress
327	89AL9	Disconnect 9 Alarm
327	*	Reserved
327	*	Reserved
328	89AM10	Disconnect 10 N/O Auxiliary Contact (SELOGIC Equation)
328	89BM10	Disconnect 10 N/C Auxiliary Contact (SELOGIC Equation)
328	89CL10	Disconnect 10 Closed

Table A.57 Relay Word Bits: Bay Control—Disconnect Status Indication and Alarms (Disconnects 6-10)[a] (Sheet 2 of 2)

Row	Bit name	Description
328	89OPN10	Disconnect 10 Open
328	89OIP10	Disconnect 10 Operation In Progress
328	89AL10	Disconnect 10 Alarm
328	*	Reserved
328	*	Reserved

[a] SEL-451-4 Relay Word Bits

Table A.58 Relay Word Bits: Bay Control—Buszone Disconnect Contacts (Disconnects 6-10)[a]

Row	Bit name	Description
329	89CLBZ6	Disconnect 6 Buszone Protection
329	89CLBZ7	Disconnect 7 Buszone Protection
329	89CLBZ8	Disconnect 8 Buszone Protection
329	89CLBZ9	Disconnect 9 Buszone Protection
329	89CLB10	Disconnect 10 Buszone Protection
329	*	Reserved
329	*	Reserved
329	*	Reserved

[a] SEL-451-4 Relay Word Bits

Table A.59 Relay Word Bits: Bay Control—Disconnect Open/Close (Disconnects 6-10)[a] (Sheet 1 of 3)

Row	Bit name	Description
330	89OC6	ASCII Open Disconnect 6 Command
330	89CC6	ASCII Close Disconnect 6 Command
330	89OCM6	Mimic Disconnect 6 Open Control
330	89CCM6	Mimic Disconnect 6 Close Control
330	89OPEN6	Disconnect Open 6 Output
330	89CLS6	Disconnect Close 6 Output
330	89OCON6	Open Disconnect 6 (SELOGIC Equation)
330	89CCON6	Close Disconnect 6 (SELOGIC Equation)
331	89OCMD6	ASCII Open Disconnect 6 Command
331	89CCMD6	ASCII Close Disconnect 6 Command
331	*	Reserved
331	*	Reserved
331	*	Reserved
331	*	Reserved
331	*	Reserved
331	*	Reserved
332	89OC7	ASCII Open Disconnect 7 Command
332	89CC7	ASCII Close Disconnect 7 Command

Table A.59 Relay Word Bits: Bay Control—Disconnect Open/Close (Disconnects 6-10)[a] (Sheet 2 of 3)

Row	Bit name	Description
332	89OCM7	Mimic Disconnect 7 Open Control
332	89CCM7	Mimic Disconnect 7 Close Control
332	89OPEN7	Disconnect Open 7 Output
332	89CLS7	Disconnect Close 7 Output
332	89OCON7	Open Disconnect 7 (SELOGIC Equation)
332	89CCON7	Close Disconnect 7 (SELOGIC Equation)
333	89OCMD7	ASCII Open Disconnect 7 Command
333	89CCMD7	ASCII Close Disconnect 7 Command
333	*	Reserved
333	*	Reserved
333	*	Reserved
333	*	Reserved
333	*	Reserved
333	*	Reserved
334	89OC8	ASCII Open Disconnect 8 Command
334	89CC8	ASCII Close Disconnect 8 Command
334	89OCM8	Mimic Disconnect 8 Open Control
334	89CCM8	Mimic Disconnect 8 Close Control
334	89OPEN8	Disconnect Open 8 Output
334	89CLS8	Disconnect Close 8 Output
334	89OCON8	Open Disconnect 8 (SELOGIC Equation)
334	89CCON8	Close Disconnect 8 (SELOGIC Equation)
335	89OCMD8	ASCII Open Disconnect 8 Command
335	89CCMD8	ASCII Close Disconnect 8 Command
335	*	Reserved
335	*	Reserved
335	*	Reserved
335	*	Reserved
335	*	Reserved
335	*	Reserved
336	89OC9	ASCII Open Disconnect 9 Command
336	89CC9	ASCII Close Disconnect 9 Command
336	89OCM9	Mimic Disconnect 9 Open Control
336	89CCM9	Mimic Disconnect 9 Close Control
336	89OPEN9	Disconnect Open 9 Output
336	89CLS9	Disconnect Close 9 Output
336	89OCON9	Open Disconnect 9 (SELOGIC Equation)
336	89CCON9	Close Disconnect 9 (SELOGIC Equation)
337	89OCMD9	ASCII Open Disconnect 9 Command
337	89CCMD9	ASCII Close Disconnect 9 Command

Table A.59 Relay Word Bits: Bay Control—Disconnect Open/Close (Disconnects 6–10)[a] (Sheet 3 of 3)

Row	Bit name	Description
337	*	Reserved
337	*	Reserved
337	*	Reserved
337	*	Reserved
337	*	Reserved
337	*	Reserved
338	89OC10	ASCII Open Disconnect 10 Command
338	89CC10	ASCII Close Disconnect 10 Command
338	89OCM10	Mimic Disconnect 10 Open Control
338	89CCM10	Mimic Disconnect 10 Close Control
338	89OPE10	Disconnect Open 10 Output
338	89CLS10	Disconnect Close 10 Output
338	89OCN10	Open Disconnect 10 (SELOGIC Equation)
338	89CCN10	Close Disconnect 10 (SELOGIC Equation)
339	89OCD10	ASCII Open Disconnect 10 Command
339	89CCD10	ASCII Close Disconnect 10 Command
339	*	Reserved
339	*	Reserved
339	*	Reserved
339	*	Reserved
339	*	Reserved
337	*	Reserved

[a] SEL-451-4 Relay Word Bits

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Appendix B

Analog Quantities

This section contains a table of the analog quantities available within the SEL-451 Relay. For information on using analog quantities in protection and automation, see the *Applications Handbook*.

Use *Table B.2* as a reference for labels in this manual and as a resource for quantities you use in SELOGIC® control equation relay settings. *Table B.1* groups the analog quantities alphanumerically; *Table B.2* groups the analog quantities by function.

Quantities Listed Alphabetically

Use *Table B.2* as a reference for labels in this manual and as a resource for quantities you use in SELOGIC® control equation relay settings. *Table B.1* groups the analog quantities alphanumerically; *Table B.2* groups the analog quantities by function.

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 1 of 8)

Label	Description	Units
3DPF	Three-phase displacement power factor	n/a
3I2D	Negative-sequence demand current	A[a]
3I2PKD	Negative-sequence peak demand current	A[a]
3MWH3T	Three-phase total energy	MWh[a]
3MWHIN	Three-phase negative (import) energy	MWh[a]
3MWHOUT	Three-phase positive (export) energy	MWh[a]
3P	Three-phase real power	MW[a]
3P_f	Three-phase fundamental real power	MW[a]
3PD	Three-phase demand real power	MW[a]
3PF	Three-phase power factor	n/a
3PPKD	Three-phase peak demand real power	MW[a]
3PSHOT	Present value of three-pole shot counter	n/a
3Q_f	Three-phase fundamental reactive power	MVAr[a]
3QD	Three-phase demand reactive power	MVAr[a]
3QPKD	Three-phase peak demand reactive power	MVAr[a]
3S_f	Three-phase fundamental apparent power	MVA[a]
3U	Three-phase apparent power	MVA[a]
3UD	Three-phase demand apparent power	MVA[a]
3UPKD	Three-phase peak demand apparent power	MVA[a]
3V0A	Zero-sequence 10-cycle average voltage angle	degrees

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 2 of 8)

