SEL-587-0, -1

Current Differential/ Overcurrent Relay

Instruction Manual

20250131

SEL SCHWEITZER ENGINEERING LABORATORIES

Part Number:PM587-01

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Preface

Safety Information

Dangers, Warnings, and Cautions

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

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

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

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

Safety Symbols

The following symbols are often marked on SEL products.

	**⚠CAUTION** Refer to accompanying documents.	**⚠ATTENTION** Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d’instructions

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Panasonic BR-2330A or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C, or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.	⚠ATTENTION Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Panasonic BR-2330A ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.

Other Safety Marks

⚠DANGER Removal of relay front panel exposes circuitry which may cause electrical shock that can result in injury or death.	⚠DANGER Le retrait du panneau avant expose à la circuiterie qui pourrait être la source de chocs électriques 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 blessures ou la mort.
⚠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 is not 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 accès nonautorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès nonautorisé.
⚠CAUTION The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.	⚠ATTENTION Le relais contient des pièces sensibles aux décharges électrostatiques. Quand on travaille sur le relais avec les panneaux avant ou du dessus enlevés, toutes les surfaces et le personnel doivent être mis à la terre convenablement pour éviter les dommages à l'équipement.
⚠CAUTION This procedure requires that you handle components sensitive to Electrostatic Discharge (ESD). If your facility is not equipped to work with these components, we recommend that you return the relay to SEL for firmware installation.	⚠ATTENTION Cette procédure requiert que vous manipuliez des composants sensibles aux décharges électrostatiques (DES). Si vous n'êtes pas équipés pour travailler avec ce type de composants, nous vous recommandons de les retourner à SEL pour leur installation.
⚠CAUTION Verify proper orientation of any replaced Integrated Circuit(s) (ICs) before reassembling the relay. Energizing the relay with an IC reversed irrecoverably damages the IC. If you mistakenly re-energize the relay with an IC reversed, do not place the relay in service using that IC, even if you correct the orientation.	⚠ATTENTION Vérifier l'orientation d'un circuit intégré (CI) que vous remplacez avant de l'installer sur le relais. La mise sous-tension du relais avec un CI inversé endommagera de façon irréversible celui-ci. Si vous remettez le relais sous tension par mégarde, ne pas laisser le relais en service avec ce CI, même si l'orientation a été corrigée.
⚠CAUTION Before performing any tests, verify that the injected test signals do not exceed the maximum specified current levels and times. See *Relay Specifications* in *Section 1: Introduction and Specifications* for details.	⚠ATTENTION Avant d'appliquer les tests, vérifier que les signaux injectés ne dépassent pas les niveaux maxima de courant pendant les intervalles de temps prescrits. Consulter pour les détails le manuel *Spécifications du relais, Section 1: Introduction et Spécifications*.

Section 1

Introduction and Specifications

Introduction

The SEL-587 is available as either an SEL-587-0 or SEL-587-1. Either model is a current differential relay and overcurrent relay that provides current differential protection plus two complete groups of overcurrent elements in one compact package. The relay measures high- and low-side currents, differential operate and restraint quantities, as well as second and fifth harmonics of the applied currents. The unit provides two optoisolated inputs, four programmable output contacts, and one alarm output contact. In addition, the SEL-587-1 measures dc and fourth harmonic of the applied currents.

Use this relay to protect two-winding power transformers, reactors, generators, large motors, and other two-terminal power apparatus. The relay settings permit you to use wye- or delta-connected high- and low-side current transformers. The relay compensates for various equipment and CT connections to derive appropriate differential operating quantities.

The SEL-587 provides three differential elements with dual slope characteristics. The second slope provides security against CT saturation for heavy through faults. Be sure to conduct detailed analysis of CT performance under worst-case saturation conditions to set the relay characteristic correctly for bus protection applications. For assistance with CT selection, obtain SEL Application Guide *AG99-07, Bus Protection Using a Four-Winding Low-Impedance Percentage Differential Relay* from the SEL website (www.selinc.com).

Overview

Instruction Manual

This instruction manual applies to SEL-587-0 and SEL-587-1 relays. If you are unfamiliar with these relays, we suggest that you read the following sections in the outlined order.

Section 1: Introduction and Specifications for a brief overview of the relay's capabilities and general specifications.

Section 3: Relay Elements to understand the protection and application.

Section 4: Tripping, Closing, and Targeting Logic for a description of the logic and how it works with logic inputs, the Relay Word, and relay outputs.

Section 5: Setting the Relay for a description of how to make setting changes and the setting sheets.

Section 6: Operator Interface for a description of the serial port commands used to set the relay for protection, set the relay for control, obtain target information, and obtain metering information, etc. This section also describes how to perform these functions by using the front panel.

Section 7: Event Reports for a description of event report generation, summary event reports, long event reports, and their interpretation.

Section 2: Installation for a description of how to configure, install, and then wire the relay.

Section 8: Testing and Troubleshooting for test procedures and a troubleshooting guide. You can use this section as a tutorial to check your understanding of the relay's operation.

Hardware

Figure 1.1 shows the front panel of both the SEL-587-0 and SEL-587-1 relays.

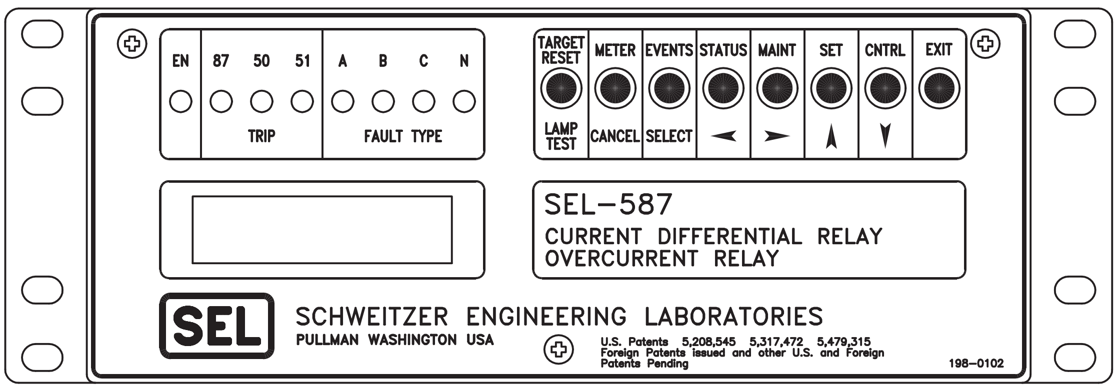

Figure 1.1 Front Panel Without Front Serial Port

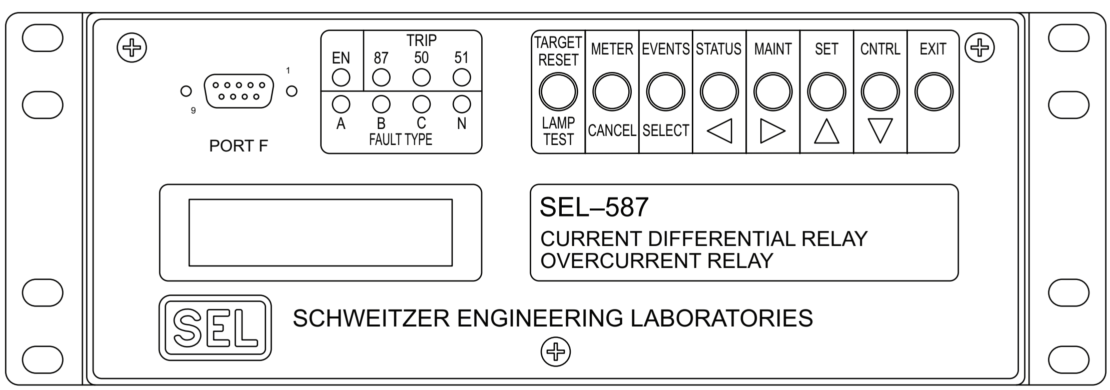

Figure 1.2 Front Panel With Front Serial Port

The block diagram in *Figure 1.3* shows the relay hardware arrangement. A single microprocessor, data acquisition system, and power supply perform the functions required to provide current differential and overcurrent protection.

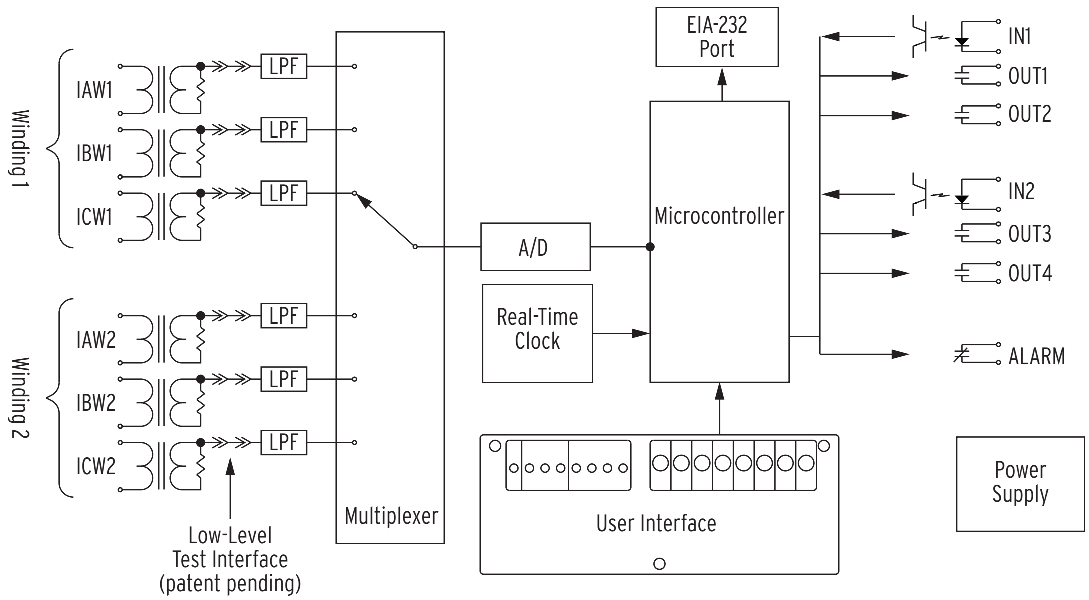

Figure 1.3 Hardware Block Diagram

SEL-587 Functions

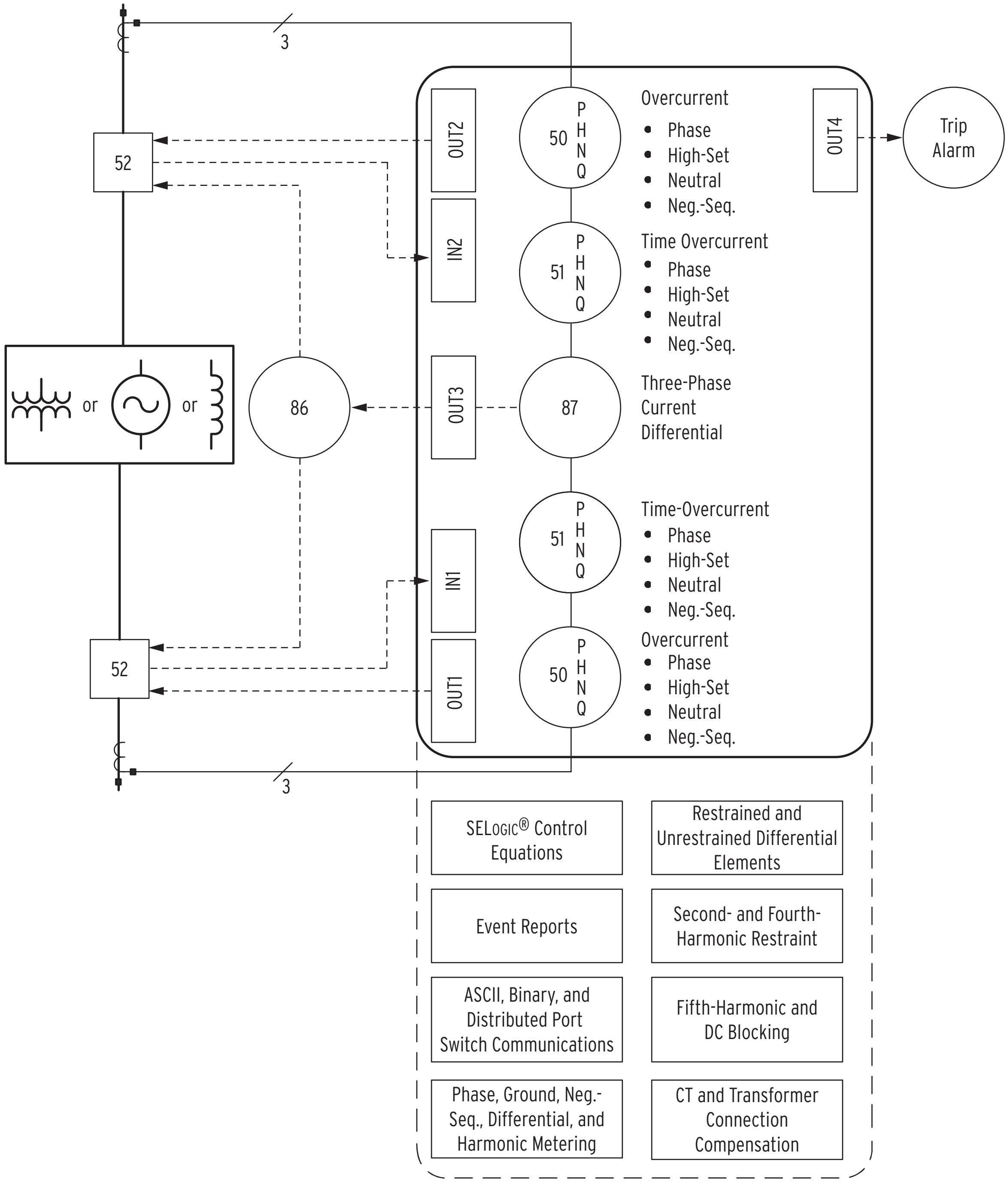

Figure 1.4 Protection Functions

Current Differential Protection

The SEL-587 includes independent restrained and unrestrained current differential elements. The restrained element has a dual-slope, percentage restraint characteristic. Where required, you can set second- and fifth-harmonic blocking functions to provide differential element security for nonfault conditions. An unrestrained differential element provides faster clearance of high-magnitude, internal faults.

Overcurrent Protection

The SEL-587 provides high- and low-side nondirectional overcurrent elements:

- Instantaneous phase and residual overcurrent elements
- Definite-time phase, residual, and negative-sequence overcurrent elements
- Inverse-time phase, residual, and negative-sequence overcurrent elements

Overcurrent element pickup settings and operating characteristics are independent of the differential element settings. Overcurrent elements operate on the secondary current that is applied to the terminals of the relay. When setting overcurrent elements with delta-connected CTs, care should be taken to consider what the primary system line currents are when compared to the secondary line-to-line current, which is supplied to the relay

Programmable Output Contacts

The SEL-587 is equipped with SELOGIC® control equations that allow you to design a custom tripping scheme. SELOGIC control equation functions include two independent timers, tripping, event report triggering, and relay output contact control. An example of this flexibility is shown in *Figure 1.4*, where OUT1 and OUT2 are set to trip the high- and low-side circuit breakers independently, while OUT3 operates the transformer lockout relay and OUT4 operates a tripping annunciator.

CT Saturation Protection

The SEL-587 phase instantaneous overcurrent elements normally operate using the output of a cosine filter algorithm. During heavy fault currents when the relay detects severe CT saturation, the overcurrent elements can operate on the adaptive current algorithm.

The adaptive current algorithm is only used for phase instantaneous overcurrent elements if and only if the corresponding pickup setting is greater than eight times the nominal phase current. For example, if 50P1P = 45 A (in a 5 A nominal phase current relay), then the 50P1P element operates on the adaptive current algorithm. However, if 50P1P = 35 A, then the 50P1P element operates on the output of a cosine filter algorithm. No other overcurrent elements use the adaptive current algorithm.

Based on the level of a "harmonic distortion index," the adaptive current is either the output of the cosine filter or the output of the bipolar peak detector. When the harmonic distortion index exceeds the fixed threshold that indicates severe CT saturation, the adaptive current is the output of the bipolar peak detector. When the harmonic distortion index is below the fixed threshold, the adaptive current is the output of the cosine filter.

The cosine filter provides excellent performance in removing dc offset and harmonics. However, the bipolar peak detector has the best performance in situations of severe CT saturation when the cosine filter magnitude estimation is significantly degraded. Combining the two filters provides an elegant solution for ensuring dependable phase instantaneous overcurrent element operation.

Model Variations

SEL-587-0 Relay

The SEL-587-0 has provided sophisticated and reliable service for many years. It continues to satisfy the needs of most of our customers. However, we recommend using the SEL-587-1 for new designs because of the additional features it provides.

SEL-587-1 Relay

The following explains the differences between the SEL-587-0 and the SEL-587-1.

- The SEL-587-0 trip logic can be set in one of two configurations, while the SEL-587-1 can be set in one of three configurations. The trip logic of each relay can be set to always latch the trip or to latch the trip if the current is above a certain threshold. The SEL-587-1 adds the ability to block trip latching.
- Each relay provides the ability to protect transformers with a variety of transformer and CT connections. Phase-angle shifts are compensated for and zero-sequence current is removed for most cases. The SEL-587-1 adds the ability to remove zero-sequence current in transformers with grounding banks within the differential zone or zigzag transformer applications.
- In addition to the harmonic blocking capabilities of the SEL-587-0, the SEL-587-1 provides second- and fourth-harmonic restraint and dc blocking capabilities.