Label	Description	Units
3V0FIA	Zero-sequence instantaneous voltage angle	degrees
3V0FIM	Zero-sequence instantaneous voltage magnitude	V
3V0M	Zero-sequence 10-cycle average voltage magnitude	kV[a]
3V2A	Negative-sequence 10-cycle average voltage angle	degrees
3V2FIA	Negative-sequence instantaneous voltage angle	degrees
3V2FIM	Negative-sequence instantaneous voltage magnitude	V
3V2M	Negative-sequence 10-cycle average voltage magnitude	kV[a]
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
ANG1DIF	Synchronizing angle difference 1	degrees
ANG2DIF	Synchronizing angle difference 2	degrees
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
B1BCWPA, B1BCWPB, B1BCWPC	Circuit Breaker 1 contact wear	percent
B1IAFA, B1IBFA, B1ICFA	Circuit Breaker 1 phase 10-cycle average fundamental current angle	degrees
B1IAFIM, B1IBFIM, B1ICFIM	Circuit Breaker 1 phase filtered instantaneous current magnitude	A
B1IAFM, B1IBFM, B1ICFM	Circuit Breaker 1 phase 10-cycle average fundamental current magnitude	A[a]
B1IARMS, B1IBRMS, B1ICRMS	Circuit Breaker 1 phase 10-cycle average rms current	A[a]
B1IGFIM	Circuit Breaker 1 zero-sequence instantaneous current magnitude	A
B2BCWPA, B2BCWPB, B2BCWPC	Circuit Breaker 2 contact wear	percent
B2IAFA, B2IBFA, B2ICFA	Circuit Breaker 2 phase 10-cycle average fundamental current angle	degrees
B2IAFIM, B2IBFIM, B2ICFIM	Circuit Breaker 2 phase filtered instantaneous current magnitude	A
B2IAFM, B2IBFM, B2ICFM	Circuit Breaker 2 phase 10-cycle average fundamental current magnitude	A[a]

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 3 of 8)

Label	Description	Units
B2IARMS, B2IBRMS, B2ICRMS	Circuit Breaker 2 phase 10-cycle average rms current	A[a]
B2IGFIM	Circuit Breaker 2 zero-sequence instantaneous current magnitude	A
CTRW	CTRW setting from active group	n/a
CTRX	CTRX setting from active group	n/a
DC1, DC2	Filtered dc monitor voltage	V
DC1MAX, DC2MAX	Maximum dc voltage	V
DC1MIN, DC2MIN	Minimum dc voltage	V
DC1NE, DC2NE	Average negative-to-ground dc voltage	V
DC1PO, DC2PO	Average positive-to-ground dc voltage	V
DC1RI, DC2RI	AC ripple of dc voltage	V
DDOM	Day of the month (1–31)	n/a
DDOW	Day of the week[b]	n/a
DDOY	Day of the year (1–365)	n/a
DFDT	Rate-of-change of frequency, df/dt[c]	Hz/s
DMON	Month (1–12)	n/a
DPFA, DPFB, DPFC	Phase displacement power factor	n/a
DYEAR	Year (2000–2200)	per unit
FLOC	Fault location[d]	per unit
FOSPM	Fraction-of-second of the synchrophasor data	seconds
FREQ	Measured system frequency[c]	Hz
I1SPMA	Synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMI	Synchrophasor positive-sequence current, imaginary component (I_W + I_X terminals)	A[a]
I1SPMM	Synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[a]
I1SPMR	Synchrophasor positive-sequence current, real component (I_W + I_X terminals)	A[a]
I1WPMA	Synchrophasor positive-sequence current angle (I_W terminals)	degrees
I1WPMI	Synchrophasor positive-sequence current, imaginary component (I_W terminals)	A[a]
I1WPMM	Synchrophasor positive-sequence current magnitude (I_W terminals)	A[a]
I1WPMR	Synchrophasor positive-sequence current, real component (I_W terminals)	A[a]
I1XPMA	Synchrophasor positive-sequence current angle (I_X terminals)	degrees
I1XPMI	Synchrophasor positive-sequence current, imaginary component (I_X terminals)	A[a]

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 4 of 8)

Label	Description	Units
I1XPMM	Synchrophasor positive-sequence current magnitude (I_X terminals)	A[a]
I1XPMR	Synchrophasor positive-sequence current, real component (I_X terminals)	A[a]
IAD, IBD, ICD	Phase demand current	A[a]
IAPKD, IBPKD, ICPKD	Phase peak demand current	A[a]
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMI, IBSPMI, ICSPMI	Synchrophasor current, imaginary component (I_W + I_X terminals)	A[a]
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude (I_W + I_X terminals)	A[a]
IASPMR, IBSPMR, ICSPMR	Synchrophasor current, real component (I_W + I_X terminals)	A[a]
IAWA, IBWA, ICWA[e]	Terminal W phase filtered instantaneous current angle (See Table note before using these quantities)	degrees
IAWM, IBWM, ICWM[e]	Terminal W phase filtered instantaneous current magnitude	A
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle (I_W terminals)	degrees
IAWPMI, IBWPMI, ICWPMI	Synchrophasor current, imaginary component (I_W terminals)	A[a]
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude (I_W terminals)	A[a]
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current, real component (I_W terminals)	A[a]
IAXA, IBXA, ICXA[e]	Terminal X phase filtered instantaneous current angle (See Table note before using these quantities)	degrees
IAXM, IBXM, ICXM[e]	Terminal X phase filtered instantaneous current magnitude	A
IAXPMA, IBXPMA, ICXPMA	Synchrophasor current angle (I_X terminals)	degrees
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current, imaginary component (I_X terminals)	A[a]
IAXPMM, IBXPMM, ICXPMM	Synchrophasor current magnitude (I_X terminals)	A[a]
IAXPMR, IBXPMR, ICXPMR	Synchrophasor current, real component (I_X terminals)	A[a]

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 5 of 8)

Label	Description	Units
IGD	Zero-sequence demand current	A[a]
IGPKD	Zero-sequence peak demand current	A[a]
IN101A–IN107A[f]	Digital input values available as floating point quantities between 0.0 and 255.0. Multiply value by 1.023 to obtain volts.	A/D counts
IN201A–IN208A[f]	Digital input values available as floating point quantities between 0.0 and 255.0. Multiply value by 1.279 to obtain volts.	A/D counts
IN301A–IN308A[f]	Digital input values available as floating point quantities between 0.0 and 255.0. Multiply value by 1.279 to obtain volts.	A/D counts
IPFIM	Filtered instantaneous polarizing current magnitude	A
L3I2A	Negative-sequence 10-cycle average current angle	degrees
L3I2M	Negative-sequence 10-cycle average current magnitude	A[a]
LI1A	Positive-sequence 10-cycle average current angle	degrees
LI1FIA	Positive-sequence instantaneous current angle	degrees
LI1FIM	Positive-sequence instantaneous current magnitude	A
LI1M	Positive-sequence 10-cycle average current magnitude	A[a]
L3I2FIA	Negative-sequence instantaneous current angle	degrees
L3I2FIM	Negative-sequence instantaneous current magnitude	A
LIAFA, LIBFA, LICFA	Phase 10-cycle average fundamental current angle	degrees
LIAFIA, LIBFIA, LICFIA	Phase filtered instantaneous current angle	degrees
LIAFIM, LIBFIM, LICFIM	Phase filtered instantaneous current magnitude	A
LIAFM, LIBFM, LICFM	Phase 10-cycle average fundamental current magnitude	A[a]
LIARMS, LIBRMS, LICRMS	Phase 10-cycle average rms current	A[a]
LIGA	Zero-sequence 10-cycle average current angle	degrees
LIGFIA	Zero-sequence instantaneous current angle	degrees
LIGFIM	Zero-sequence instantaneous current magnitude	A
LIGM	Zero-sequence 10-cycle average current magnitude	A[a]
MB1A–MB7A	MIRRORED BITS® communications A Channel received analog values	n/a
MB1B–MB7B	MIRRORED BITS communications B Channel received analog values	n/a
MWHAIN, MWHBIN, MWHCIN	Phase negative (import) energy	MWh[a]
MWHAOUT, MWHBOUT, MWHCOUT	Phase positive (export) energy	MWh[a]

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 6 of 8)

Label	Description	Units
MWHAT, MWHBT, MWHCT	Phase total energy	MWh[a]
NVS1M	Normalized synchronizing voltage 1	V
NVS2M	Normalized synchronizing voltage 2	V
PA, PB, PC	Phase real power	MW[a]
PA_f, PB_f, PC_f	Phase fundamental real power	MW[a]
PAD, PBD, PCD	Phase demand real power	MW[a]
PAPKD, PBPKD, PCPKD	Phase peak demand real power	MW[a]
PCN01CV–PCN32CV	Protection counter current value	n/a
PCN01PV–PCN32PV	Protection counter preset value	n/a
PCT01DO–PCT32DO	Protection conditioning timer dropout time	cycles
PCT01PU–PCT32PU	Protection conditioning timer pickup time	cycles
PFA, PFB, PFC	Phase power factor	n/a
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
PTRY	PTRY setting from active group, divided by 1000	n/a
PTRZ	PTRZ setting from active group, divided by 1000	n/a
QA_f, QB_f, QC_f	Phase fundamental reactive power	MVAr[a]
QAD, QBD, QCD	Phase demand reactive power	MVAr[a]
QAPKD, QBPKD, QCPKD	Phase peak demand reactive power	MVAr[a]
RA001–RA256	Remote analogs from Ethernet card	n/a
RTD01–RTD12	Instantaneous temperatures from the SEL-2600	°C
SA_f, SB_f, SC_f	Phase fundamental apparent power	MVA[a]
SHOT3_1	Total number of first-shot three-pole reclosures	n/a
SHOT3_2	Total number of second-shot three-pole reclosures	n/a
SHOT3_3	Total number of third-shot three-pole reclosures	n/a
SHOT3_4	Total number of fourth-shot three-pole reclosures	n/a
SHOT3_T	Total number of three-pole reclosures	n/a
SLIP1	Synchronism-check element 1 slip frequency	Hz
SLIP2	Synchronism-check element 2 slip frequency	Hz
SODPM	Second-of-day of the synchrophasor data	seconds

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 7 of 8)

Label	Description	Units
TE	Time error	seconds
TECORR[g]	Time-error correction factor	seconds
THR	Hour (0–23)	hours
TMIN	Minute (0–59)	minutes
TMSEC	Milliseconds (0–999)	ms
TNSEC	Nanoseconds (0–999999)	ns
TODMS[h]	Time of day in milliseconds (0–86399999)	ms
TQUAL	Worst-case IRIG-B clock time error	seconds
TSEC	Seconds (0–59)	seconds
TUTC	Offset from IRIG-B time to UTC time	hours
UA, UB, UC	Phase apparent power	MVA[a]
UAD, UBD, UCD	Phase demand apparent power	MVA[a]
UAPKD, UBPKD, UCPKD	Phase peak demand apparent power	MVA[a]
V1A	Positive-sequence 10-cycle average voltage angle	degrees
V1FIA	Positive-sequence instantaneous voltage angle	degrees
V1FIM	Positive-sequence instantaneous voltage magnitude	V
V1LPMA	Synchrophasor positive-sequence voltage angle	degrees
V1LPMI	Synchrophasor positive-sequence voltage, imaginary component	kV[a]
V1LPMM	Synchrophasor positive-sequence voltage magnitude	kV[a]
V1LPMR	Synchrophasor positive-sequence voltage, real component	kV[a]
V1M	Positive-sequence 10-cycle average voltage magnitude	kV[a]
VABFA, VBCFA, VCAFA	Phase-to-phase 10-cycle average fundamental voltage angle	degrees
VABFM, VBCFM, VCAFM	Phase-to-phase 10-cycle average fundamental voltage magnitude	kV[a]
VABRMS, VBCRMS, VCARMS	Phase-to-phase 10-cycle average rms voltage	kV[a]
VABYA, VBCYA, VCAYA[e]	Terminal Y phase-to-phase filtered instantaneous voltage angle (See Table note before using these quantities)	degrees
VABYM, VBCYM, VCAYM[e]	Terminal Y phase-to-phase filtered instantaneous voltage magnitude	V
VABZA, VBCZA, VCAZA[e]	Terminal Z phase-to-phase filtered instantaneous voltage angle (See Table note before using these quantities)	degrees
VABZM, VBCZM, VCAZM[e]	Terminal Z phase-to-phase filtered instantaneous voltage magnitude	V
VAFA, VBFA, VCFA	Phase 10-cycle average fundamental voltage angle	degrees

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 8 of 8)

Label	Description	Units
VAFIA, VBFIA, VCFIA	Phase filtered instantaneous voltage angle	degrees
VAFIM, VBFIM, VCFIM	Phase filtered instantaneous voltage magnitude	V
VAFM, VBFM, VCFM	Phase 10-cycle average fundamental voltage magnitude	kV[a]
VALPMA, VBLPMA, VCLPMA	Synchrophasor voltage angle	degrees
VALPMI, VBLPMI, VCLPMI	Synchrophasor voltage, imaginary component	kVa
VALPMM, VBLPMM, VCLPMM	Synchrophasor voltage magnitude	kVa
VALPMR, VBLPMR, VCLPMR	Synchrophasor voltage, real component	kVa
VARMS, VBRMS, VCRMS	Phase 10-cycle average rms voltage	kV[a]
VAYA, VBYA, VCYA[e]	Terminal Y phase filtered instantaneous voltage angle (See Table note before using these quantities)	degrees
VAYM, VBYM, VCYM[e]	Terminal Y phase filtered instantaneous voltage magnitude	V
VAZA, VBZA, VCZA[e]	Terminal Z phase filtered instantaneous voltage angle (See Table note before using these quantities)	degrees
VAZM, VBZM, VCZM[e]	Terminal Z phase filtered instantaneous voltage magnitude	V
VPM	Synchronism-check polarizing voltage magnitude	V
Z1FA	Positive-sequence instantaneous impedance angle	degrees
Z1FM	Positive-sequence instantaneous impedance magnitude	Ω

[a] Primary value of measurement.
[b] Encoded value: 1 = Sun, 2 = Mon, 3 = Tue, 4 = Wed, 5 = Thur, 6 = Fri, 7 = Sat.
[c] Measured value if the relay can track frequency, otherwise FREQ = nominal frequency setting NFREQ, and DFDT is undefined. (DFDT operates only when Global setting EPMU := Y)
[d] See Fault Location on page R.1.17 for more information on this value.
[e] These terminal-specific magnitude and angle quantities are calculated separately from all other analog quantities. These angle values are non-stationary and should not be used in SELOGIC Math expressions with any other (stationary) angle quantities. Angle accuracy: Phase-to-ground ±3°, Phase-to-phase ±6°
[f] Digital input values are not available for boards that have optoisolated inputs.
[g] Copy of last value set by TEC command or DNP3.
[h] Cannot contain 1/8-cycle accuracy throughout the day because as a floating point value, there are only 7 digits of precision.