Conventional Terminal Blocks

This model includes hardware that supports six current inputs, two optoisolated inputs, four programmable output contacts, one alarm contact, two serial communications ports, and IRIG-B time code. It uses terminal blocks that support #6 ring terminals. This robust package meets or exceeds numerous industry standard type tests.

This relay is available in a 3.5" (2U) rack-mount package or a 4.9" panel-mount package.

Plug-In Connectors (Connectorized®)

This model includes hardware that supports all of the features of the conventional terminal blocks model. It differs in its use of plug-in connectors instead of terminal blocks. In addition, it provides:

- High-current interrupting output contacts.
- Quick connect/release hardware for rear-panel terminals.
- Level-sensitive optoisolated inputs.

This robust package meets or exceeds numerous industry standard type tests. It is available in a 3.5" (2U) rack-mount package or a 4.9" panel-mount package.

ACSELERATOR QuickSet SEL-5030 Software

The SEL-587 and SEL-587-1 relays with firmware version R702 and later are compatible with ACSELERATOR QuickSet® SEL-5030 Software. Use this software to read, set, and save relay settings, as well as monitor and control relay functions. QuickSet also provides automated help for the relay settings, and the ability to retrieve event reports from the relay. QuickSet communicates via the front serial port of the relay by using SEL ASCII communications.

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

UL Listed to U.S. and Canadian safety standards (File E212775; NRGU, NRGU7)

CE Mark

UKCA Mark

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

General

Tightening Torque

Terminal Block:

Minimum:	9 in-lb (1.1 Nm)
Maximum:	12 in-lb (1.3 Nm)

Connectorized:

Minimum:	5 in-lb (0.6 Nm)
Maximum:	7 in-lb (0.8 Nm)

Terminal Connections

Terminals or stranded copper wire. Ring terminals are recommended. Minimum temperature rating of 105°C.

AC Current Inputs

5 A nominal:	15 A continuous, 500 A for 1 s, linear to 100 A symmetrical 625 A for 1 cycle (sinusoidal waveform)
Burden:	0.16 VA @ 5 A, 1.15 VA @ 15 A
1 A nominal:	3 A continuous, 100 A for 1 s, linear to 20 A symmetrical 250 A for 1 cycle (sinusoidal waveform)
Burden:	0.06 VA @ 1 A, 0.18 VA @ 3 A

Power Supply

Rated:	125/250 V
Range:	85–350 Vdc or 85–264 Vac
Interruption:	100 ms @ 250 Vdc
Ripple:	5%
Burden:	<5.5 W
Rated:	48/125 Vdc or 125 Vac
Range:	36–200 Vdc or 85–140 Vac
Interruption:	100 ms @ 125 Vdc
Ripple:	5%
Burden:	<5.5 W
Rated:	24 Vdc
Range:	16–36 Vdc polarity-dependent
Interruption:	25 ms @ 36 Vdc
Ripple:	5%
Burden:	<5.5 W

Note: Interruption and Ripple per IEC 60255-11:1979.

Output Contacts

Conventional Terminal Blocks Option (Standard Outputs):

Make:	30 A
Carry:	6 A
1 s Rating:	100 A
MOV Protection:	270 Vac, 360 Vdc, 40 J
Pickup/Dropout Time:	< 5 ms

Breaking Capacity (10000 operations):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Cyclic Capacity (2.5 cycles/second):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Plug-In Connectors Option (High-Current Interrupting Outputs):

Make:	30 A
Carry:	6 A
MOV Protection:	330 Vdc, 40 J
Pickup/Dropout Time:	< 5 ms
Dropout Time:	< 8 ms, typical

Breaking Capacity (10000 operations):

24 V	10 A	L/R = 40 ms
48 V	10 A	L/R = 40 ms
125 V	10 A	L/R = 40 ms
250 V	10 A	L/R = 20 ms

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

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

Note: Do not use high-current interrupting output contacts to switch ac control signals. These outputs are polarity-dependent.

Note: Make per IEEE C37.90-1989; Breaking and Cyclic Capacity per IEC 60255-0-20:1974.

Optoisolated Inputs

Conventional Terminal Blocks Option:

Jumper-Selectable:

24 Vdc:	15–30 Vdc
48 Vdc:	30–60 Vdc
125 Vdc:	80–150 Vdc
250 Vdc:	150–300 Vdc

Level-Sensitive:

48 Vdc:	Pickup 38.4–60 Vdc; Dropout 28.8 Vdc
110 Vdc:	Pickup 88–132 Vdc; Dropout 66 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout 75 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout 132 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout 150 Vdc

Plug-In Connectors Option:

Standard (Non-Level-Sensitive):

24 Vdc:	Pickup 15–30 Vdc

Level-Sensitive:

48 Vdc:	Pickup 38.4–60 Vdc; Dropout 28.8 Vdc
110 Vdc:	Pickup 88–132 Vdc; Dropout 66 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout 75 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout 150 Vdc

Note: Optoisolated inputs draw approximately 4 mA of current. All current ratings are at nominal input voltages.

Routine Dielectric Strength Tests

AC Current Inputs,:	2500 Vac for 10 s
Power Supply, Optoisolated Inputs, and Output Contacts:	3100 Vdc for 10 s

Frequency and Rotation

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

Communications Port Options

Front-Panel Port:	EIA-232
Rear-Panel Port:	EIA-232 or EIA-485
Baud:	300–38400 bps

Time-Code Input

Relay accepts demodulated IRIG-B time-code input at Port 1.

Dimensions

See *Figure 2.1* through *Figure 2.3*.

Operating Temperature

–40° to +85°C (–40° to +185°F)

Weight

2.6 kg (5 lb, 12 oz)

Relay Shipping Weight

4 kg (9 lb)

Type Tests

Emissions

Electromagnetic Emissions for Relays:	EIC 60255-25:2000 [BS EN 60255-25:2000]
*Generic Emissions, Heavy Industrial:	EN 50081-2:1993, Class A
*Generic Immunity, Heavy Industrial:	EN 50082-2:1995, Class A
*Radiated and Conducted Emissions:	EN 55011:1998, +A1:1999 +A2:2002
Emissions	Canada ICES-001 (A) / NMB-001 (A)

Environmental Tests

Cold:	IEC 60068-2-1:1990 +A1:1993 +A2:1994 [BS EN 60068-2-1:1993 +REAF:2005] Test Ad; 16 hr at –40°C
Dry Heat:	IEC 60068-2-2:1974 +A1:1993 +A2:1994 [BS EN 60068-2-2:1993 +REAF:2005] Test Bd: 16 hr at +85 C
Damp Heat, Cyclic:	IEC 60068-2-30:1980, Test Db: 55ºC, 6 cycles, 95% humidity

Dielectric Strength and Impulse Tests

Dielectric Strength:	IEC 60255-5:1977 2500 Vac on analogs, contact inputs, and contact outputs; 3100 Vdc on power supply
Impulse:	IEC 60255-5:1977 0.5 J, 5 kV

Electromagnetic Compatibility Immunity

Magnetic Field:	IEC 61000-4-8:1993 [BS EN 61000-4-8:1994] 1000 A/m for 3 seconds, 100 A/m for 1 minute
Radiated Radio Frequency:	ENV 50140:1993 10 V/m
Electrostatic Discharge:	IEC 60255-22-2:1996 [BS EN 60255-22-2:1997], Level 2, 4, 6, 8 kV
1 MHZ Burst Disturbance	IEC 60255-22-1:1988 Class 3 (2500 V common and differential mode)
Fast Transient Disturbance:	IEEE C37.90.2-1987 10 V/m IEC 60255-22-4:1992, Level 4 (4 kv @ 2.5 kHz on power supply; 2 kV @ 5 kHz on input/output, signal, data, and control lines)
*Conducted Radio Frequency:	IEC 61000-4-6:1996 ENV 50141:1993, 10 Vrms
Radiated Radio Frequency (900 MHz With Modulation):	ENV 50204:1995 10 V/m
Surge Withstand:	IEEE C37.90.1-1989 3.0 kV oscillatory; 5.0 kV transient

Vibration and Shock Testing

Vibration:	IEC 60255-21-1:1988 [BS EN 60255-21-1:1996 +A1:1996] Class 1 Endurance, Class 2 Response
Shock and Bump:	IEC 60255-21-2:1988 [BS EN 60255-21-2:1996 +A1:1996], Class 1 Shock Withstand, Bump; Class 2 Shock Response
Seismic:	IEC 60255-21-3:1993 [BS EN 60255-21-3:1995 +A1:1995], Class 2 (Conventional Terminal Block only)

Object Penetration

Object Penetration:	IEC 60529:1989 IP30

Note: * = terminal block version only.

Sampling

16 samples per power system cycle

Processing

Differential elements, optoisolated inputs, and contact outputs are processed at 1/8 cycle.
Overcurrent elements are processed at 1/4 cycle.

Metering Accuracy

Instantaneous Currents:

5 A Model:	±2% ±0.10 A
1 A Model:	±2% ±0.02 A

Demand Currents:

5 A Model:	±2% ±0.10 A
1 A Model:	±2% ±0.02 A

Differential Element

Unrestrained Pickup Range:	1–16 in per unit of TAP
Restrained Pickup Range:	0.1–1.0 in per unit of TAP

Pickup Accuracy (A secondary):

5 A Model:	±5% ±0.10 A
1 A Model:	±5% ±0.02 A

Unrestrained Element Pickup Time

Min/Typ/Max:	0.8/1.1/2.0 cycles

Restrained Element (with harmonic blocking) Pickup Time

Min/Typ/Max:	1.6/1.7/2.3 cycles

Restrained Element (with harmonic restraint) Pickup Time (SEL-587-1)

Min/Typ/Max:	2.2/2.6/2.8 cycles

Harmonic Blocking Element

Pickup Range (% of fundamental):	5%–100%

Pickup Accuracy (A secondary):

5 A Model:	±5% ±0.10 A
1 A Model:	±5% ±0.02 A
Time-Delay Accuracy:	±0.1% ±0.25 cycle

Instantaneous/Definite-Time Overcurrent Elements (Winding)

Pickup Range (A secondary):

5 A Model:	0.5–80.0 A
1 A Model:	0.1–16.0 A

Pickup Accuracy (A secondary):

5 A Model:	±5% ±0.10 A
1 A Model:	±5% ±0.02 A
Pickup Time (Typ/Max):	0.75/1.20 cycles
Time-Delay Range:	0–16,000 cycles
Time-Delay Accuracy:	± 0.1% ± 0.25 cycle
Transient Overreach:	<5% of pickup

Time-Overcurrent Elements (Winding and Combined Current)

Pickup Range (A secondary):

5 A Model:	0.50–16.00 A
1 A Model:	0.10–3.20 A

Pickup Accuracy (A secondary):

5 A Model:	±5% ±0.10 A
1 A Model:	±5% ±0.02 A
Pickup Time (Typ/Max):	0.75/1.20 cycles

Curves:

U1 =	U.S. Moderately Inverse
U2 =	U.S. Inverse
U3 =	U.S. Very Inverse
U4 =	U.S. Extremely Inverse
C1 =	IEC Class A (Standard Inverse)
C2 =	IEC Class B (Very Inverse)
C3 =	IEC Class C (Extremely Inverse)
C4 =	IEC Long-Time Inverse

Time-Dial Range

U.S. Curves:	0.50–15.00, 0.01 step
IEC Curves:	0.05–1.00, 0.01 step
Timing Accuracy:	±4% ±2% (I_{NOM}/I_{SEC}) ±1.5 cycles for current between 2 and 30 multiples of pickup. Curves operate on definite-time for current greater than 30 multiples of pickup or 16 times nominal.
Reset Characteristic:	Induction-disk reset emulation or 1-cycle linear reset

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Section 2
Installation

Design your installation by using the mounting and connection information in this section. Options include rack or panel mounting and terminal block or plug-in connector (Connectorized®) wiring. This section also includes information on configuring the relay for your application.

Relay Mounting

Rack Mount

A single SEL-587 is roughly half the size of a standard 19-inch rack (see *Figure 2.1*, *Figure 2.6*, and *Figure 2.8*). To mount the relay in a standard 19-inch rack, use another SEL-500 series relay in a package (P/N 9101) or use the Rack-Mount Bracket (P/N 9100). See *Figure 2.2*, *Figure 2.3*, and *Figure 2.4*. Secure the relays with four rack screws (two on each side) that you insert from the front of the relays through the holes on the relay mounting flanges.

Reverse the relay mounting flanges on the single or package versions to cause the relays to project 2.60 in (66.1 mm). This provides additional space at the rear of the relays for applications where the relays might otherwise be too deep to fit.

Panel Mount

We also offer the SEL-587 in a panel-mount version for a clean look. Panel-mount relays have sculpted front-panel molding that covers all installation holes. See *Figure 2.1* and *Figure 2.8*. Cut your panel and drill mounting holes according to the dimensions in *Figure 2.1*. Insert the relay into the cutout, aligning four relay mounting studs on the rear of the relay front panel with the drilled holes in your panel, and use nuts to secure the relay to your panel.

The projection panel-mount option covers all installation holes and maintains the sculpted look of the panel-mount option; the relay projects 2.60 in (66.1 mm) from the front of your panel. This ordering option increases space at the rear of the relay for applications where the relay would ordinarily be too deep to fit your cabinet.