Quantities Listed by Function

Table B.2 Analog Quantities Sorted By Function (Sheet 1 of 8)

Label	Description	Units
Current		
IAWM, IBWM, ICWM[a]	Terminal W phase filtered instantaneous current magnitude	A
IAWA, IBWA, ICWA[a]	Terminal W phase filtered instantaneous current angle (See Table note before using these quantities)	degrees
IAXM, IBXM, ICXM[a]	Terminal X phase filtered instantaneous current magnitude	A
IAXA, IBXA, ICXA[a]	Terminal X phase filtered instantaneous current angle (See Table note before using these quantities)	degrees
LIAFIM, LIBFIM, LICFIM	Phase filtered instantaneous current magnitude	A
LIAFIA, LIBFIA, LICFIA	Phase filtered instantaneous current angle	degrees
IPFIM	Filtered instantaneous polarizing current magnitude	A
LIAFM, LIBFM, LICFM	Phase 10-cycle average fundamental current magnitude	A[b]
LIAFA, LIBFA, LICFA	Phase 10-cycle average fundamental current angle	degrees
LIARMS, LIBRMS, LICRMS	Phase 10-cycle average rms current	A[b]
LI1FIM	Positive-sequence instantaneous current magnitude	A
LI1FIA	Positive-sequence instantaneous current angle	degrees
LI1M	Positive-sequence 10-cycle average current magnitude	A[b]
LI1A	Positive-sequence 10-cycle average current angle	degrees
L3I2FIM	Negative-sequence instantaneous current magnitude	A
L3I2FIA	Negative-sequence instantaneous current angle	degrees
L3I2M	Negative-sequence 10-cycle average current magnitude	A[b]
L3I2A	Negative-sequence 10-cycle average current angle	degrees
LIGFIM	Zero-sequence instantaneous current magnitude	A
LIGFIA	Zero-sequence instantaneous current angle	degrees
LIGM	Zero-sequence 10-cycle average current magnitude	A[b]
LIGA	Zero-sequence 10-cycle average current angle	degrees
B1IAFIM, B1IBFIM, B1ICFIM	Circuit Breaker 1 phase filtered instantaneous current magnitude	A
B2IAFIM, B2IBFIM, B2ICFIM	Circuit Breaker 2 phase filtered instantaneous current magnitude	A
B1IAFM, B1IBFM, B1ICFM	Circuit Breaker 1 phase 10-cycle average fundamental current magnitude	A[b]

Table B.2 Analog Quantities Sorted By Function (Sheet 2 of 8)

Label	Description	Units
B2IAFM, B2IBFM, B2ICFM	Circuit Breaker 2 phase 10-cycle average fundamental current magnitude	A[b]
B1IAFA, B1IBFA, B1ICFA	Circuit Breaker 1 phase 10-cycle average fundamental current angle	degrees
B2IAFA, B2IBFA, B2ICFA	Circuit Breaker 2 phase 10-cycle average fundamental current angle	degrees
B1IARMS, B1IBRMS, B1ICRMS	Circuit Breaker 1 phase 10-cycle average rms current	A[b]
B2IARMS, B2IBRMS, B2ICRMS	Circuit Breaker 2 phase 10-cycle average rms current	A[b]
B1IGFIM	Circuit Breaker 1 zero-sequence instantaneous current magnitude	A
B2IGFIM	Circuit Breaker 2 zero-sequence instantaneous current magnitude	A
Voltage		
VAYM, VBYM, VCYM[a]	Terminal Y phase filtered instantaneous voltage magnitude	V
VAYA, VBYA, VCYA[a]	Terminal Y phase filtered instantaneous voltage angle (See Table note before using these quantities)	degrees
VAZM, VBZM, VCZM[a]	Terminal Z phase filtered instantaneous voltage magnitude	V
VAZA, VBYA, VCYA[a]	Terminal Z phase filtered instantaneous voltage angle (See Table note before using these quantities)	degrees
VAFIM, VBFIM, VCFIM	Phase filtered instantaneous voltage magnitude	V
VAFIA, VBFIA, VCFIA	Phase filtered instantaneous voltage angle	degrees
VAFM, VBFM, VCFM	Phase 10-cycle average fundamental voltage magnitude	kV[b]
VAFA, VBFA, VCFA	Phase 10-cycle average fundamental voltage angle	degrees
VARMS, VBRMS, VCRMS	Phase 10-cycle average rms voltage	kV[b]
VABFM, VBCFM, VCAFM	Phase-to-phase 10-cycle average fundamental voltage magnitude	kV[b]
VABFA, VBCFA, VCAFA	Phase-to-phase 10-cycle average fundamental voltage angle	degrees
VABRMS, VBCRMS, VCARMS	Phase-to-phase 10-cycle average rms voltage	kV[b]
VABYM, VBCYM, VCAYM[a]	Terminal Y phase-to-phase filtered instantaneous voltage magnitude	V
VABYA, VBCYA, VCAYA[a]	Terminal Y phase-to-phase filtered instantaneous voltage angle (see Table note before using these quantities)	degrees

Table B.2 Analog Quantities Sorted By Function (Sheet 3 of 8)

Label	Description	Units
VABZM, VBCZM, VCA-ZM[a]	Terminal Z phase-to-phase filtered instantaneous voltage magnitude	V
VABZA, VBCZA, VCA-ZA[a]	Terminal Z phase-to-phase filtered instantaneous voltage angle (see Table note before using these quantities)	degrees
V1FIM	Positive-sequence instantaneous voltage magnitude	V
V1FIA	Positive-sequence instantaneous voltage angle	degrees
V1M	Positive-sequence 10-cycle average voltage magnitude	kV[b]
V1A	Positive-sequence 10-cycle average voltage angle	degrees
3V2FIM	Negative-sequence instantaneous voltage magnitude	V
3V2FIA	Negative-sequence instantaneous voltage angle	degrees
3V2M	Negative-sequence 10-cycle average voltage magnitude	kV[b]
3V2A	Negative-sequence 10-cycle average voltage angle	degrees
3V0FIM	Zero-sequence instantaneous voltage magnitude	V
3V0FIA	Zero-sequence instantaneous voltage angle	degrees
3V0M	Zero-sequence 10-cycle average voltage magnitude	kV[b]
3V0A	Zero-sequence 10-cycle average voltage angle	degrees
Synchronism Check		
VPM	Synchronism-check polarizing voltage magnitude	V
NVS1M	Normalized synchronizing voltage 1	V
NVS2M	Normalized synchronizing voltage 2	V
ANG1DIF	Synchronizing angle difference 1	degrees
ANG2DIF	Synchronizing angle difference 2	degrees
SLIP1	Synchronism-check element 1 slip frequency	Hz
SLIP2	Synchronism-check element 2 slip frequency	Hz
Frequency		
FREQ	Measured system frequency[c]	Hz
DFDT	Rate-of-change of frequency, df/dt[c]	Hz/s
DC Monitor		
DC1, DC2	Filtered dc monitor voltage	V
DC1PO, DC2PO	Average positive-to-ground dc voltage	V
DC1NE, DC2NE	Average negative-to-ground dc voltage	V
DC1RI, DC2RI	AC ripple of dc voltage	V
DC1MIN, DC2MIN	Minimum dc voltage	V
DC1MAX, DC2MAX	Maximum dc voltage	V
Power		
PA_f, PB_f, PC_f	Phase fundamental real power	MW[b]
3P_f	Three-phase fundamental real power	MW[b]
PA, PB, PC	Phase real power	MW[b]

Table B.2 Analog Quantities Sorted By Function (Sheet 4 of 8)

Label	Description	Units
3P	Three-phase real power	MW[b]
QA_f, QB_f, QC_f	Phase fundamental reactive power	MVAr[b]
3Q_f	Three-phase fundamental reactive power	MVAr[b]
SA_f, SB_f, SC_f	Phase fundamental apparent power	MVA[b]
3S_f	Three-phase fundamental apparent power	MVA[b]
UA, UB, UC	Phase apparent power	MVA[b]
3U	Three-phase apparent power	MVA[b]
DPFA, DPFB, DPFC	Phase displacement power factor	n/a
3DPF	Three-phase displacement power factor	n/a
PFA, PFB, PFC	Phase power factor	n/a
3PF	Three-phase power factor	n/a
Demand		
IAPKD, IBPKD, ICPKD	Phase peak demand current	A[b]
3I2PKD	Negative-sequence peak demand current	A[b]
IGPKD	Zero-sequence peak demand current	A[b]
PAPKD, PBPKD, PCPKD	Phase peak demand real power	MW[b]
3PPKD	Three-phase peak demand real power	MW[b]
QAPKD, QBPKD, QCPKD	Phase peak demand reactive power	MVAr[b]
3QPKD	Three-phase peak demand reactive power	MVAr[b]
UAPKD, UBPKD, UCPKD	Phase peak demand apparent power	MVA[b]
3UPKD	Three-phase peak demand apparent power	MVA[b]
IAD, IBD, ICD	Phase demand current	A[b]
3I2D	Negative-sequence demand current	A[b]
IGD	Zero-sequence demand current	A[b]
PAD, PBD, PCD	Phase demand real power	MW[b]
3PD	Three-phase demand real power	MW[b]
QAD, QBD, QCD	Phase demand reactive power	MVAr[b]
3QD	Three-phase demand reactive power	MVAr[b]
UAD, UBD, UCD	Phase demand apparent power	MVA[b]
3UD	Three-phase demand apparent power	MVA[b]

Table B.2 Analog Quantities Sorted By Function (Sheet 5 of 8)

Label	Description	Units
Energy		
MWHAOUT, MWHBOUT, MWHCOUT	Phase positive (export) energy	MWh[b]
MWHAIN, MWHBIN, MWHCIN	Phase negative (import) energy	MWh[b]
MWHAT, MWHBT, MWHCT	Phase total energy	MWh[b]
3MWHOUT	Three-phase positive (export) energy	MWh[b]
3MWHIN	Three-phase negative (import) energy	MWh[b]
3MWH3T	Three-phase total energy	MWh[b]
RTD Temperature		
RTD01–RTD12	Instantaneous temperatures from the SEL-2600	°C
Mirrored Bits®		
MB1A–MB7A	Mirrored Bits communications A Channel received analog values	n/a
MB1B–MB7B	Mirrored Bits communications B Channel received analog values	n/a
SELogic and Automation Elements		
PMV01–PMV64	Protection SELogic control equation math variable	n/a
PCT01PU–PCT32PU	Protection conditioning timer pickup time	cycles
PCT01DO–PCT32DO	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
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

Table B.2 Analog Quantities Sorted By Function (Sheet 6 of 8)

Label	Description	Units
Breaker Wear		
B1BCWPA, B1BCWPB, B1BCWPC	Circuit Breaker 1 contact wear	percent
B2BCWPA, B2BCWPB, B2BCWPC	Circuit Breaker 2 contact wear	percent
Date and Time		
TODMS[d]	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
TNSEC	Nanoseconds (0–999999)	ns
DDOW	Day of the week[e]	n/a
DDOM	Day of the month (1–31)	n/a
DDOY	Day of the year (1–365)	n/a
DMON	Month (1–12)	n/a
DYEAR	Year (2000–2200)	n/a
TUTC	Offset from IRIG-B time to UTC time	hours
TQUAL	Worst-case IRIG-B clock time error	seconds
Time-Error Calculation		
TECORR[f]	Time error correction factor	seconds
TE	Time error	seconds
Reclosing		
3PSHOT	Present value of three-pole shot counter	n/a
SHOT3_1	Total number of first-shot three-pole reclosures	n/a
SHOT3_2	Total number of second-shot three-pole reclosures	n/a
SHOT3_3	Total number of third-shot three-pole reclosures	n/a
SHOT3_4	Total number of fourth-shot three-pole reclosures	n/a
SHOT3_T	Total number of three-pole reclosures	n/a
Fault Location		
FLOC	Fault location[g]	per unit
Positive-Sequence Impedance		
Z1FM	Positive-sequence instantaneous impedance magnitude	Ω
Z1FA	Positive-sequence instantaneous impedance angle	degrees
Current and Voltage Scaling Settings		
CTRW	CTRW setting from active group	n/a
CTRX	CTRX setting from active group	n/a
PTRY	PTRY setting from active group, divided by 1000	n/a
PTRZ	PTRZ setting from active group, divided by 1000	n/a

Table B.2 Analog Quantities Sorted By Function (Sheet 7 of 8)

Label	Description	Units
Synchrophasor Measurements		
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude (I_W terminals)	A[b]
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle (I_W terminals)	degrees
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current, real component (I_W terminals)	A[b]
IAWPMI, IBWPMI, ICWPMI	Synchrophasor current, imaginary component (I_W terminals)	A[b]
IAXPMM, IBXPMM, ICXPMM	Synchrophasor current magnitude (I_X terminals)	A[b]
IAXPMA, IBXPMA, ICXPMA	Synchrophasor current angle (I_X terminals)	degrees
IAXPMR, IBXPMR, ICXPMR	Synchrophasor current, real component (I_X terminals)	A[b]
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current, imaginary component (I_X terminals)	A[b]
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude (I_W + I_X terminals)	A[b]
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMR, IBSPMR, ICSPMR	Synchrophasor current, real component (I_W + I_X terminals)	A[b]
IASPMI, IBSPMI, ICSPMI	Synchrophasor current, imaginary component (I_W + I_X terminals)	A[b]
I1WPMM	Synchrophasor positive-sequence current magnitude (I_W terminals)	A[b]
I1WPMA	Synchrophasor positive-sequence current angle (I_W terminals)	degrees
I1WPMR	Synchrophasor positive-sequence current, real component (I_W terminals)	A[b]
I1WPMI	Synchrophasor positive-sequence current, imaginary component (I_W terminals)	A[b]
I1XPMM	Synchrophasor positive-sequence current magnitude (I_X terminals)	A[b]
I1XPMA	Synchrophasor positive-sequence current angle (I_X terminals)	degrees
I1XPMR	Synchrophasor positive-sequence current, real component (I_X terminals)	A[b]

Table B.2 Analog Quantities Sorted By Function (Sheet 8 of 8)

Label	Description	Units
I1XPMI	Synchrophasor positive-sequence current, imaginary component (I_X terminals)	A[b]
I1SPMM	Synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[b]
I1SPMA	Synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMR	Synchrophasor positive-sequence current, real component (I_W + I_X terminals)	A[b]
I1SPMI	Synchrophasor positive-sequence current, imaginary component (I_W + I_X terminals)	A[b]
VALPMM, VBLPMM, VCLPMM	Synchrophasor voltage magnitude	kV[b]
VALPMA, VBLPMA, VCLPMA	Synchrophasor voltage angle	degrees
VALPMR, VBLPMR, VCLPMR	Synchrophasor voltage, real component	kV[b]
VALPMI, VBLPMI, VCLPMI	Synchrophasor voltage, imaginary component	kV[b]
V1LPMM	Synchrophasor positive-sequence voltage magnitude	kV[b]
V1LPMA	Synchrophasor positive-sequence voltage angle	degrees
V1LPMR	Synchrophasor positive-sequence voltage, real component	kV[b]
V1LPMI	Synchrophasor positive-sequence voltage, imaginary component	kV[b]
SODPM	Second-of-day of the synchrophasor data	seconds
FOSPM	Fraction-of-second of the synchrophasor data	seconds
Control Inputs		
IN101A–IN107A[h]	Digital input values available as floating point quantities between 0.0 and 255.0. Multiply value by 1.04 to obtain volts.	A/D counts
IN201A–IN208A[h]	Digital input values available as floating point quantities between 0.0 and 255.0. Multiply value by 1.27 to obtain volts.	A/D counts
IN301A–IN308A[h]	Digital input values available as floating point quantities between 0.0 and 255.0. Multiply value by 1.27 to obtain volts.	A/D counts
Database Structure		
RA001–RA256	Remote analogs from Ethernet card.	n/a

[a] These terminal-specific magnitude and angle quantities are calculated separately from all other analog quantities. These angle values are non-stationary, and should not be used in SELOGIC Math expressions with any other (stationary) angle quantities. Angle accuracy: Phase-to-ground ±3°, Phase-to-phase ±6°
[b] Primary value of measurement.
[c] Measured value if the relay can track frequency, otherwise nominal frequency setting NFREQ, and DFDT is undefined. (DFDT operates only when Global setting EPMU := Y)
[d] Cannot contain 1/8-cycle accuracy throughout the day because as a floating point value, there are only 7 digits of precision.
[e] Encoded value: 1 = Sun, 2 = Mon, 3 = Tue, 4 = Wed, 5 = Thu, 6 = Fri, 7 = Sat.
[f] Copy of last value set by TEC command or DNP3.
[g] See Fault Location on page R.1.17 for more information on this value.
[h] Digital input analog values are not available for boards that have 24 inputs.