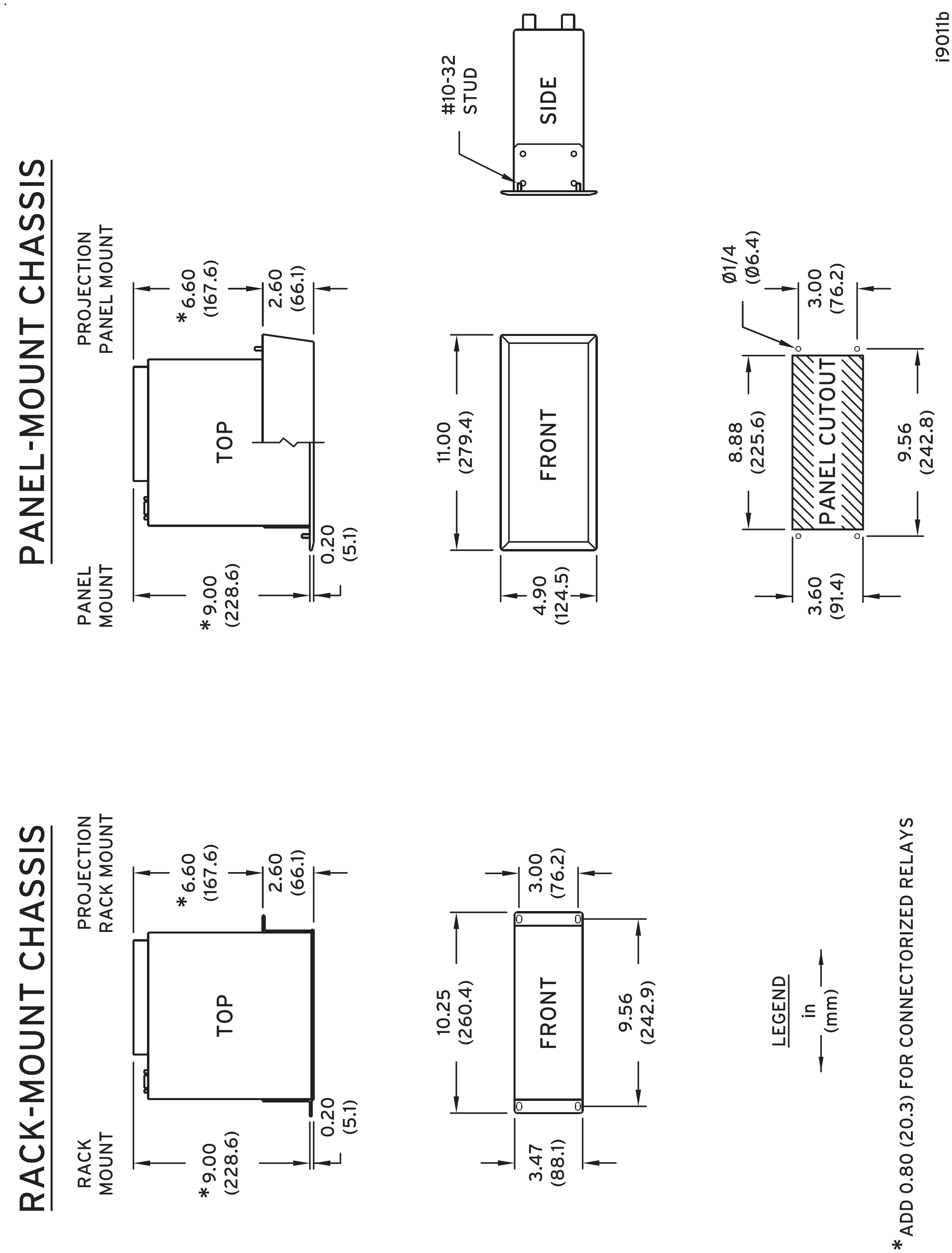

Figure 2.1 Relay Dimensions, Panel Cutout, and Drill Plan

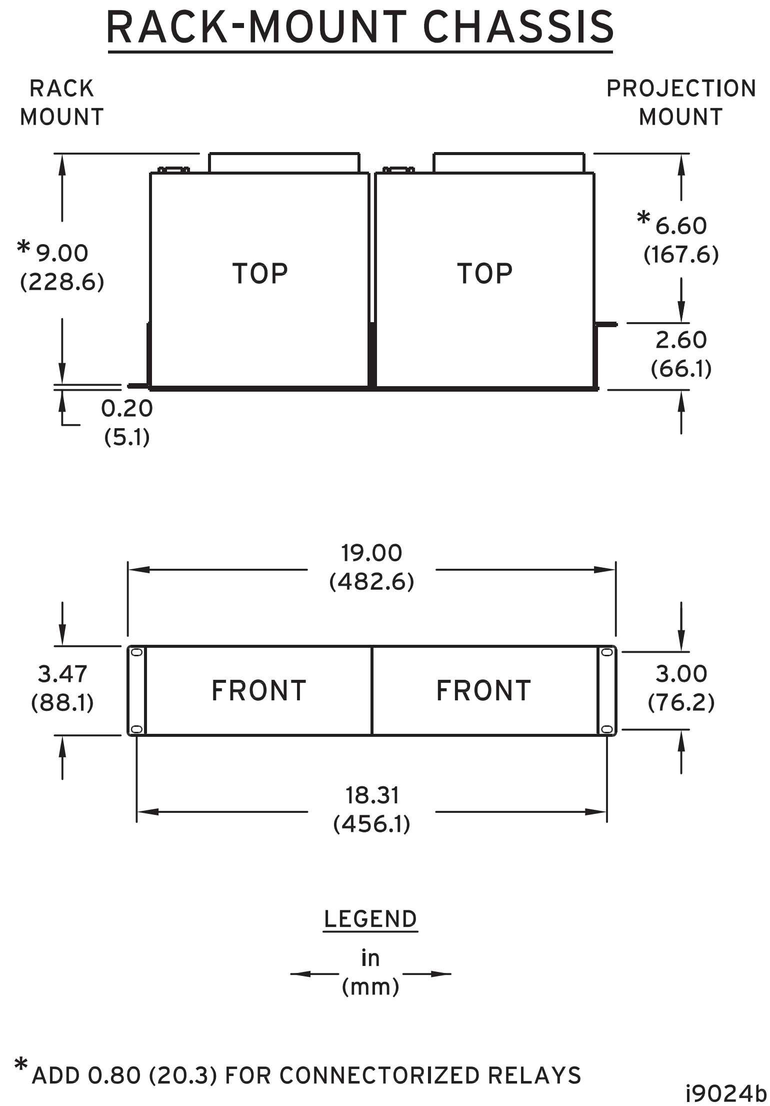

Figure 2.2 Relay Dimensions and Drill Plan for Mounting Two SEL-500 Series Relays Together by Using Mounting Block (SEL P/N 9101)

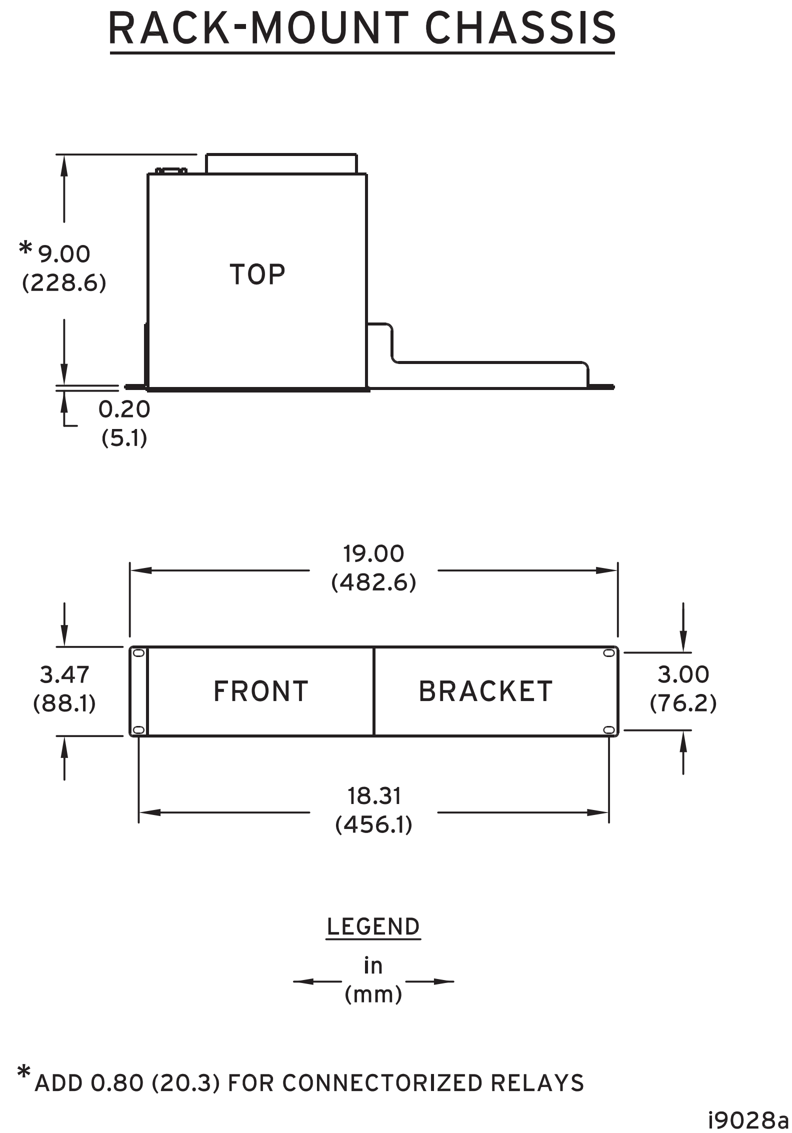

Figure 2.3 Relay Dimensions and Drill Plan for Mounting an SEL-587 Relay With Rack-Mount Bracket 9100 (Bracket on Right Side in Front View)

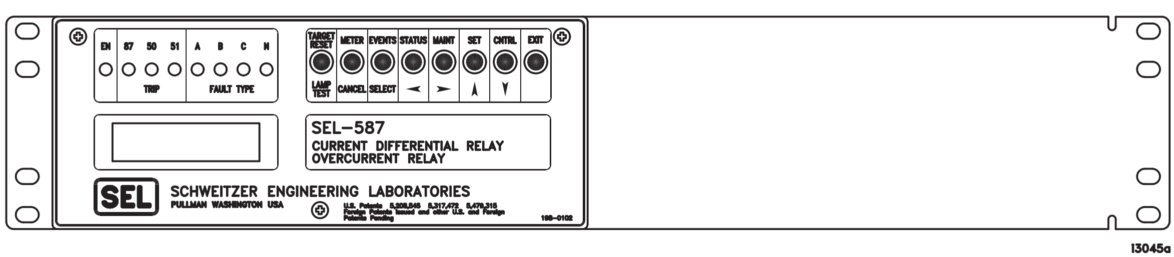

Figure 2.4 SEL-587 Without Front Serial Port Fitted With Mounting Bracket (SEL P/N 9100) for Mounting in 19-Inch Rack

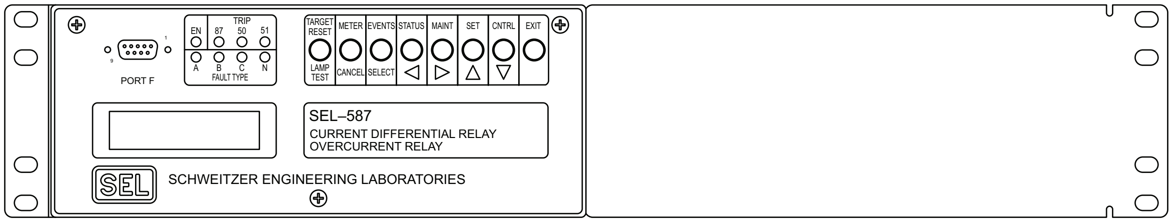

Figure 2.5 SEL-587 With Front Serial Port Fitted With Mounting Bracket (SEL P/N 9100) for Mounting in 19-Inch Rack

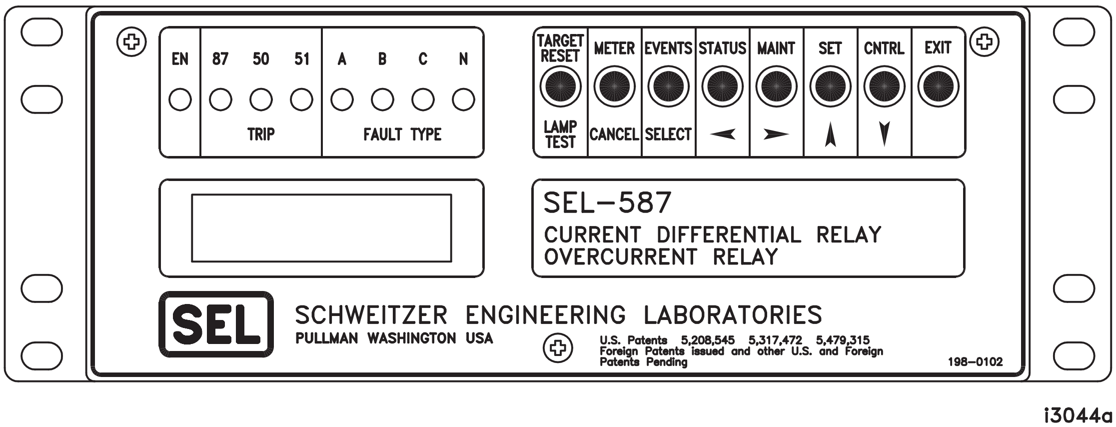

Figure 2.6 SEL-587 Front Panel Without Front Serial Port, Rack-Mount Version (Half-Rack Width)

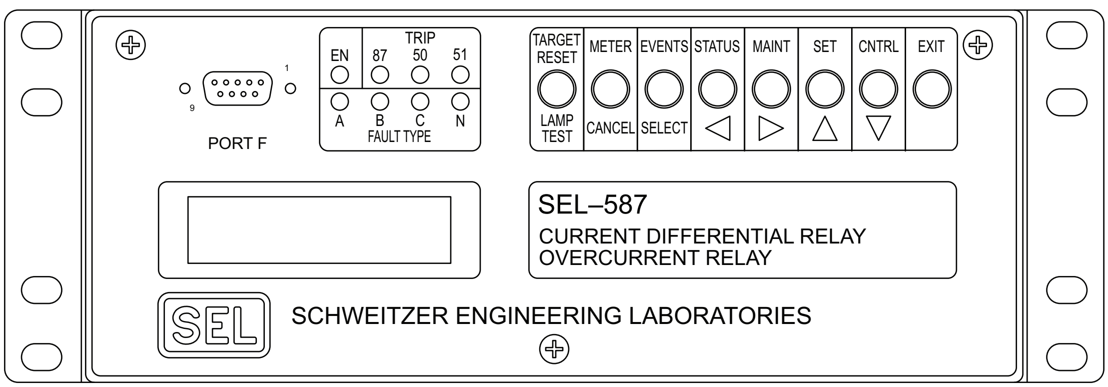

Figure 2.7 SEL-587 Front Panel With Front Serial Port, Rack-Mount Version (Half-Rack Width)

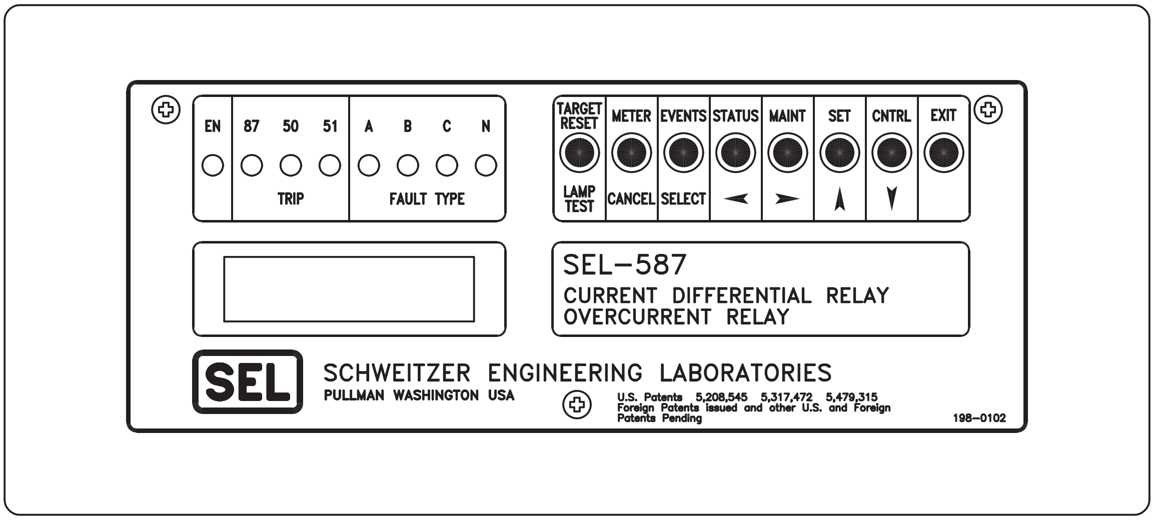

Figure 2.8 SEL-587 Front Panel Without Front Serial Port, Panel-Mount Version

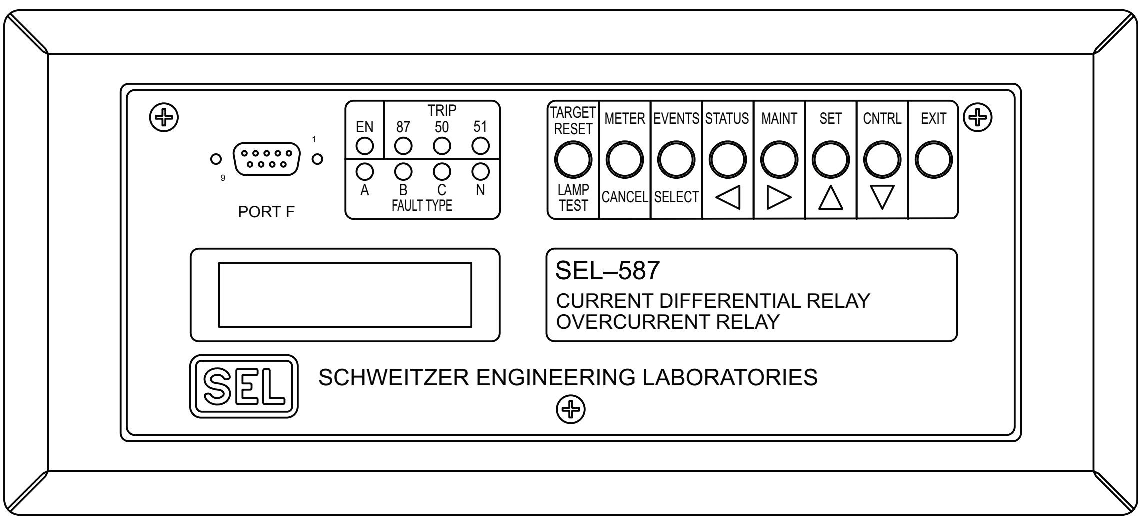

Figure 2.9 SEL-587 Front Panel With Front Serial Port, Panel-Mount Version

Rear-Panel Connections

We provide two options for secure connection of wiring to the relay rear panel. One of these is the conventional terminal block, in which you use size #6-32 screws to secure rear-panel wiring. The other option uses plug-in (Connectorized) connections that offer robust connections while minimizing installation and replacement time. These connections are intended for use with copper conductors only.

Connectorized rear-panel connections reduce repair time dramatically in the unlikely event that a relay should fail. These connections greatly simplify routine bench testing; connecting and disconnecting rear-panel wiring takes only a few minutes.

Connectorized relays use a current shorting connector for current inputs, a plug-in terminal block that provides maximum wiring flexibility for inputs and outputs, and a quick disconnect voltage rated connector for voltage inputs. The manufacturers of these connectors have tested them thoroughly, and many industry applications have proven the performance of these connectors. In addition, we have tested these connectors thoroughly to ensure that they conform to our standards for protective relay applications.

Terminal Block

Make terminal block connections with size #6-32 screws by using a Phillips or slotted screwdriver. You can request locking screws from the factory. Refer to *Figure 2.10* to make all terminal block connections.

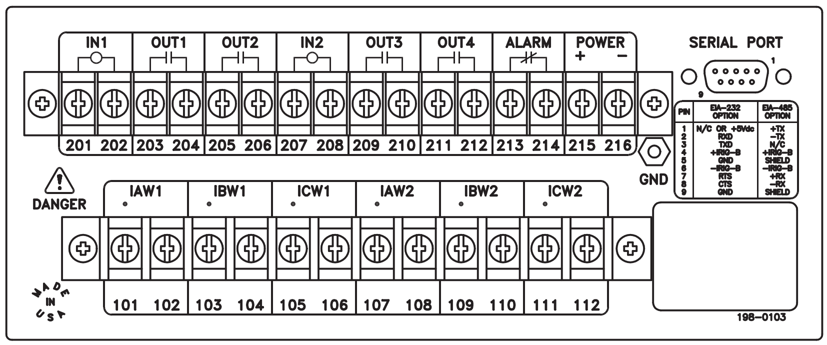

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Figure 2.10 Rear Panel For SEL-587 Without Front Serial Port (Conventional Terminal Blocks Option)

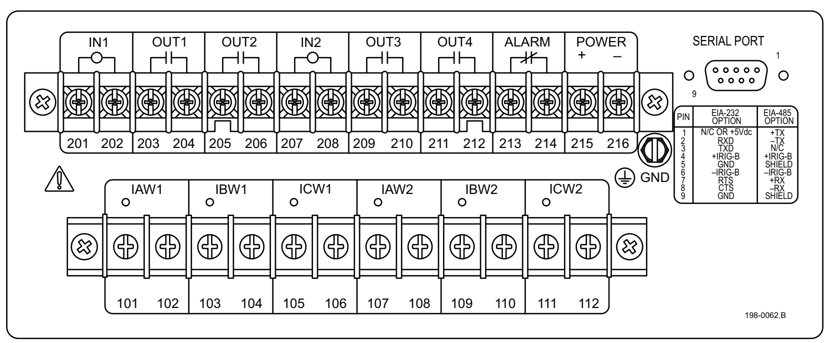


Figure 2.11 Rear Panel For SEL-587 With Front Serial Port (Conventional Terminal Blocks Option)

Output contacts OUT1–OUT4 and ALARM are not polarity-dependent.

Optoisolator inputs IN1 and IN2 are not polarity-dependent.

All screws are size #6-32. All screw/washer styles on SEL relays are recognized by UL for field wiring using terminals or bare wire. However, SEL strongly recommends the use of ring or fork terminals for the following reasons:

- ➤ Stray strands and inconsistent wire stripping can compromise hi-pot clearances and give rise to the potential for shorting the adjacent terminals.
- ➤ Wire/terminal secureness with ring terminals has been tested at SEL to 20 lb minimum. Bare wire has not been tested at SEL.

Both the terminal block manufacturer and UL requirements have qualified the standard terminal blocks for use with bare stranded wire, however, SEL’s qualification requirements are more stringent as required by the utility and industrial applications of protective relays.

The SEL terminal retention and hi-pot test voltage requirements are both twice that required by the UL standard.

All SEL qualification testing of terminal blocks and relays is performed with ring or fork terminals.

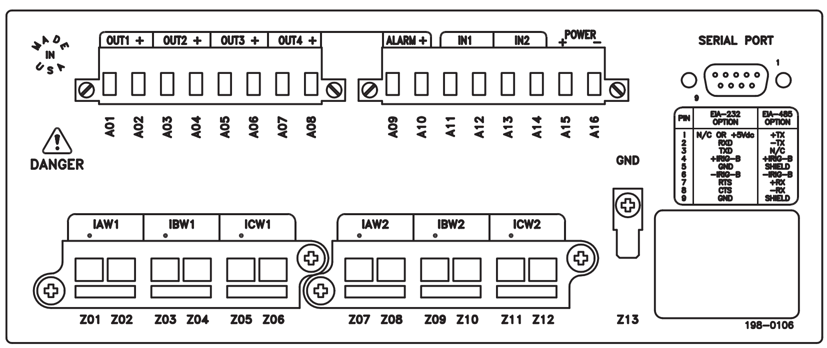
Notes:

- #6 ring and fork terminals will accommodate wire sizes from 22 AWG to 10 AWG.
- There is no limit to the number of terminals that can be clamped under one screw, however there is a maximum total thickness of .120" (3 mm). Ring terminals typically range in thickness .030" to .060".

⚠**WARNING**
Substituting a too-long screw for those provided with the terminal block will damage the inside part of the terminal.

Connectorized

To use the Connectorized version of the SEL-587, ask your SEL sales or customer service representative for the appropriate model option table and order wiring harness kit WA05010WxXxA, where x designates wire sizes and length. You can find the model option table on the SEL website at selinc.com. Refer to *Figure 2.12* to make all Connectorized connections.



i3047a

Figure 2.12 Relay Rear Panel (Plug-In Connectors Option)

IMPORTANT: Improvements in Connectorized SEL-587 (plug-in connectors) result in part number changes.

The current transformer shorting connectors for current channel inputs IAW1, IBW1, ICW1, and IAW2, IBW2, and ICW2 have been made more robust. This improvement makes the new connector design incompatible with the old design. Thus, new Connectorized SEL-587 relays with this improved connector have a new part number (partial part numbers shown):

Old	New
0587xJ	0587xW

The respective wiring harness part numbers for these old and new Connectorized SEL-587 relays are (partial part numbers shown):

Old	New
WA0587xJ	WA0587xW

The other connectors on the SEL-587 rear panel (power input, outputs contacts, etc.) are the same for the old or new models. Only the current transformer shorting connectors have changed.

Figure 2.12 shows the rear panel for new model 0587xW. Because all terminal labeling/numbering remains the same between the new and old relays, these figures can also be used as a reference for old model 0587xJ. Only the connectors and part numbers have changed.

Connector terminals A01–A16 accept wire size AWG 24 to 12 (install wires with a small slotted-tip screwdriver).

Output contacts OUT1–OUT4 and ALARM are polarity-dependent (note the “+” above terminals A02, A04, A06, A08, and A10).

See *Specifications on page 1.7* for high-current interrupting output contact ratings.

Optoisolator inputs IN1 and IN2 are not polarity-dependent.

Current input connector (terminals Z01–Z12):

- ➤ Contains current transformer shorting mechanisms
- ➤ Can be ordered prewired

Ground connection (terminal Z13): tab size 0.250" x 0.032", screw size #6-32.

AC/DC Connection Diagram

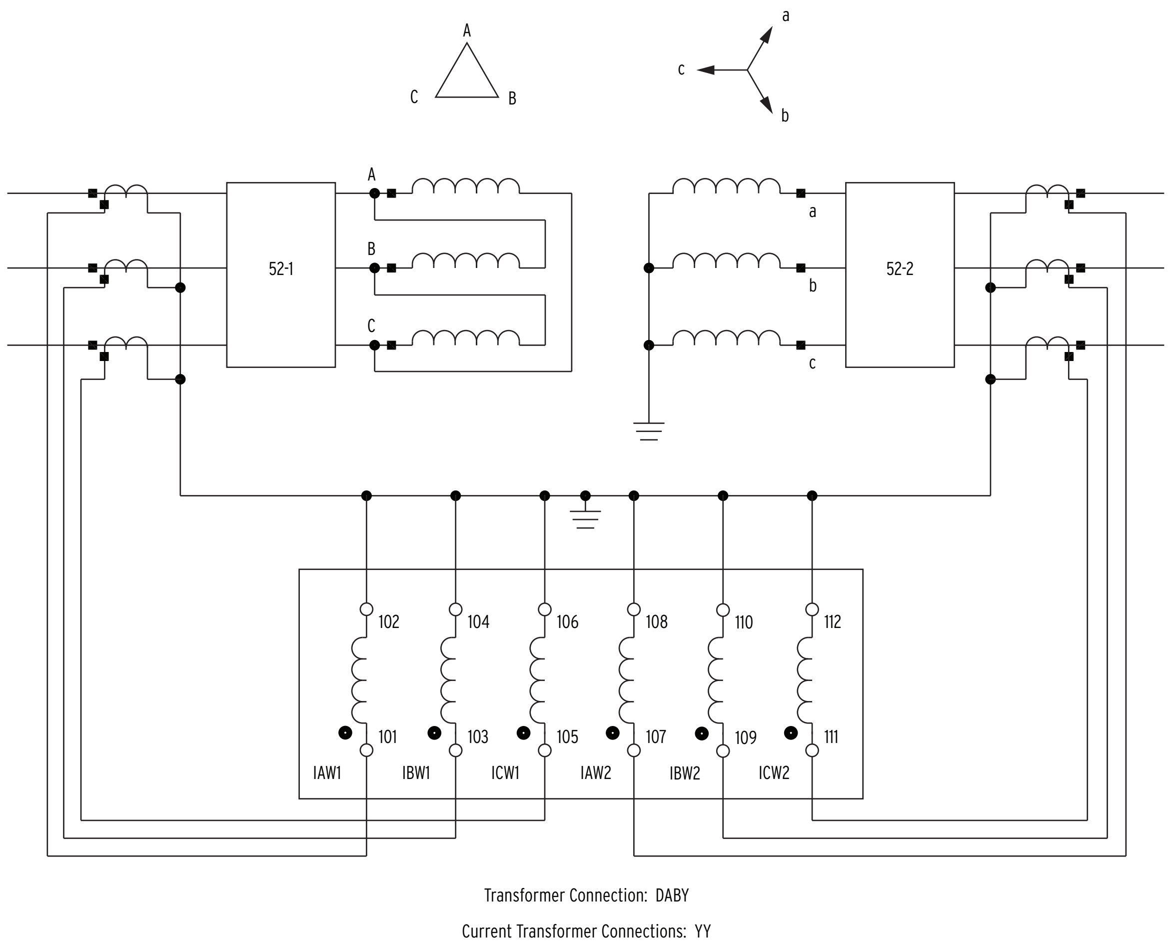


Figure 2.13 Example AC Connections—See Appendix F: Transformer/CT Winding Connection Diagrams for Other Configurations

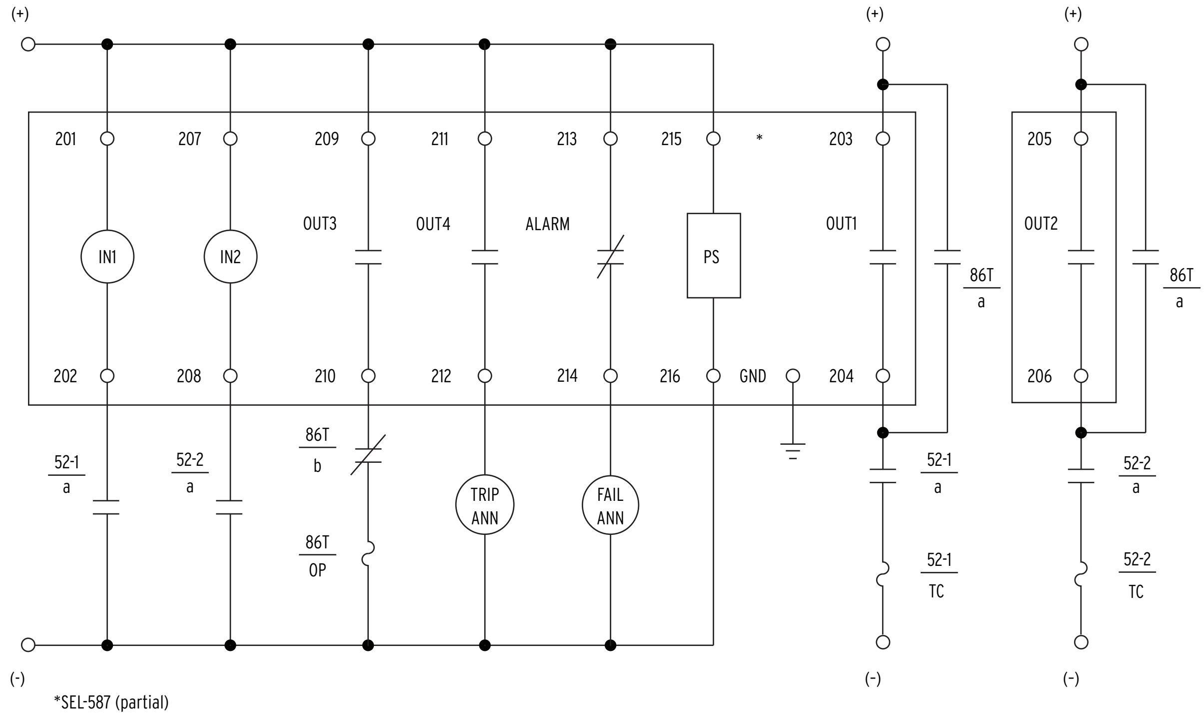


Figure 2.14 Example DC Connections

Circuit Board Jumpers and Battery

Control Voltage Jumpers (Conventional Terminal Blocks Option Only)

The SEL-587 relays equipped with conventional terminal blocks can be ordered with either jumper-selectable voltage optoisolated inputs or level-sensitive optoisolated inputs. Level-sensitive inputs are not jumper-selectable. See *Specifications on page 1.7* for ratings.

The jumper-selectable control voltage models are factory configured to the control voltage specified at time of ordering. The jumpers can be changed as outlined below.

To change the control input voltage range by using internal jumpers, take the following steps:

Step 1. De-energize the relay.

Step 2. Remove the three front-panel screws and the relay front panel.

Step 3. Disconnect the analog signal ribbon cable from the underside of the relay main board. Grasp the black knob on the front of the drawout assembly and pull the assembly from the relay chassis.

Step 4. Locate the control voltage jumpers near the rear edge of the relay main board. The jumpers are numbered JMP6 through JMP11. Refer to *Figure 2.15*.

Step 5. Install or remove jumpers according to *Table 2.1* to select the desired control voltage level.

Step 6. Slide the drawout assembly into the relay chassis. Reconnect the analog signal ribbon cable. Replace the relay front panel and re-energize the relay.

⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

Table 2.1 Control Input Voltage Selection Jumper Positions[a]

Control Voltage	IN1			IN2		
	JMP6	JMP7	JMP8	JMP9	JMP10	JMP11
250 Vdc	. .	. .	. .	. .	. .	. .
125 Vdc	.—.	. .	. .	.—.	. .	. .
48 Vdc	.—.	.—.	. .	.—.	.—.	. .
24 Vdc	.—.	.—.	.—.	.—.	.—.	.—.

[a] For use with relays equipped with the jumper-selectable control input voltage option only. Not supported in the level-sensitive control input option. See product Model Option Table (MOT) for details.

Output Contact Jumpers (Conventional Terminal Blocks Option Only)

Refer to *Figure 2.15*. Jumpers JMP1 through JMP5 select the contact type for the output contacts. With a jumper in the A position, the corresponding output contact is an a type output contact. An a type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. With a jumper in the B position, the corresponding output contact is a b type output contact. A b type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized. These jumpers are soldered in place.

NOTE: For a relay with Plug-In Connectors Option, the contact types are fixed. There are no jumpers available to change the contact types. Output contacts OUT1 through OUT4 are all a type contacts. The ALARM output contact is a b type contact.

In *Figure 2.15*, note that the ALARM output contact is a b contact and the other output contacts are all a contacts. This is how these jumpers are configured in a standard relay shipment.

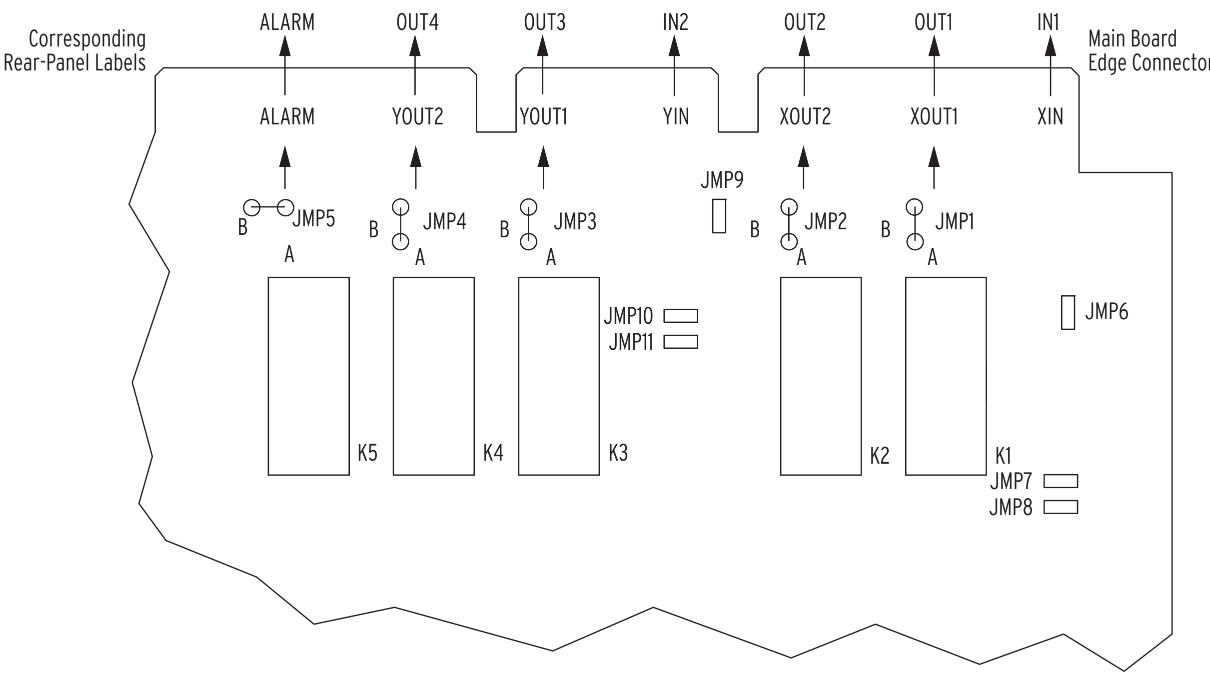


Figure 2.15 Input and Output Jumper Locations (Conventional Terminal Blocks With Jumper-Selectable Control Input Voltage Option Only)

Password and Breaker Control Command Jumpers

Section 6: Operator Interface contains operation information regarding the password and breaker control commands. Password and breaker control command jumpers are on the front edge of the relay main board between the front-panel LEDs and the control pushbuttons. Remove the relay front panel to change them.