Glossary

"a" Contact A breaker auxiliary contact (ANSI Standard Device Number 52A) that closes when the breaker is closed and opens when the breaker is open.

"a" Output A relay control output that closes when the output relay asserts.

"b" Contact A breaker auxiliary contact (ANSI Standard Device Number 52B) that opens when the breaker is closed and closes when the breaker is open.

"b" Output A relay control output that opens when the output relay asserts.

"c" Contact A breaker auxiliary contact that can be set to serve either as an "a" contact or as a "b" contact.

"c" Output An output with both an "a" output and "b" output sharing a common post.

3U, 4U, 5U The designation of the vertical height of a device in rack units. One rack unit, U, is approximately 1.75 inches or 44.45 mm.

A Abbreviation for amps or amperes; unit of electrical current flow.

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. Such testing 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. Except for Access Level 0, you must have the correct password to enter an access level.

Access Level 0 The least secure and most limited access level. No password protects this level. From this level, you must enter a password to go to a higher level.

Access Level 1 A relay command level you use to monitor (view) relay information. The default access level for the relay front panel.

Access Level 2 The most secure access level where you have total relay functionality and control of all settings types.

Access Level A A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Automation, Alias, Global, Front Panel, Report, Port, and DNP settings.

Access Level B
A relay command level you use for Access Level 1 functions plus circuit breaker control and data.

Access Level O
A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Output, Alias, Global, Front Panel, Report, Port, and DNP settings.

Access Level P
A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Protection, SELOGIC, Alias, Global, Group, Breaker Monitor, Front Panel, Report, Port, 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-451 is presently using from among six settings groups available in the relay.

Admittance
The reciprocal of impedance; I/V.

Advanced Settings
Settings for customizing protection functions; these settings are hidden unless you set EADVS := Y and EGADVS := Y.

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:

- 21 Distance element
- 25 Synchronism-check element
- 27 Undervoltage Element
- 32 Directional Elements
- 50 Overcurrent Element
- 51 Inverse-Time Overcurrent Element
- 52 AC Circuit Breaker
- 59 Overvoltage Element
- 67 Definite Time Overcurrent
- 79 Recloser
- 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
- G Residual/Ground Element
- N Neutral/Ground Element
- Q Negative-Sequence (3I2) Element

Anti-Aliasing Filter A low pass filter that blocks frequencies too high for the given sampling rate to accurately reproduce.

Apparent Power, S Complex power expressed in units of volt-amps (VA), kilovolt-amps (kVA), or megavolt-amps (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: $S = P + jQ$. This is power at the fundamental frequency only; no harmonics are included in this quantity.

Arcing Resistance The resistance in the arc resulting from a power line fault.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The SEL-451 uses ASCII text characters to communicate using front-panel and rear-panel EIA-232 serial ports on the relay and through 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-451 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 (an SEL 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.

Automatic Reclose Automatic closing of a circuit breaker after a breaker trip by a protective relay.

Automation Variables Variables that you include in automation SELOGIC control equations.

Auto-Reclose-Drive-to-Lockout A logical condition that drives the auto-reclose function out of service with respect to a specific circuit breaker.

Autotransformer A transformer with at least two common windings.

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.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Best Choice Ground Directional Supervision™ logic An SEL logic that determines the directional element that the relay uses for ground faults.

Bit Label The identifier for a particular bit.

Bit Value Logical 0 or logical 1.

Block Trip Extension Continuing the blocking signal at the receiving relay by delaying the dropout of Relay Word bit BT.

Blocking Signal Extension The blocking signal for the DCB (directional comparison blocking) trip scheme is extended by a time delay on dropout timer to prevent unwanted tripping following current reversals.

Bolted Fault A fault with essentially zero impedance or resistance between the shorted conductors.

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.

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.

C37.118 C37.118 IEEE Standard for Synchrophasors for Power Systems

Category A collection of similar relay settings.

CCVT Coupling-capacitor voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CVT.

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.

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-451 detects and warns of failure or incomplete operation of a circuit breaker in clearing a fault or in performing a trip or close sequence.

Circuit Breaker History Report A concise circuit breaker event history that contains as many as 128 events. This breaker history report includes circuit breaker mechanical operation times, electrical operation times, interrupted currents, and dc battery monitor voltages.

Circuit Breaker Report A full report of breaker parameters for the most recent operation. These parameters include interrupted currents, number of operations, and mechanical and electrical operating times among many parameters.

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.

Cold Start Beginning a system from power up without carryover of previous system activities.

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.

Common Time Delay Both ground and phase distance protection follow a common time delay on pickup.

Common Zone Timing Both ground and phase distance protection follow a common time delay on pickup.

Communications Protocol A language for communication between devices.

Communications-Assisted Tripping Circuit breaker tripping resulting from the transmission of a control signal over a communications medium.

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.

COMTRADE Abbreviation for Common Format for Transient Data Exchange. The SEL-451 supports the IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999.

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.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

Control Input Relay inputs for monitoring the state of external circuits. Connect auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay outputs that affect the state of other equipment. Connect control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

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.

Cross-country fault A cross-country fault consists of simultaneous separate single phase-to-ground faults on parallel lines.

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 Reversal Guard Logic Under this logic, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal when a reverse-looking element detects an external fault.

Current Transformer Saturation The point of maximum current input to a current transformer; any change of input beyond the saturation point fails to produce any appreciable change in output.

CVT Capacitive voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CCVT.

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.

DCB (Directional Comparison Blocking) A communications-assisted protection scheme. A fault occurring behind a sending relay causes the sending relay to transmit a blocking signal to a remote relay; the blocking signal interrupts the tripping circuit of the remote relay and prevents tripping of the protected line.

DCE Devices Data communication equipment devices (modems).

DCUB (Directional Comparison Unblocking) A communications-assisted tripping scheme with logic added to a POTT scheme that allows high-speed tripping of overreaching elements for a brief time during a loss of channel. The logic then blocks trip permission until the communications channel guard returns for a set time.

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-451 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-451 uses in DNP protocol.

Delta A phase-to-phase series connection of circuit elements, particularly voltage transformers or loads.

Demand Meter A measuring function that calculates a rolling average or thermal average of instantaneous measurements over time.

Direct Tripping Local or remote protection elements provide tripping without any additional supervision.

Directional Start A blocking signal provided by reverse reaching elements to a remote terminal used in DCB communications-assisted tripping schemes. If the fault is internal (on the protected line), the directional start elements do not see the fault and do not send a blocking signal. If the fault is external (not on the protected line), the directional start elements start sending the block signal.

Directional Supervision The relay uses directional elements to determine whether protective elements operate based on the direction of a fault relative to the relay.

Disabling Time Delay A DCUB scheme timer (UBDURD) that prevents high-speed tripping following a loss-of-channel condition.

DMTC Period The time of the demand meter time constant in demand metering.

DNP (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol.

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.