Put jumper JMP22 (left-most jumper) in place to disable serial port and front-panel password protection. With the jumper removed, password security is enabled. Set the password with the **PASSWORD** command. The relay is shipped with the password set to **587**.

Put jumper JMP24 (right-most jumper) in place to enable the output contact control commands (**OPEN**, **CLOSE**, and **PULSE**). Breaker output contact control commands are ignored while JMP24 is removed.

EIA-232 Serial Communications Port Voltage Jumper (EIA-232 Option Only)

Jumper JMP12 and Jumper JMP14 apply to the EIA-232 option only for Port 1 (rear port) and are at the rear of the main board, near the rear-panel EIA-232 serial communications port. Jumper JMP12 connects or disconnects +5 Vdc to pin 1 on the EIA-232 serial communications port. For successful port voltage output, you must also apply Jumper JMP14 (located near the rear communications port) to short Pin 5 and Pin 9 for the +5 Vdc ground return path. When Jumper JMP12 and Jumper JMP14 are in place, the rear communications port is no longer isolated. In a standard relay shipment, Jumpers JMP12 and JMP14 are removed (out of place) so that the +5 Vdc is not connected on the EIA-232 serial communications port and the port is isolated from ground.

Table 2.2 Jumper Designations

SEL-587 Main Board Part Number	+5 V Jumper
BS1800-xxx	JMP14
BS1802-xxx	JMP12

Output Contact YOUT2 Control Jumper

Refer to *Figure 2.16*. Main board Jumper JMP13 controls the operation of output contact OUT4. It provides the option of a second alarm output contact by changing the signal that drives output contact OUT4.

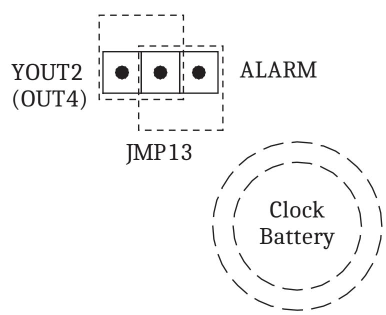


Figure 2.16 Output Contact OUT4 Control Jumper Location

Table 2.3 Required Position of Jumper JMP13 for Desired Output Contact OUT4 Operation

Position	Output Contact YOUT2 Operation
Jumper Left	Regular output contact OUT4 (operated by Relay Word bit OUT4). Jumper JMP13 comes in this position in a standard relay shipment.
Jumper Right	Extra Alarm output contact (operated by alarm logic/circuitry). Relay Word bit OUT4 does not have any effect on output contact OUT4 when jumper JMP13 is in this position.

NOTE: Some initial shipments of SEL-587 Relays did not have this jumper JMP13 feature.

If Jumper JMP13 is in position ALARM and both output contacts OUT4 and ALARM are the same output contact type (a or b), these outputs will be in the same state (closed or open). If Jumper JMP13 is in position ALARM and output contacts **OUT4** and **ALARM** are different output contact types (one is an a and one is a b), these outputs will be in opposite states (one is closed and one is open).

Clock Battery

A lithium battery powers the relay clock (date and time) if the external dc source is lost or removed. The battery is a 3 V lithium coin cell. At room temperature (25°C) the battery will operate nominally for 10 years at rated load.

If the dc source is lost or disconnected, the battery discharges to power the clock. When the relay is powered from an external source, the battery only experiences a low self-discharge rate. Thus, battery life can extend well beyond the nominal 10 years because the battery rarely has to discharge after the relay is installed. The battery cannot be recharged.

If the battery voltage is out of tolerance, an automatic status message is sent to the serial port and the front-panel display.

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Panasonic BR-2330A or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C, or incinerate. Dispose of used batteries according to the manufacturer’s instructions. Keep battery out of reach of children.

⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

To change the battery, take the following steps:

Step 1. De-energize the relay.

Step 2. Remove the three front-panel screws and remove the relay front panel.

Step 3. Disconnect the analog signal ribbon cable and power supply cable from the underside of the relay main board. Grasp the black knob on the front of the drawout assembly and pull the assembly from the relay chassis.

Step 4. Locate the battery on the right-hand side of the relay main board.

Step 5. Remove the battery from beneath the clip and install a new one. The positive side (+) of the battery faces up.

Step 6. Slide the drawout assembly into the relay chassis. Reconnect the analog signal ribbon cable and power supply cable. Replace the relay front panel and re-energize the relay.

Step 7. Set the relay date and time (see *Section 6: Operator Interface*).

Port Connector and Communications Cables

Figure 2.17 is a drawing of the 9-pin port connector.

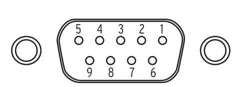


Figure 2.17 Female Chassis Connector, as Viewed From Outside Panel

Table 2.4 identifies pinouts for each pin of a 9-pin EIA-232 or 9-pin EIA-485 port connector, while *Table 2.5* defines the function of each serial communications port pin.

Table 2.4 Pinouts for EIA-232 and EIA-485 Ports

Pin	EIA-232 Option	EIA-485 (4-wire) Option
1	N/C or +5 Vdc (main board jumper JMP12 or JMP14)	+TX
2	RXD	–TX
3	TXD	N/C
4	+IRIG-B	+IRIG-B
5	GND	SHIELD
6	–IRIG-B	–IRIG-B
7	RTS	+RX
8	CTS	–RX
9	GND	SHIELD

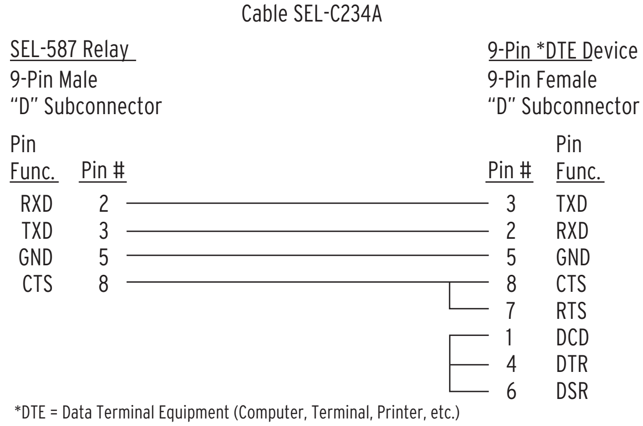
Table 2.5 Serial Communications Port Pin Functions Definitions

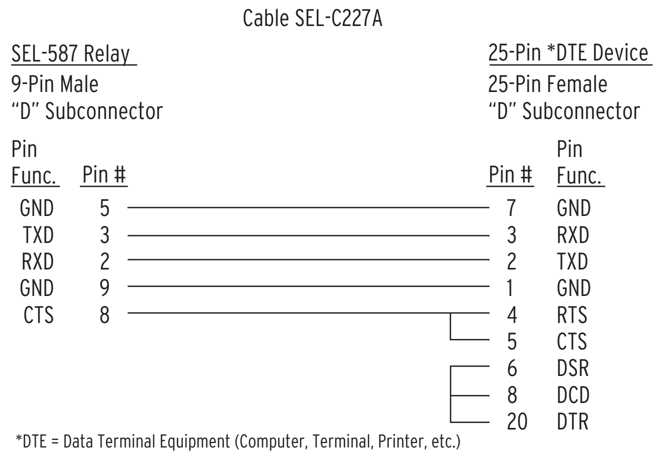
Pin Function	Definition
N/C	No Connection
+5 Vdc	5-Volt DC Power Connection
+12 Vdc	12-Volt DC Power Connection
RXD, RX	Receive Data
TXD, TX	Transmit Data
IRIG+/IRIG–	Positive/Negative Terminal of the IRIG-B Time-Code Input
GND	Ground
SHIELD	Shielded Ground
RTS	Request to Send
CTS	Clear to Send
DCD	Data Carrier Detect
DTR	Data Terminal Ready
DSR	Data Set Ready

The following cable diagrams show several types of EIA-232 serial communications cables. Obtain these and other cables from SEL. Contact the factory for more information.

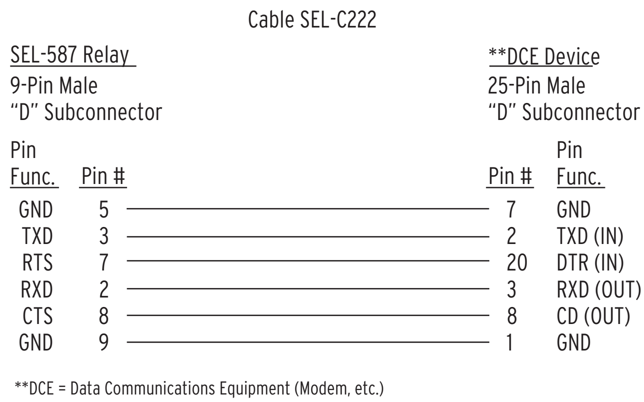
SEL-587 to Computer

Cable SEL-C234A

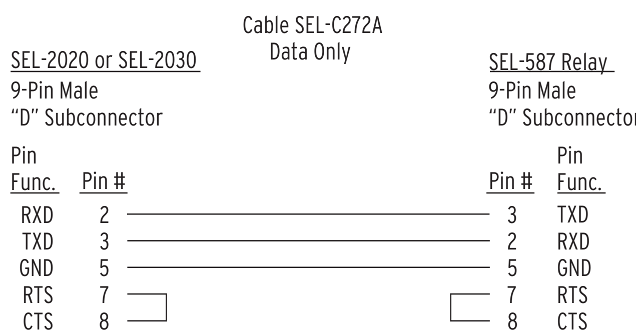




SEL-587 to Modem



SEL-587 to SEL-2020 or to SEL-2030



Cable SEL-C273A
Data Only

SEL-2020 or SEL-2030 9-Pin Male "D" Subconnector			SEL-587 Relay 9-Pin Male "D" Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
RXD	2	—	3	TXD
TXD	3	—	2	RXD
IRIG+	4	—	4	IRIG+
GND	5	—	5	GND
IRIG-	6	—	6	IRIG-
RTS	7	—	8	CTS
CTS	8	—	7	RTS

For long-distance communications up to 500 meters and for electrical isolation of communications ports, use the SEL-2800 or SEL-2810 Fiber-Optic Transceivers. Contact SEL for more details on these devices.

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Section 3
Relay Elements

Introduction

This section discusses the operation of the restrained and unrestrained differential elements, blocking logic, restraint logic, and overcurrent elements. The section also presents recommendations for calculating protection element settings. Differential protection elements are discussed first, followed by overcurrent elements.

Application Guides

Application guides for the SEL-587 are available at our website: selinc.com. You may find the following application guides useful:

Table 3.1 Application Guides Related to the SEL-587

Application Guide Number	Application Guide Title	Date Code
AG95-18	*Protecting Three Single-Phase Transformers Connected Delta-Wye With Current Transformers Inside the Delta With the SEL-587 Relay*	20031105
AG96-09	*Protecting ±30º and ±150º Delta-Wye Transformers with the SEL-587 Relay*	970530
AG97-12	*Using SEL-587 Relay for Protection of Power Transformer with One Zig-Zag Connection*	970523
AG2000-01	*Determining the Correct TRCON Setting in the SEL-587 Current Differential Relay When Applied to Delta-Wye Power Transformers*	20100216

Differential Protection

Differential Protection Overview

Apply the SEL-587 to provide current differential protection for two-winding transformers, reactors, generators, large motors, and other two-terminal apparatus. The relay accommodates various power transformer connections and the settings permit you to connect the high- and low-side current transformers in either wye or delta. The relay automatically compensates for the connections to derive the appropriate differential operating quantities.

The SEL-587 current differential element is designed with a settable operating current pickup and a single- or dual-slope percentage restraint slope characteristic. This enables you to set the relay sensitively, while allowing the relay to discriminate between internal and external faults at high fault currents. The relay also provides an unrestrained element to quickly clear high magnitude internal faults.

The SEL-587-0 consists of three current differential elements. Each differential element provides percentage differential protection with independent second- and fifth-harmonic blocking. You can select independent or common harmonic blocking.

The SEL-587-1 also consists of three current differential elements. Each differential element provides percentage differential protection with independent even-harmonic restraint and fifth-harmonic and dc blocking. The user can select even-harmonic blocking instead of even-harmonic restraint. You can select independent harmonic and dc blocking or common harmonic and dc blocking.

Restraint and blocking elements enable discrimination between differential current caused by internal faults and that caused by magnetizing inrush or overexcitation. Each blocking element has an independent settable threshold. Use the fifth-harmonic element to produce an overexcitation alarm if fifth-harmonic current is detected for a settable time.

Differential Protection Characteristic

The differential element characteristic can be set as either a single-slope, percentage differential characteristic or as a dual-slope, variable-percentage differential characteristic, see *Figure 3.1*. Element operation is determined by operate (IOP) and restraint (IRT) quantities calculated from the winding input currents. Tripping occurs if the operate quantity is greater than the minimum pickup level and is greater than the curve value, for the particular restraint quantity. Four settings define the characteristic.

By careful selection of these settings, the user can closely duplicate the characteristics of existing current differential relays.

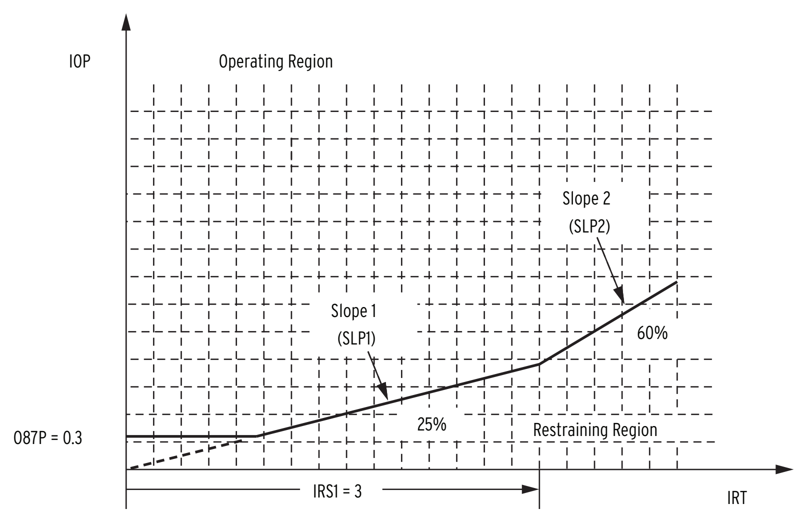

Figure 3.1 Percentage Restraint Differential Characteristic

Figure 3.2 and *Figure 3.4* illustrate how input currents are acquired and used in the differential relay. Data acquisition, filtering, TAP scaling, and transformer and CT connection compensation for Winding 1 are shown in *Figure 3.2*. Four digital band-pass filters extract the fundamental, second, fourth, and fifth (not shown) harmonics of the input currents. A dc filter (not shown) forms one cycle sums of the positive and negative values. I1W1F1C, I2W1F1C, and I3W1F1C are the fundamental frequency A-phase, B-phase, and C-phase compensated currents for Winding 1. Similarly, I1W1F2C, I2W1F2C, and I3W1F2C are the second-harmonic compensated currents for Winding 1. The dc, fourth-harmonic, and fifth-harmonic compensated currents use similar names.

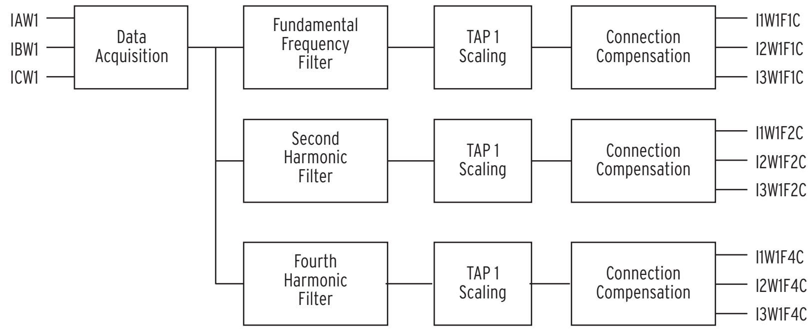

Figure 3.2 Differential Relay Compensated Currents (W1)

The I1 compensated currents are used with differential element 87-1, I2 with element 87-2, and I3 with element 87-3. *Figure 3.4* illustrates how IOP1 and IRT1 are calculated and used to generate unrestrained (87U1) and restrained (87R1) elements. IOP1 is generated by summing the winding currents in a phasor addition. IRT1 is generated by summing the magnitudes of the winding currents in a simple scalar addition and dividing by two.

Unrestrained elements (87U1, 87U2, and 87U3) compare the IOP quantity to a setting value (U87P), typically about 10 times TAP, and trip if this level is exceeded. It is essentially an instantaneous unit set high enough that the pickup level could only mean an internal fault. Elements 87U1, 87U2, and 87U3 are combined to form element 87U as shown in *Figure 3.3*.

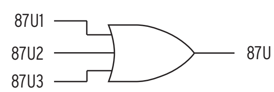

Figure 3.3 SEL-587 Unrestrained Element (87U)

Restrained elements (87R1, 87R2, and 87R3) determine whether the IOP quantity is greater than the restraint quantity by using the differential characteristic shown in *Figure 3.1*. Set HRSTR = Y (harmonic restraint), only available in the SEL-587-1, to modify this characteristic as a function of the second- and fourth-harmonic content in the input currents.

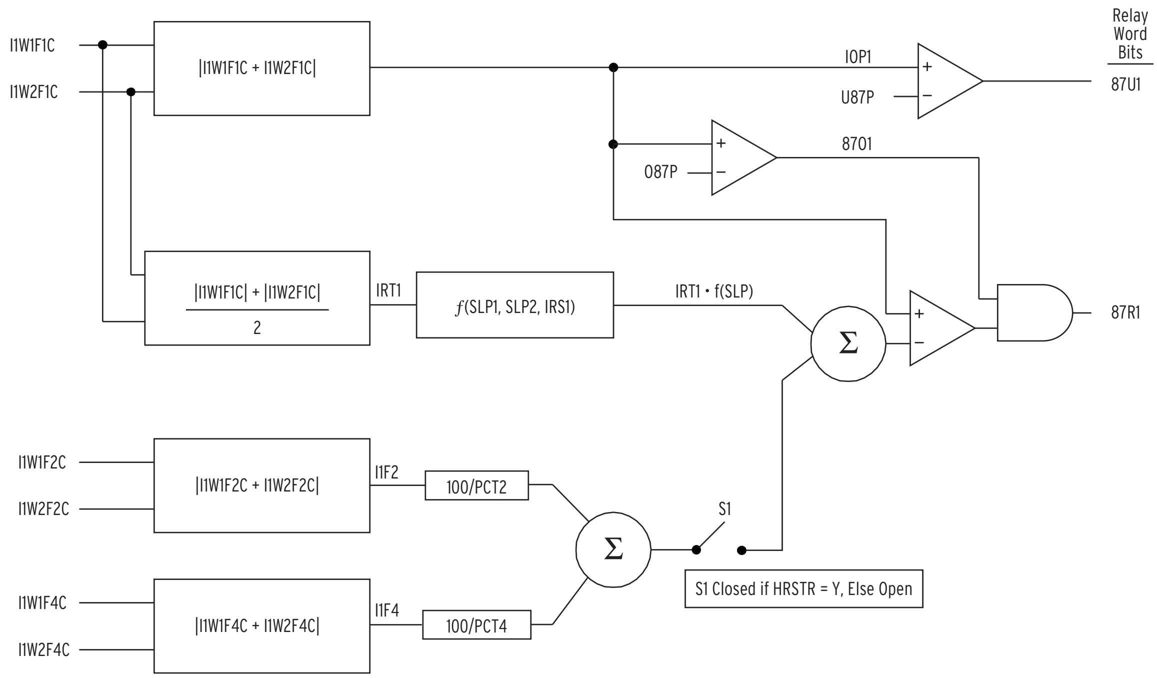

Figure 3.4 Differential Element (87-1) Decision Logic

Use common or independent harmonic blocking elements (87BL1, 87BL2, and 87BL3) to supervise the restrained differential elements. Common harmonic blocking disables all restrained elements if any blocking element is picked up. *Figure 3.5* shows how independent harmonic blocking disables the restrained element associated with the blocking element. Differential element blocking is driven by dc and harmonic content. *Figure 3.6* (SEL-587-0) and *Figure 3.7* (SEL-587-1) show how blocking elements (87BL1, 87BL2, and 87BL3) will pick up if the second-, fourth-, or fifth-harmonic operating current, as a percentage of fundamental operating current, are above the PCT2, PCT4, or PCT5 setting threshold, respectively. The blocking elements will also pick up if the ratio of positive and negative dc exceeds a threshold as shown in *Figure 3.8*. The blocking prevents improper tripping during transformer inrush or allowable overexcitation conditions.

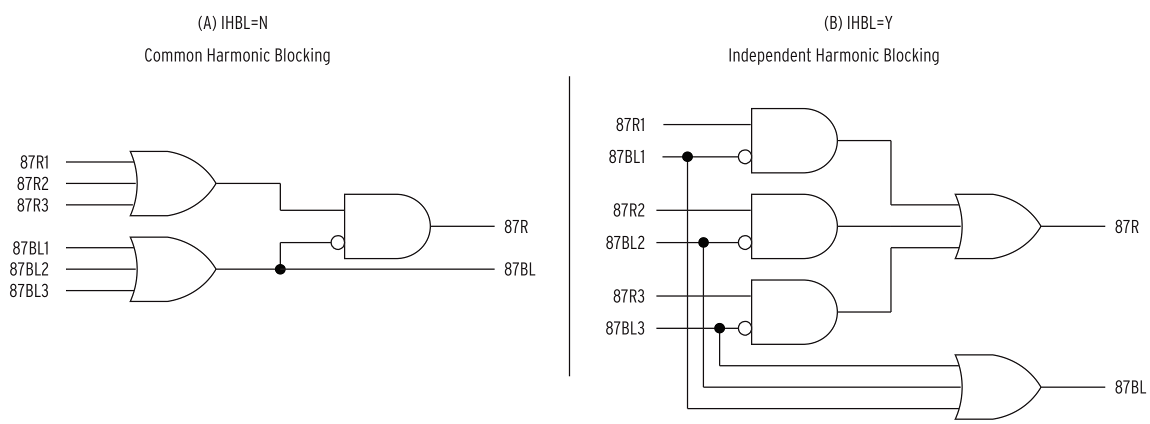

Figure 3.5 Differential Relay Blocking Logic

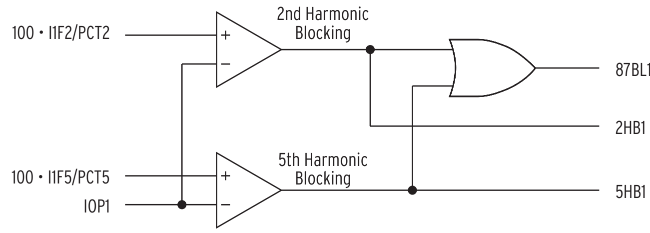

Figure 3.6 SEL-587-0 Differential Element (87BL1 Blocking Logic)

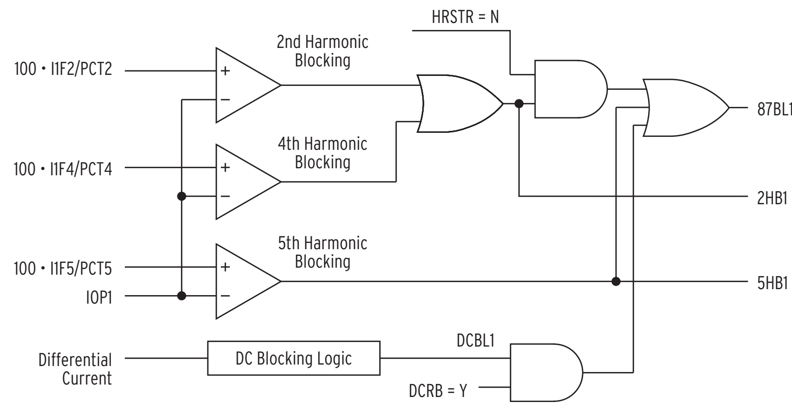

Figure 3.7 SEL-587-1 Differential Element (87BL1) Blocking Logic

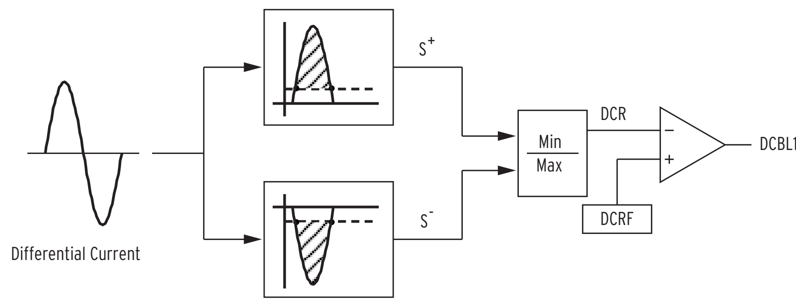

Figure 3.8 SEL-587-1 DC Blocking (DCBL1) Logic

Differential Protection Setting Descriptions

Maximum Power Transformer Capacity (MVA)

MVA is typically set to the highest expected transformer rating, such as FOA (Forced Oil and Air Cooled) rating or a higher emergency rating. SEL recommends considering other factors while setting MVA to achieve better security and sensitivity. Refer to the technical paper "Application Considerations for Protecting Transformers With Dual Breaker Terminals" (available at selinc.com) for additional information.

Winding Line-to-Line Voltages (VWDG1, VWDG2)

Enter the nominal line-to-line transformer terminal voltages. If a load TAP changer is included in the transformer differential zone, assume that it is in the neutral position. The setting units are kilovolts.

Transformer Connection (TRCON) and CT Connection (CTCON)

The SEL-587 automatically compensates for 14 different combinations of power transformer winding connections and current transformer winding connections. Internal compensation factors (CON1 and CON2) are used to compensate for any phase-angle shifts due to winding connections and remove zero-sequence current when necessary, see *Table 3.2*. All acceptable transformer and CT connection combinations are shown in diagrams in *Appendix F: Transformer/CT Winding Connection Diagrams*.

To set the relay TRCON and CTCON settings:

1. Review the drawings in *Appendix F: Transformer/CT Winding Connection Diagrams*.
2. Enter the TRCON and CTCON relay settings associated with the drawing that matches your application.

In new installations, use wye-grounded CT connection on both sides of the transformer. This allows easier application of relay overcurrent elements.

Table 3.2 TRCON and CTCON Determine CON1, CON2, C1, and C2

TRCON	CTCON	CON1	CON2	C1	C2
YY	DACDAC	Y	Y	$\sqrt{3}$	$\sqrt{3}$
YY	DABDAB	Y	Y	$\sqrt{3}$	$\sqrt{3}$
YDAC	DACY	Y	Y	$\sqrt{3}$	1
YDAB	DABY	Y	Y	$\sqrt{3}$	1
DACDAC	YY	Y	Y	1	1
DABDAB	YY	Y	Y	1	1
DABY	YDAB	Y	Y	1	$\sqrt{3}$
DACY	YDAC	Y	Y	1	$\sqrt{3}$
YY	YY	DAB	DAB	1	1
YDAC	YY	DAC	Y	1	1
YDAB	YY	DAB	Y	1	1
DABY	YY	Y	DAB	1	1
DACY	YY	Y	DAC	1	1
OTHER	YY	Y	Y	1	1

Compensated currents (I1W1F1C, I2W1F1C, I3W1F1C and I1W2F1C, I2W2F1C, I3W2F1C) are determined using the following equations where *n* =1 for Winding 1 and *n* = 2 for Winding 2. These phasor equations remove phase-angle shift and zero-sequence current when appropriate.

For CON*n* = Y and RZS = N (SEL-587-1) or CON*n* = Y (SEL-587-0)

I1W*n*F1C = IAW*n*F1

I2W*n*F1C = IBW*n*F1

I3W*n*F1C = ICW*n*F1

For CONn = Y and RZS = Y (SEL-587-1)

I1WnF1C = IAWnF1 – I0WnF1

I2WnF1C = IBWnF1 – I0WnF1

I3WnF1C = ICWnF1 – I0WnF1

where

3I0WnF1 = IAWnF1 + IBWnF1 + ICWnF1

For CONn = DAB

$$\mathrm{I1WnF1C} = \frac{(\mathrm{IAWnF1} - \mathrm{IBWnF1})}{\sqrt{3}}$$ **Equation 3.1**

$$\mathrm{I2WnF1C} = \frac{(\mathrm{IBWnF1} - \mathrm{ICWnF1})}{\sqrt{3}}$$ **Equation 3.2**

$$\mathrm{I3WnF1C} = \frac{(\mathrm{ICWnF1} - \mathrm{IAWnF1})}{\sqrt{3}}$$ **Equation 3.3**

For CONn = DAC

$$\mathrm{I1WnF1C} = \frac{(\mathrm{IAWnF1} - \mathrm{ICWnF1})}{\sqrt{3}}$$ **Equation 3.4**

$$\mathrm{I2WnF1C} = \frac{(\mathrm{IBWnF1} - \mathrm{IAWnF1})}{\sqrt{3}}$$ **Equation 3.5**

$$\mathrm{I3WnF1C} = \frac{(\mathrm{ICWnF1} - \mathrm{IBWnF1})}{\sqrt{3}}$$ **Equation 3.6**

Remove Zero Sequence (RZS)

Set RZS = Y to remove zero-sequence current from the differential calculation when you have a delta transformer with a grounding bank. TRCON and CTCON automatically remove zero-sequence current for all other cases when necessary. This feature is only available with the SEL-587-1.

CT Ratio (CTR1, CTR2)

This setting is the numerical ratio of the current transformers for the particular winding, calculated by dividing the primary CT current by the secondary CT current. For example, a 2000/5 A CT has a primary current rating of 2000 A and a secondary current rating of 5 A and thus a ratio of 400.

Current TAPs (TAP1, TAP2)

You can set the TAP by setting MVA = OFF and entering TAP1 and TAP2 values directly. However, in most applications, you should have the relay automatically calculate the TAP value by using the MVA, winding voltages, CT ratios, and connection settings described earlier. The relay uses the following equations to set TAP1 and TAP2 where C1 and C2 are defined by the transformer and CT connections shown in *Table 3.2*. Drawings are found in *Appendix F: Transformer/CT Winding Connection Diagrams*.

$$\mathrm{TAP1} = \frac{\mathrm{MVA} \bullet 1000 \bullet \mathrm{C1}}{\sqrt{3} \bullet \mathrm{VWDG1} \bullet \mathrm{CTR1}} \qquad \textbf{Equation 3.7}$$

$$\mathrm{TAP2} = \frac{\mathrm{MVA} \bullet 1000 \bullet \mathrm{C2}}{\sqrt{3} \bullet \mathrm{VWDG2} \bullet \mathrm{CTR2}} \qquad \textbf{Equation 3.8}$$

The relay calculates TAP1 and TAP2 with the following limitations:

1. The TAP settings are within the range $0.1{,}I_N$ and $32{,}I_N$
2. The ratio, $\frac{TAP_{MAX}}{TAP_{MIN}} \leq 4.5$

Operating Current PU (O87P)

Set the operating current pickup at a minimum pickup for increased sensitivity, but high enough to avoid operation due to steady state CT error and transformer excitation current. An O87P setting of 0.3 is suggested.

The O87P setting range is 0.1 to 1.0 multiple of TAP. O87P $\geq 0.1 \bullet I_N/TAP_{MIN}$ where TAP_{MIN} is the lesser of TAP1 or TAP2. For example, if TAP_{MIN} is equal to 1.0 and $I_N = 5$, the minimum O87P setting available is 0.5.

Restraint Slope Percentages (SLP1, SLP2, and IRS1)

The restraint slope percentage settings are used to discriminate between internal and external faults. Set SLP1 or SLP2 to accommodate current differences due to power transformer TAP changer, magnetizing current, and relay error.

For example:

The current transformer error, e, is equal to ±10 percent. In per unit:

$e = 0.1$

The voltage ratio variation of the power transformer load TAP changer (LTC) is from 90 percent to 110 percent. In per unit:

$a = 0.1$

In a through-current situation, the worst-case theoretical differential current occurs when all of the input currents are measured with maximum positive CT error, and all of the output currents are measured with maximum negative CT error as well as being offset by maximum LTC variation. Therefore, the maximum differential current expected for through-current conditions is:

$$\mathrm{Id\ max} = (1 + e) \bullet \sum_{\mathrm{IN}} \mathrm{IWn} - \frac{(1 - e)}{(1 + a)} \bullet \sum_{\mathrm{OUT}} \mathrm{IWn}$$

where the summation terms are the total input and output power transformer secondary currents, after TAP compensation. Since these summations must be equal for external faults and load current, we can express the maximum differential current as a percentage of winding current:

$$(1 + e) - \frac{(1 - e)}{(1 + a)} = \frac{2 \bullet e + a + e \bullet a}{1 + a} \bullet 100\% = 28.18\%$$

In addition to the error calculated above we have to consider additional errors due to the transformer excitation current (≈3 percent) and the relay measurement error (≤5 percent). The maximum total error comes to 36 percent. Therefore, if only one slope is being used, a conservative slope setting, SLP1, is about 40 percent. This represents a fixed percentage differential application and is a good average setting to cover the entire current range.

A two-slope, or variable-percentage differential application, improves sensitivity in the region where CT error is smaller, and increases security in the high-current region where CT error is greater. Both slopes must be defined, as well as the slope 1 limit or crossover point, IRS1. If we assume CT error to be only 1 percent, SLP1 can be set at about 25 percent. A good choice for IRS1 is about 3.0 per unit of TAP, while SLP2 should probably be set in the 50 to 60 percent range to avoid problems with CT saturation at high currents. A 60 percent SLP2 setting covers CT error up to about 20 percent.

Instantaneous Unrestrained Current PU (U87P)

Set the instantaneous unrestrained current pickup (U87P) to 8 per unit. The setting is adjustable and can be changed, if necessary. The unrestrained differential element responds to fundamental frequency only.

The instantaneous unrestrained differential element is not affected by the SLP1, SLP2, IRS1, PCT2, PCT5, or IHBL settings.

The U87P setting range is 1.0 to 16.0 multiples of TAP. The setting must also yield an operating current less than or equal to 32 • I_N, when multiplied by TAP_{MAX}, the greater of TAP1 or TAP2. For example, if TAP_{MAX} is equal to 12.0 and I_N = 5, the maximum U87P setting is 32 • 5/12.0, or 13.3 multiples of TAP.