DUTT (Direct Underreaching Transfer Trip) A communications-assisted tripping scheme. Detection of a Zone 1 fault at either end of a line causes tripping of the local circuit breaker as well as simultaneous transmission of a tripping signal to the relay at the opposite end of the line. The scheme is said to be underreaching because the Zone 1 relays at both ends of the line reach only 80 percent (typically) of the entire line length.

Echo The action of a local relay returning (echoing) the remote terminal permissive signal to the remote terminal when the local breaker is open or a weak infeed condition exists.

Echo Block Time Delay A time delay that blocks the echo logic after dropout of local permissive elements.

Echo Duration Time Delay A time delay that limits the duration of the echoed permissive signal.

ECTT (Echo Conversion to Trip) An element that allows a weak terminal, after satisfaction of specific conditions, to trip by converting an echoed permissive signal to a trip signal.

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 at the farthest end of a zone that a relay is required to protect.

Energy Metering Energy metering provides a look at imported power, exported power, and net usage over time; measured in MWh (megawatt hours).

Equalize Mode A procedure where substation batteries are overcharged intentionally for a preselected time in order to bring all cells to a uniform output.

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, fault location, time source, recloser shot counter, prefault and fault voltages, currents, and sequence current, and MIRRORED BITS communications channel status (if enabled).

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 Hybrid Control Output A control output similar to, but faster than, the hybrid control output. The fast hybrid output uses an insulated gate bipolar junction transistor (IGBT) to interrupt (break) high inductive dc currents and to very rapidly make and hold the current until a metallic contact operates, at which time the IGBT turns off and the metallic contact holds the current. Unlike the hybrid control output, this output is not polarity sensitive; reversed polarity causes no misoperations.

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.

Fast Message SEL binary serial port protocol used for Fast SER, Fast Message Synchrophasors, and RTD communications.

Fault Type Identification Selection Logic the relay uses to identify balanced and unbalanced faults (FIDS).

FID Relay firmware identification string. Lists the relay model, firmware version and date code, and other information that uniquely identifies the firmware installed in a particular relay.

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.

Flashover A disruptive discharge over the surface of a solid dielectric in a gas or liquid.

Float High The highest charging voltage supplied by a battery charger.

Float Low The lowest charging voltage supplied by a battery charger.

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 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, date format, phase rotation, nominal system frequency, enables, station dc monitoring, control inputs, settings group selection, data reset controls, frequency tracking, time and date management, and current and voltage source selection.

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.

Ground Directional Element Priority The order the relay uses to select directional elements to provide ground directional decisions; relay setting ORDER.

Ground Distance Element A mho or quadrilateral distance element the relay uses to detect faults involving ground along a transmission line.

Ground Fault Loop Impedance The impedance in a fault-caused electric circuit connecting two or more points through ground conduction paths.

Ground Overcurrent Elements Elements that operate by comparing a residual ground calculation of the three-phase inputs with the residual overcurrent threshold setting. The relay asserts

ground overcurrent elements when a relay residual current calculation exceeds ground current setting thresholds.

Ground Return Resistance Fault resistance that can consist of ground path resistance typically in tower footing resistance and tree resistance.

Guard-Present Delay A timer that determines the minimum time before the relay reinstates permissive tripping following a loss-of-channel condition in the DCUB communications-assisted tripping scheme; relay setting GARD1D.

GUI Graphical user interface.

Hexadecimal Address A register address consisting of a numeral with an “h” suffix or a “0x” prefix.

High-Resolution Data Capture Reporting of 3 kHz low-pass analog filtered data from the power system at each event trigger or trip at high sample rates of 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second.

HMI Human machine interface.

Homogeneous System A power system with nearly the same angle (<5 ° difference) for the impedance angles of the local source, the protected line, and the remote source.

HV High voltage. System voltage greater than or equal to 100 kV and less than 230 kV.

Hybrid Control Output Contacts that use an insulated gate bipolar junction transistor (IGBT) in parallel with a mechanical contact to interrupt (break) high inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients. These contacts are polarity dependent and cannot be used to switch ac control signals.

IA, IB, IC Measured A-phase, B-phase, and C-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.

IEEE Institute of Electrical and Electronics Engineers, Inc.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero.

IGBT Insulated gate bipolar junction transistor.

Infinite Bus A constant-voltage bus.

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.

Instantaneous Meter Type of meter data presented by the SEL-451 that includes the present values measured at the relay ac inputs. The word "Instantaneous" is used to differentiate these values from the measurements presented by the demand, thermal, energy, and other meter types.

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.

Load Encroachment The load-encroachment feature allows setting of phase overcurrent elements independent of load levels.

Local Bits The Relay Word bit outputs of local control switches that you access through the SEL-451 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 by hand.

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.

Loss of Channel Loss of guard and no permissive signal from communications gear in a DCUB (directional comparison unblocking scheme) for either two or three terminal lines.

Loss of Guard No guard signal from communications gear.

Loss of Potential Loss of one or more phase voltage inputs to the relay secondary inputs.

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 and provide a numerical base-10 result.

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.

Maximum/Minimum Meter Type of meter data presented by the SEL-451 that includes a record of the maximum and minimum of each value, along with the date and time that each maximum and minimum occurred.

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 technique 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.

MOD Motor-operated disconnect.

Model Model of device (or component of a device) including the data, control access, and other features in UCA protocol.

Motor Running Time The circuit breaker motor running time. Depending on your particular circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressor motor.

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 A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°, and have clockwise phase rotation with current and voltage maxima that occur

differently from that for positive-sequence configuration. If positive-sequence maxima occur as ABC, negative-sequence maxima occur as ACB.

Negative-Sequence Current Supervision Pickup An element allowed to operate only when a negative-sequence current exceeds a threshold.

Negative-Sequence Directional Element An element that provides directivity by the sign, plus or minus, of the measured negative-sequence impedance.

Negative-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced negative-sequence set of voltage sources.

Negative-Sequence Overcurrent Elements Elements that operate by comparing a negative-sequence calculation of the three-phase secondary inputs with negative-sequence overcurrent setting thresholds. The relay asserts these elements when a relay negative-sequence calculation exceeds negative-sequence current setting thresholds.

Negative-Sequence Voltage-Polarized Directional Element These directional elements are 32QG and 32Q. 32QG supervises the ground distance elements and residual directional overcurrent elements; 32Q supervises the phase distance elements.

NEMA National Electrical Manufacturers' Association.

Neutral Impedance An impedance from neutral to ground on a device such as a generator or transformer.

No Current/Residual Current Circuit Breaker Failure Protection Logic Logic for detecting and initiating circuit breaker failure protection with a logic transition, or when a weak source drives the fault or a high-resistance ground fault occurs.

Nondirectional Start A blocking signal provided by nondirectional overcurrent elements to a remote terminal used in DCB communications-assisted tripping schemes. The nondirectional start elements start sending the block signal.

Nonhomogeneous System A power system with a large angle difference (>5° difference) for the impedance angles of the local source, the protected line, and the remote source.

Nonvolatile Memory Relay memory that persists over time to maintain the contained data even when the relay is deenergized.

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.

Override Values Test values you enter in Fast Meter, DNP, and communications card database storage.

Parentheses Operator Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Peak Demand Metering Maximum demand and a time stamp for phase currents, negative-sequence and zero-sequence currents, and powers. The SEL-451 stores peak demand values and the date and time these occurred to nonvolatile storage once per day, overwriting the previously stored value if the new value is larger. Should the relay lose control power, the relay restores the peak demand information saved at 23:50 hours on the previous day.

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.

Phase Rotation The sequence of voltage or current phasors in a multiphase electrical system. In an ABC phase rotation system, the B-phase voltage lags the A-phase voltage by 120°, and the C-phase voltage lags B-phase voltage by 120°. In an ACB phase rotation system, the C-phase voltage lags the A-phase voltage by 120°, and the B-phase voltage lags the C-phase voltage by 120°.

Phase Selection Ability of the relay to determine the faulted phase or phases.

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.

Polarizing Memory A circuit that provides a polarizing source for a period after the polarizing quantity has changed or gone to zero.

Pole-Open Logic Logic that determines the conditions that the relay uses to indicate an open circuit breaker pole.

Port Settings Communications port settings such as Data Bits, Speed, and Stop Bits.

Positive-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°. With conventional rotation in the counter-clockwise direction, the positive-sequence current and voltage maxima occur in ABC order.

Positive-Sequence Current Restraint Factor, a2 This factor compensates for highly unbalanced systems with many untransposed lines and helps prevent misoperation during current transformer saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current (I2/I1).

Positive-Sequence Current Supervision Pickup An element that operates only when a positive-sequence current exceeds a threshold.

Positive-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced positive-sequence set of voltage sources.

POTT (Permissive Overreaching Transfer Trip) A communications-assisted line protection scheme. At least two overreaching protective relays must receive a permissive signal from the other terminal(s) before all relays trip and isolate the protected line.

Power Factor The cosine of the angle by which phase current lags or leads phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a pure resistive load.

PPS Pulse per second from a GPS receiver. Previous SEL-451 relays had a TIME 1k PPS input.

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 deenergization of all control outputs.

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.

Real Power Power that produces actual work. The portion of apparent power that is real, not imaginary.

Reclose The act of automatically closing breaker contacts after a protective relay trip has opened the circuit breaker contacts and interrupted current through the breaker.

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.

Residual Current The sum of the measured phase currents. In normal, balanced operation, this current is very small or zero.

Residual Directional Overcurrent Element A residual overcurrent element allowed to operate in only the forward or reverse direction.

Residual Overcurrent Protection Overcurrent protection that operates at conditions exceeding a threshold of system unbalance ($3I_0 = I_A + I_B + I_C$).

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.

Reverse Fault A fault operation behind a relay terminal.

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.

Rolling Demand A sliding time-window arithmetic average in demand metering.

RTD Resistance Temperature Detector

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 GOMSFE in the UCA2 protocol. A master device can request a description of all of the GOMSFE models 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-451 has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR QuickSet SEL-5030 Software program for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

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.

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.

Shot Counter A counter that records the number of times a recloser attempts to close a circuit breaker.

Shunt Admittance The admittance resulting from the presence of a device in parallel across other devices or apparatus that diverts some current away from these devices or apparatus.

Shunt Capacitance The capacitance between a network connection and any existing ground.

Shunt Current The current that a parallel-connected high-resistance or high-impedance device diverts away from devices or apparatus.

SIN Operator Operator in math SELOGIC control equations that provides the sine function.

SIR Source-to-line impedance ratio.

SOTF (Switch-Onto-Fault Protection Logic) Logic that provides tripping if a circuit breaker closes into a zero voltage bolted fault, such as would happen if protective grounds remained on the line following maintenance.

Source Impedance The impedance of an energy source at the input terminals of a device or network.

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 lower-case 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.

Synch Reference A phasor the relay uses as a polarizing quantity for synchronism check calculations.

Synchronism Check Verification by the relay that system components operate within a preset frequency difference and within a preset phase angle displacement between voltages.

Synchronized Phasor A phasor calculated from data samples using an absolute time signal as the reference for the sampling process. The phasors from remote sites have a defined common phase relationship. Also known as Synchrophasor.

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 Emulation Software Software that can be used to send and receive ASCII text messages and files via a computer serial port.

Thermal Demand Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities; used in demand metering.

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.

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 pre-determined time.

Time Error A measurement of how much time an ac powered clock would be ahead or behind a reference clock, as determined from system frequency measurements.

Time-Overcurrent Element An element that operates according to an inverse relationship between input current and time, with higher current causing faster relay operation.

Time Quality An indication from a GPS clock receiver that specifies the maximum error in the time information. Defined in IEEE C37.118.

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.

Tower Footing Resistance The resistance between true ground and the grounding system of a tower.

Transformer Impedance The resistive and reactive parameters of a transformer looking in to the transformer primary or secondary windings. Use industry accepted open-circuit and short-circuit tests to determine these transformer equivalent circuit parameters.

Tree Resistance Resistance resulting from a tree in contact with a power line.

TVE Total Vector Error. A measurement of accuracy for phasor quantities that combines magnitude and angle errors into one quantity. Defined in IEEE C37.118.

TXD Transmitted data.

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.

Unconditional Tripping Protection element tripping that occurs apart from conditions such as those involving communication, switch-onto-fault logic, etc.

Untransposed Line A transmission line with phase conductors that are not regularly transposed. The result is an imbalance in the mutual impedances between phases.

User ST Region in GOOSE for user-specified applications.

VA, VB, VC Measured A-phase-to-neutral, B-phase-to-neutral, and C-phase-to-neutral voltages.

VAB, VBC, VCA Measured or calculated phase-to-phase voltages.

VG Residual voltage calculated from the sum of the three phase-to-neutral voltages, if connected.

Virtual Terminal Connection A mechanism that uses a virtual serial port to provide the equivalent functions of a dedicated serial port and a terminal.

Volatile Storage A storage device that cannot retain data following removal of relay power.

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.

Weak Infeed Logic Logic that permits rapid tripping for internal faults when a line terminal has insufficient fault current to operate protective elements.

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 A configuration of three-phase currents and voltages with currents and voltages that occur simultaneously, are always in phase, and have equal magnitude ($3I_0 = I_A + I_B + I_C$).

Zero-Sequence Impedance Impedance of a device or circuit resulting in current flow when a single voltage source is applied to all phases.

Zero-Sequence Mutual Coupling

Zero-sequence current in an unbalanced circuit in close proximity to a second circuit induces voltage into the second circuit. When not controlled by protection system design and relay settings, this situation can cause improper operation of relays in both systems.

Zero-Sequence Overcurrent Element

Overcurrent protection that operates at conditions exceeding a threshold of system unbalance.

Zero-Sequence Voltage-Polarized Directional Element

An element that provides directionality by the sign, plus or minus, of the measured zero-sequence impedance.

Z-Number

That portion of the relay FID string that identifies the proper ACSELERATOR QuickSet software relay driver version and HMI driver version when creating or editing relay settings files.

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SEL-451 Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
89CLOSE *n*	Close disconnect switch *n* in SEL-451-4 (*n* = disconnect switches 1–10)
89OPEN *n*	Open disconnect switch *n* in SEL-451-4 (*n* = disconnect switches 1–10)
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)
BREAKER *n*	Display the circuit breaker report and breaker history; preload and reset breaker monitor data (*n* = 1 is BK1; *n* = 2 is BK2)
CASCII	Generate the Compressed ASCII response configuration message
CBREAKER	BREAKER command for the Compressed ASCII response
CEVENT	EVENT command for the Compressed ASCII response
CHISTORY	HISTORY command for the Compressed ASCII response
CLOSE *n*	Close the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
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 01–32)
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
HIZ	Displays a report of ground overcurrent high-impedance fault (50G HIZ) detection activity.
ID	Display the firmware id, user id, device code, part number, and configuration information
INI HIF	Restarts the 24-hour tuning process used in high-impedance fault detection.
IRIG	Update the internal clock/calendar from the IRIG-B input
LOG HIF	Displays the progress of the HIF detection in the percentage to their final pickup.
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)

Command[a, b]	Description
OPEN *n*	Open the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
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 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
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
TEC	Display time-error estimate; display or modify time-error correction value.
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

[a] See Section 9: 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
B	Bay	Bay Control Settings (SEL-451-4)
D	DNP3	Direct Network Protocol remapping (serial port only)
F	Front Panel	Front-panel HMI settings
G	Global 1–6	Relay-wide settings
L *n*	Protection Logic Group 1–6	Protection SELOGIC control equations
M	Breaker Monitor	Circuit breaker monitor settings
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

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