Second-Harmonic Block Setting (PCT2)

Energization of a transformer causes a temporary large flow of magnetizing inrush current into one terminal of a transformer, without this current being seen at other terminals. Thus, it appears as a differential current and could cause improper relay operation. Magnetizing inrush currents contain larger amounts of second-harmonic current than do fault currents. This second-harmonic current can be used to identify the inrush phenomenon and to prevent the relay from misoperating. The SEL-587 measures the amount of second-harmonic current flowing in the transformer. You can set the relay to block the percentage-restrained differential element if the ratio of second-harmonic current to fundamental current (IF2/IF1) is greater than the PCT2 setting.

Transformer simulations show that magnetizing inrush current usually yields over 30 percent of (IF2/IF1) in the first cycle of the inrush. A setting of 15 percent usually provides a margin for security. However, some types of transformers, or the presence within the differential zone of equipment that draws a fundamental current of its own, may require setting the threshold as low as about 7 percent. For example, the additional fundamental frequency charging current of a long cable run on the transformer secondary terminals could “dilute” the level of second-harmonic seen at the primary to below 15 percent.

When using harmonic restraint (HRSTR = Y in the SEL-587-1), use the PCT2 setting to scale the amount of second-harmonic content that will be added to the restraint slope characteristic. The larger the PCT2 setting, the smaller the increase on the restraint slope as a result of the measured second-harmonic content. See *Figure 3.4* for details. Setting PCT2 to OFF is not recommended when using harmonic restraint as this will eliminate any second-order harmonics from affecting the restraint slope characteristic.

Fourth-Harmonic Block Setting (PCT4)

Magnetizing inrush current contains second- and fourth-harmonic current. The SEL-587-1 adds the capability of using fourth-harmonic current to block the differential element. You can set the relay to block the percentage-restrained differential element if the ratio of fourth-harmonic current to fundamental current (IF4/IF1) is greater than the PCT4 setting.

A setting of 15 percent usually provides a margin for security.

When using harmonic restraint (HRSTR = Y in the SEL-587-1), use the PCT4 setting to scale the amount of fourth-harmonic content that will be added to the restraint slope characteristic. The larger the PCT4 setting, the smaller the increase on the restraint slope as a result of the measured fourth-harmonic content. See *Figure 3.4* for details. Setting PCT4 to OFF is not recommended when using harmonic restraint as this will eliminate any fourth-order harmonics from affecting the restraint slope characteristic.

Fifth-Harmonic Blocking (PCT5, TH5, TH5D)

Overexcitation is defined by ANSI/IEEE (C37.91, C37.102) as a condition where the ratio of the voltage to frequency (V/Hz) applied to the transformer terminals exceeds 1.05 per unit at full load or 1.1 per unit at no load. Transformer overexcitation produces odd order harmonics, which can appear as differential current to a transformer differential relay. Fifth-harmonic blocking is primarily used on unit-generator step-up transformers at power plants. The transformer voltage and generator frequency can vary somewhat during startup, overexciting the transformer.

Fourier analysis of these currents during overexcitation indicates that a 35 percent fifth-harmonic setting is adequate to block the percentage differential element. To disable fifth-harmonic blocking, set PCT5 to OFF.

Fifth-harmonic blocking is independent of the harmonic restraint setting (HRSTR) and does not affect the restraint slope characteristic

You can use the presence of fifth-harmonic differential current to assert an alarm output during startup. This alarm indicates that the rated transformer excitation current is exceeded. A settable delay, TH5D, prevents the relay from indicating transient presence of fifth-harmonic currents.

You may consider triggering an event report if the fifth-harmonic threshold is exceeded.

The TH5 setting range is 0.1 to 3.2 multiples of TAP. The setting must also yield an operating current greater than or equal to $0.1 \cdot I_N$, when multiplied by TAP_{MIN}, the lesser of TAP1 or TAP2. Stated in equation form:

$$TAP_{MIN} \cdot TH5 \geq 0.1\ I_N$$

For example, if TAP_{MIN} is equal to 1.0 and $I_N = 5$, the minimum TH5 setting available is 0.5.

DC Ratio Blocking (DCRB)

Some magnetizing inrush cases contain very little harmonic content but contain dc. The SEL-587-1 adds the capability of detecting dc current and using it in the blocking logic. This blocking is enabled by setting DCRB = Y. Set DCRB = N when applying the differential element for generator protection or generator transformer group protection.

Harmonic Restraint (HRSTR)

The SEL-587-1 adds the capability of using even-harmonic restraint for security during inrush conditions. Consider the harmonic restraint feature (HRSTR = Y) if your practices require independent harmonic restraint. When HRSTR = Y, harmonic blocking is not used. Even though harmonic blocking is disabled, the relay forces the IHBL setting to Y to use the routing logic on the right side of *Figure 3.5* to assert 87R.

When using harmonic restraint, the second- and fourth-harmonic compensated currents, scaled by the PCT2 and PCT4 settings, are added to the restraint quantity. Increasing the values used for PCT2 and PCT4 settings decreases the respective harmonic content that is added to the restraint characteristic of the relay. This is a result of the inverse relationship created by the 100/PCT2 and 100/PCT4 multipliers on the respective second- and fourth harmonic content quantities prior to addition to the restraint characteristic.

Use the default values for these settings to provide secure differential element operation for inrush conditions. It is important to note that setting PCT2 or PCT4 to OFF will effectively remove all harmonic restraint for that particular harmonic content and is not advised. See *Figure 3.4* for details. Tests suggest that this method ensures security for inrush currents having very low second harmonic content. Fifth-harmonic and dc blocking should be used in conjunction with this feature for maximum security.

Independent Harmonic Blocking Element (IHBL)

When a three-phase transformer is energized, inrush harmonics are present on at least two phase currents. In traditional single-phase relays, each relay performs a comparison of the harmonic current flowing through its phase. The SEL-587 can perform harmonic blocking two ways:

1. Independent Harmonic Blocking (IHBL = Y) blocks the percentage differential element for a particular phase if the harmonic (second or fifth) in that phase is above the block threshold. Other elements are not blocked.
2. Common Harmonic Blocking (IHBL = N) blocks all of the percentage differential elements if any one phase has a harmonic magnitude above the blocking threshold.

Common Harmonic Blocking is a more secure scheme, but can slightly delay percentage differential element operation since harmonics in all three phases must drop below their thresholds.

Differential Protection Application Guideline

It is vital that you select adequate current transformers for a transformer differential application. Use the following procedure, based on ANSI/IEEE Standard C37.110:1996, *IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes*.

CT Arrangements

Use separate relay restraint circuits for each power source to the relay. In the SEL-587, you can apply a maximum of two restraint inputs to the relay. You can connect CT secondary windings in parallel only if both circuits:

- Are outgoing loads.
- Are connected at the same voltage level.
- Have CTs that are matched in ratio, C-rating (CT ANSI voltage classification), and core dimensions.

CT Sizing

Sizing a CT to avoid saturation for the maximum asymmetrical fault is ideal, but not always possible. This requires a CT ANSI voltage classification greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

Use caution when selecting CTs for saturation conditions in firmware revisions released prior to August 28, 2002 (see *Appendix A: Firmware and Manual Versions*). If you apply the SEL-587 in high fault current situations, such as in power plant auxiliary buses with as much as 40000 A of line-to-line fault current, current transformers used with the SEL-587 should meet the following criterion:

$$262.5 \geq \left(\frac{X}{R} + 1\right) \bullet I_f \bullet Z_b \qquad \textbf{Equation 3.9}$$

where:

I_f is the maximum fault current in per unit of CT rating

Z_b is the CT burden in per unit of standard burden

X/R is the X/R ratio of the primary fault circuit

This ensures a two-cycle trip of an instantaneous element set at 80 A. The following examples show how the criterion is used.

Example 1: Maximum Fault Current with an 80 A Instantaneous Setting

Maximum fault current in terms of primary CT and ANSI voltage rating, burden in ohms, and X/R ratio is:

$$I_{MAX} = \frac{262.5}{\left(1 + \frac{X}{R}\right)} \bullet \frac{ANSI}{100 \bullet Z_B} \bullet CT_{RATING} \qquad \textbf{Equation 3.10}$$

Equation 3.10 is an actual-value equation derived from *Equation 3.9* above

where:

I_{MAX} is the maximum primary fault current for line-to-line fault

CT_{RATING} is the CT primary rating in amperes

Z_B is the total CT secondary burden in ohms

ANSI is the ANSI voltage classification of CTs

An SEL-587 phase instantaneous overcurrent element is to be set at 80 A. The relay will be used with a C400, 400:5 current transformer with a 0.50 Ω total burden. The X/R ratio is 20. Determine the maximum fault current for dependable operation.

The burden is primarily from the CT windings and external leads to the SEL-587 (the SEL-587 has a negligible burden):

300 feet full-circuit run of #10 AWG (1.0 Ω /1000-ft)	0.30
CT winding of 80 turns at 0.0025 Ω /turn	+ 0.20
Total burden	0.50 Ω

$$I_{MAX} = \frac{262.5}{\left(1 + \frac{X}{R}\right)} \bullet \frac{ANSI}{100 \bullet Z_B} \bullet CT_{RATING}$$

$$= \frac{262.5}{(1+20)} \bullet \frac{400}{100 \bullet 0.50\ \Omega} \bullet 400 = 40000\ \text{A}$$

Example 2: Minimum CT Rating with an 80 A Instantaneous Setting

CT rating in terms of maximum fault current, X/R ratio, ANSI rating, and burden is:

$$CT_{RATING} = \frac{\left(1 + \frac{X}{R}\right)}{262.5} \bullet \frac{100}{ANSI} \bullet I_{MAX} \bullet Z_B \qquad \textbf{Equation 3.11}$$

With an 80 A instantaneous setting, what is the minimum CT rating that can be used when the maximum fault current is 40000 A, X/R = 20, and the burden is 0.50 Ω ohms?

$$CT_{RATING} = \frac{\left(1 + \frac{X}{R}\right)}{262.5} \bullet \frac{100}{ANSI} \bullet I_{MAX} \bullet Z_B$$

$$= \frac{(1+20)}{2625} \bullet \frac{100}{400} \bullet 40000 \bullet 0.50 = 400\ \text{A}$$

Example 3: Determine Whether the Following Application Meets the Above Criteria

CTs used	400:5 A, class C400
Instantaneous element pickup setting	80 A secondary
Maximum current for a line-to-line fault	40000 A primary
X/R ratio	20
Total CT secondary burden	0.50 Ω

Apply *Equation 3.9* to verify if the CTs meet the required criteria.

$$\left(\frac{X}{R} + 1\right) \bullet I_f \bullet Z_b = (20 + 1) \bullet \frac{40000}{400} \bullet \frac{0.50\ \Omega}{4} = 262.5$$

The calculation shows that the 400:5 (class C400) CT meets the criteria in *Equation 3.9*.

CT Ratio Selection

As a general rule, CT performance will be satisfactory if the CT secondary maximum symmetrical external fault current multiplied by the total secondary burden is less than half of the C-voltage rating of the CT. The following CT selection procedure uses this second guideline.

Step 1. Determine the high-side and low-side CT burdens, RHS and RLS, respectively.

Step 2. Select the high-side CT ratio, CTR1, by considering the maximum high-side continuous current, IHS. For wye-connected CTs, the relay current, IREL1, equals IHS. For delta-connected CTs, the relay current, IREL1, equals $\sqrt{3}$ • IHS. Select the nearest standard ratio such that IREL1 is between 0.1 • IN and 1.0 • IN A secondary where IN is the relay nominal secondary current, 1 A or 5 A.

Step 3. Select the low-side CT ratio, CTR2, by considering the maximum low-side continuous current, ILS. For wye-connected CTs, the relay current, IREL2, equals ILS. For delta-connected CTs, the relay current, IREL2, equals $\sqrt{3}$ • ILS. Select the nearest standard ratio such that IREL2 is between 0.1 • IN and 1.0 • IN A secondary.

Step 4. The SEL-587 internally calculates settings TAP1 and TAP2 if the ratio TAPMAX/TAPMIN is less than or equal to 4.5. When the relay calculates the TAP settings, it reduces CT mismatch to less than 1 percent. Manually calculate TAP1 and TAP2 following the example shown in *Appendix G: Manual Calculation of Relay TAP Settings* to verify that the TAP values fall within the acceptable relay setting ranges.

Step 5. If the ratio TAPMAX/TAPMIN is greater than 4.5, select a different CT ratio to meet the above conditions. You may need to apply auxiliary CTs in one circuit to achieve the required ratio. Repeat *Step 2* through *Step 5*.

Step 6. Calculate the maximum symmetrical fault current for an external fault and verify that the CT secondary currents do not exceed your utility standard maximum allowed CT current, typically 20 times rated current. If necessary, reselect the CT ratios and repeat *Step 2* through *Step 6*.

Step 7. For each CT, multiply the burden calculated in *Step 1* by the magnitude of the expected maximum symmetrical fault current for an external fault. Select nominal accuracy class voltages for high- and low-side CTs greater than twice the voltage calculated. If necessary, select a higher CT ratio to meet this requirement, then repeat *Step 2* through *Step 7*. This selection criterion helps reduce the likelihood of CT saturation for a fully offset fault current signal.

Note that the effective C-rating of a CT is lower than the nameplate rating if a TAP other than the maximum is used. Derate the CT C-rating by a factor of ratio used/ratio max.

Current TAPS (TAP1, TAP2) are defined in one of two ways:

1. In most applications the relay automatically calculates the TAP values by using the MVA, VWDG1, VWDG2, TRCON, CTCON, CTR1, and CTR2 settings you enter.
2. You can directly enter TAP values calculated using the procedure found in *Appendix G: Manual Calculation of Relay TAP Settings*. To directly enter your own TAP values, set MVA = OFF and enter the settings TRCON, CTCON, CTR1, CTR2, TAP1, and TAP2.

Overcurrent Protection

Overcurrent Protection Overview

The SEL-587 includes two groups of nondirectional overcurrent elements to supplement the differential protection. One group of elements is operated by Winding 1 current measurements and the other group is operated by Winding 2 current measurements. All elements have independent pickup and time-delay settings. If necessary, you can externally torque control selected elements by using a control input.

Overcurrent element pickup settings and operating characteristics are independent of the differential element settings. Overcurrent elements operate on the secondary current that is applied to the terminals of the relay. When setting overcurrent elements with delta-connected CTs, take care to consider what the primary system line currents are when compared to the secondary line-to-line current, which is supplied to the relay.

The overcurrent elements measure the fundamental frequency winding input currents. If the transformer CTs are wye connected, the relay can provide phase, negative-sequence, and residual overcurrent elements for that winding. If the CTs are delta-connected, the relay provides only phase and negative-sequence overcurrent elements for that winding. The residual overcurrent elements are disabled automatically because the delta-connected CT cannot deliver any residual operating current. In new installations, use wye-connected CTs whenever possible to maximize available protection and simplify overcurrent relay settings.

Overcurrent Protection Characteristic

Table 3.3 provides a summary of the overcurrent elements provided by the SEL-587.

Table 3.3 Overcurrent Element Summary

	Definite-Time Elements	Instantaneous Elements	Inverse-Time Elements
Phase (Ia, Ib, and Ic)			
Winding 1	50P1	50P1H	51P1
Winding 2	50P2	50P2H	51P2
Negative-Sequence (IQ = 3 • I_2)			
Winding 1	50Q1		51Q1
Winding 2	50Q2		51Q2
Residual (IR = Ia + Ib + Ic)			
Winding 1	50N1	50N1H	51N1
Winding 2	50N2	50N2H	51N2

Definite-Time Overcurrent Element

Logic for the definite-time phase overcurrent element 50P*n* is shown in *Figure 3.9*. The logic provides a definite-time element output (50P*n*T) and an instantaneous output (50P*n*P) for time-delay accuracy testing. Pickup, torque control, and time delay are programmed with settings. Definite-time negative-sequence overcurrent element 50Q*n* and definite-time residual overcurrent element 50N*n* logic are similar.

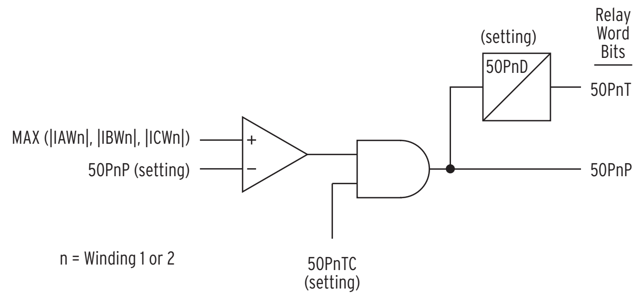

Figure 3.9 Definite-Time Overcurrent Element

Instantaneous Overcurrent Element

Logic for the instantaneous high-set phase overcurrent element 50P*n*H is shown in *Figure 3.10*. Pickup and torque control are programmed with settings. Instantaneous residual overcurrent element 50N*n*H logic is similar.

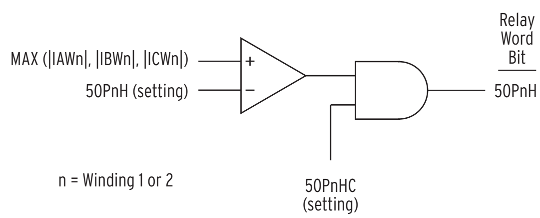

Figure 3.10 Instantaneous Overcurrent Element

Inverse-Time Overcurrent Element

Logic for the inverse-time phase overcurrent element 51P*n* is shown in *Figure 3.11*. The logic provides inverse-time (51P*n*T), instantaneous (50P*n*P), and reset (51P*n*R) outputs. The instantaneous and reset outputs are provided for testing purposes. Pickup, torque-control, curve shape, time-dial, and reset characteristics are programmed with settings. Definite-time negative-sequence overcurrent element 51Q*n* and definite-time residual overcurrent element 51N*n* logic are similar.

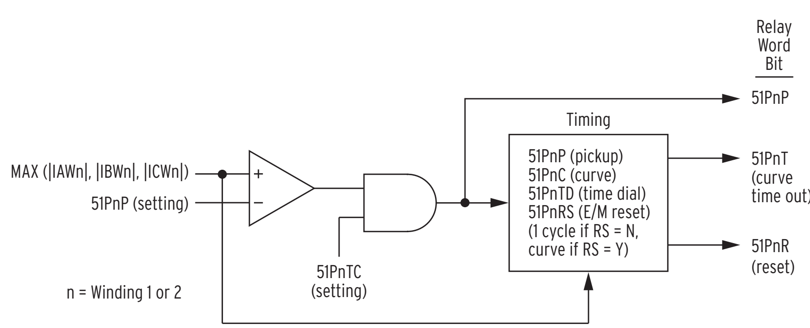

Figure 3.11 Inverse-Time Overcurrent Element

Overcurrent Protection Setting Descriptions

Pickup Settings (50PnP, 50PnH, 51PnP, 50QnP, 51QnP, 50NnP, 50NnH, 51NnP)

Use this setting to determine at what level the instantaneous overcurrent elements assert and what level the time-overcurrent elements begin timing. The time-overcurrent element curves are scaled in multiples of this pickup setting. Disable an element by setting the pickup to OFF and disregard the element's other settings.

Set the phase time-overcurrent element to provide sensitive detection and coordinated time-overcurrent protection for balanced and unbalanced fault conditions. Use the negative-sequence time-overcurrent element to provide sensitive detection and coordinated time-overcurrent protection for unbalanced fault conditions including phase-to-phase, phase-to-ground, and phase-to-phase ground faults. Set the residual time-overcurrent to provide sensitive detection and coordinated time-overcurrent protection for phase-to-ground faults.

Torque-Control Settings (50PnTC, 51PnTC, 50QnTC, 51QnTC, 50NnTC, 51NnTC)

Set IN1 or IN2 to TCEN (torque-control enable) or TCBL (torque-control block) to enable and display the overcurrent torque-control Y/N settings. Use torque control to enable or disable the element for certain conditions.

Select Y for each overcurrent element that you want to torque control with a control input. Only one input can be assigned a torque-control option and it torque controls all overcurrent elements with a torque-control setting of Y. Do not set IN1 or IN2 to TCEN or TCBL if you need to set them to 52A or !52A to enable close operations.

Time-Delay Settings (50PnD, 50QnD, 50NnD)

Coordinate with downstream devices by delaying the instantaneous pickup of an element that uses this setting.

The time-delay settings 50PnD, 50QnD and 50NnD are adjustable in increments of 0.25 cycles.

Curve Shape (51PnC, 51QnC, 51NnC) and Time-Dial (51PnTD, 51QnTD, 51NnTD) Settings

Select curve shape and time-dial settings to coordinate with downstream phase, negative-sequence, and residual time-overcurrent elements. Refer to the time-overcurrent equations and curves at the end of this section for the specific time-overcurrent characteristic equations.

US Curve Shapes

- U1: Moderately Inverse
- U2: Inverse
- U3: Very Inverse
- U4: Extremely Inverse

IEC Curve Shapes

- C1: Class A (Standard Inverse)
- C2: Class B (Very Inverse)

- ➤ C3: Class C (Extremely Inverse)
- ➤ C4: Long-time Inverse

Reset Characteristic Settings (51PnRS, 51QnRS, 51NnRS)

Set the time-overcurrent reset characteristic to emulate an induction-disk relay reset characteristic or linear one cycle reset.

The induction-disk selection emulates the spring-torque governed disk reset action of an induction time-overcurrent unit. Set 51*xx*RS = Y when the time-overcurrent element must coordinate with upstream electromechanical time-overcurrent relays during trip-reclose cycles.

The one cycle reset selection fully resets the element one cycle after current drops below the element pickup setting. Set 51*xx*RS = N when the time-overcurrent element must coordinate with upstream static or microprocessor-based time-overcurrent elements, which have fast reset characteristics.

Overcurrent Protection Application Guidelines

Transformer Overcurrent Protection

Instantaneous overcurrent elements typically provide high-speed protection for high-current, internal transformer faults and coordinated backup protection for faults on the adjacent bus and/or feeders. You can use inverse-time overcurrent elements to prevent transformer damage due to excessive through currents caused by slow clearing external faults. Thermal and mechanical damage curves should be available from the transformer manufacturer for specific transformer designs. You can consult several references, including the *IEEE Guide for Protective Relay Applications to Power Transformers*, C37.91, that provide generic through-current limitations for various classes of transformers.

Set the SEL-587 instantaneous overcurrent elements to detect high-current faults within the transformer differential protection zone. Use definite-time and time-overcurrent elements to detect lower current faults inside and outside the transformer differential protection zone. Use appropriate delays to coordinate with upstream and downstream protection.

Conventional instantaneous overcurrent elements must be set sufficiently high to avoid tripping on transformer magnetizing inrush current, where peak currents can be 30 times the transformer full-load current. Transformer magnetizing inrush current contains substantial second-harmonic current and often contains a significant dc component. Unlike conventional electromechanical overcurrent elements, the SEL-587 overcurrent elements ignore all but the fundamental frequency current, making them insensitive to the off-fundamental-frequency content of the magnetizing inrush current. The SEL-587 instantaneous, definite-time, and time-overcurrent elements need only be set with regard to expected load and fault conditions.

Where the SEL-587 is applied to a distribution substation transformer serving load centers, expected load conditions include steady state load as well as transient conditions caused by hot and cold load pickup.

Hot load pickup inrush occurs when a distribution circuit is energized shortly after being de-energized, such as in a feeder trip-reclose cycle. Hot load pickup inrush current that the SEL-587 can see consists primarily of motor starting current from motor loads, incandescent and fluorescent lighting load inrush, and resistive heating element inrush. The overall effect is an inrush current several times the normal load current that can last for several seconds.

Cold load pickup inrush occurs when a distribution circuit is energized after being de-energized for a relatively long period of time. Cold load pickup includes many of the same inrush characteristics as hot load pickup, but is usually more severe and longer lasting because more thermostatically controlled systems need to satisfy their heating or cooling requirements after the prolonged outage.

For these reasons, overcurrent protection must be tailored to meet the protection requirements for the specific transformer, avoid tripping for various types of nonfault transient conditions, and coordinate with upstream and downstream protection devices. These factors constrain the selection of settings and characteristics for the applied overcurrent protection.

Phase Overcurrent Protection

Set phase overcurrent element pickup settings above the highest expected load current to avoid tripping on normal load current. You can set the pickup lower if you use external torque control.

Since you can use the negative-sequence overcurrent elements to detect phase to-phase faults, you can set the phase overcurrent elements for three-phase fault detection only. This setting selection improves the ratio of the minimum phase fault current to maximum load current required for secure phase overcurrent relay application.

Negative-Sequence Overcurrent Protection

The negative-sequence elements respond to $|3I_2|$ current, where $3I_2 = Ia + Ib \cdot (1A240) + Ic \cdot (1A120)$. The negative-sequence overcurrent elements are uniquely suited to detect phase-to-phase faults and are not sensitive to balanced load.

For a phase-to-phase fault:

$$|I_2| = \left(\frac{\sqrt{3}}{3}\right) \cdot |Ip|$$

$$3 \cdot |I_2| = \sqrt{3} \cdot |Ip|$$

$$\therefore \frac{|3I_2|}{|Ip|} = 1.73$$

where Ip is the maximum phase current.

Thus, the negative-sequence element is 1.73 times more sensitive to phase-to-phase faults than a phase overcurrent element with the same pickup setting.

While negative-sequence overcurrent elements do not respond to balanced load, they do detect the negative-sequence current present in unbalanced load. For this reason, select an element pickup setting above the maximum $3I_2$ current expected due to load unbalance.

When applied on the delta side of a delta-wye transformer, negative-sequence relay elements also provide sensitive fault protection for ground faults on the wye side of the transformer. This is not possible using only phase and residual overcurrent elements.

Residual Overcurrent Protection

The residual element responds to $3I_0$ current, where $3I_0$ = Ia + Ib + Ic. Residual overcurrent elements detect ground faults and do not respond to balanced load. The residual element is sensitive to unbalanced load, however, and should be set above the maximum $3I_0$ current expected because of load unbalance.

When applied on the delta side of a delta-wye transformer, residual overcurrent elements are insensitive to any type of fault on the wye side of the transformer and can only detect ground faults on the delta side. This eliminates any coordination constraints with protection devices on the wye side of the transformer, permitting very sensitive residual overcurrent element pickup settings.

Time-Overcurrent Element Operate/Reset Curve Equations

Definitions:

tp = operating time in seconds

tr = 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 (tp), M > 1; for reset time (tr), M ≤ 1)

Table 3.4 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time
U1 (Moderately Inverse)	$t_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$
U2 (Inverse)	$t_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$
U3 (Very Inverse)	$t_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$
U4 (Extremely Inverse)	$t_p = TD \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.67}{1 - M^2}\right)$

Table 3.5 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time
C1 (Standard Inverse)	$t_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$
C2 (Very Inverse)	$t_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$
C3 (Extremely Inverse)	$t_p = TD \bullet \left(\frac{80.0}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{80.0}{1 - M^2}\right)$
C4 (Long-Time Inverse)	$t_p = TD \bullet \left(\frac{120.0}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{120.0}{1 - M}\right)$

Full-sized time-current curve transparencies are available.

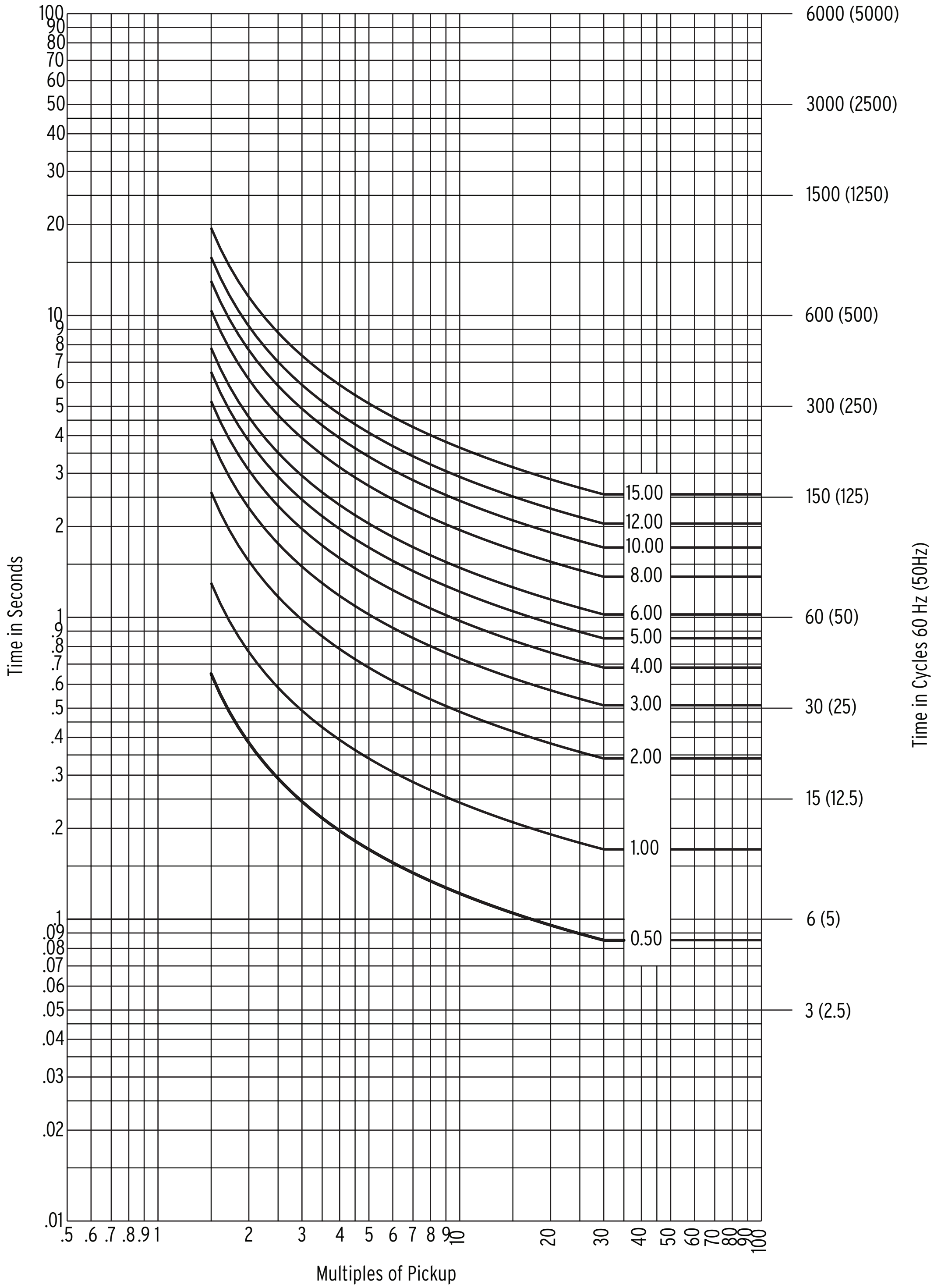

Figure 3.12 Time Curve U1

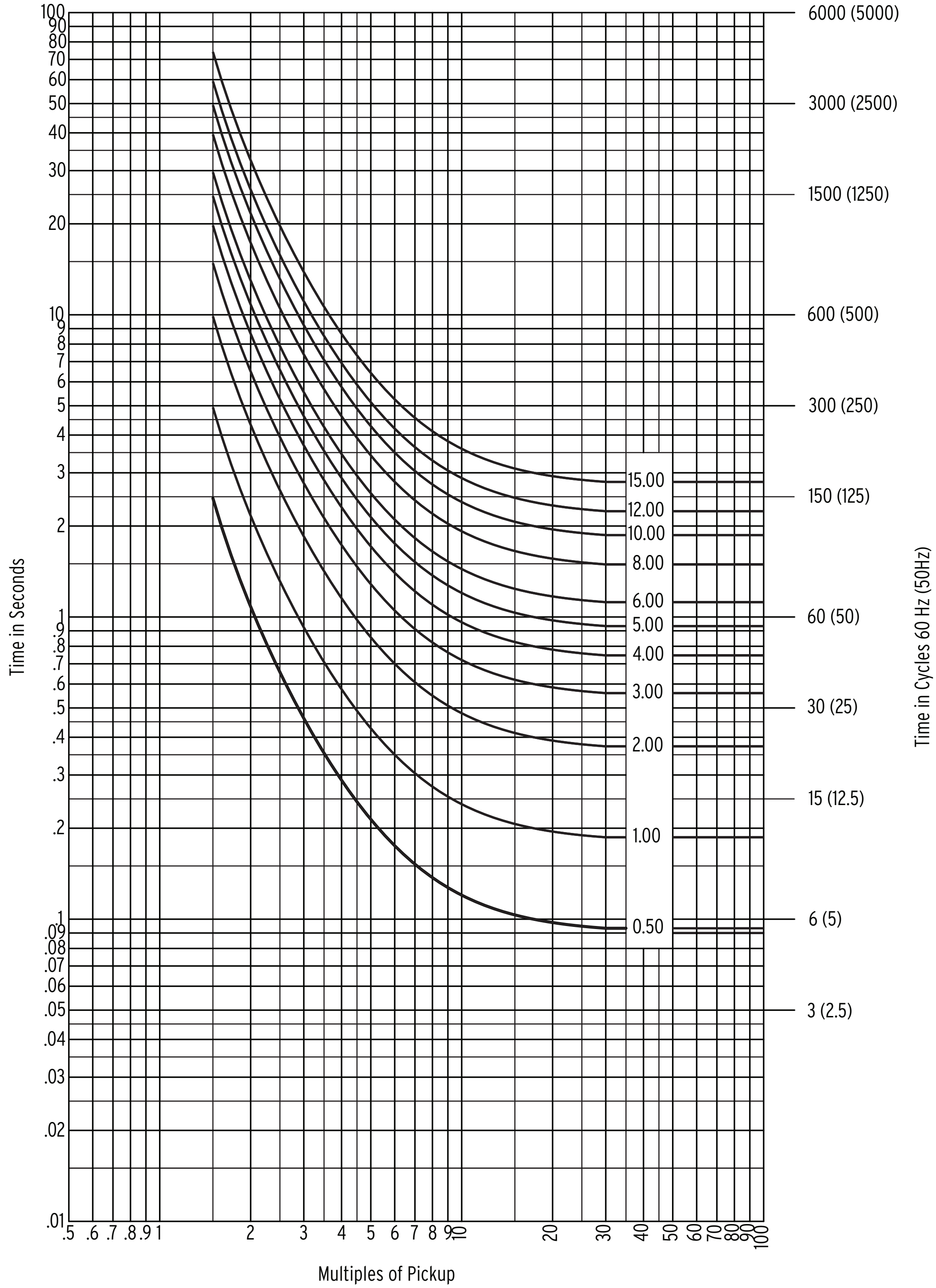

Figure 3.13 Time Curve U2

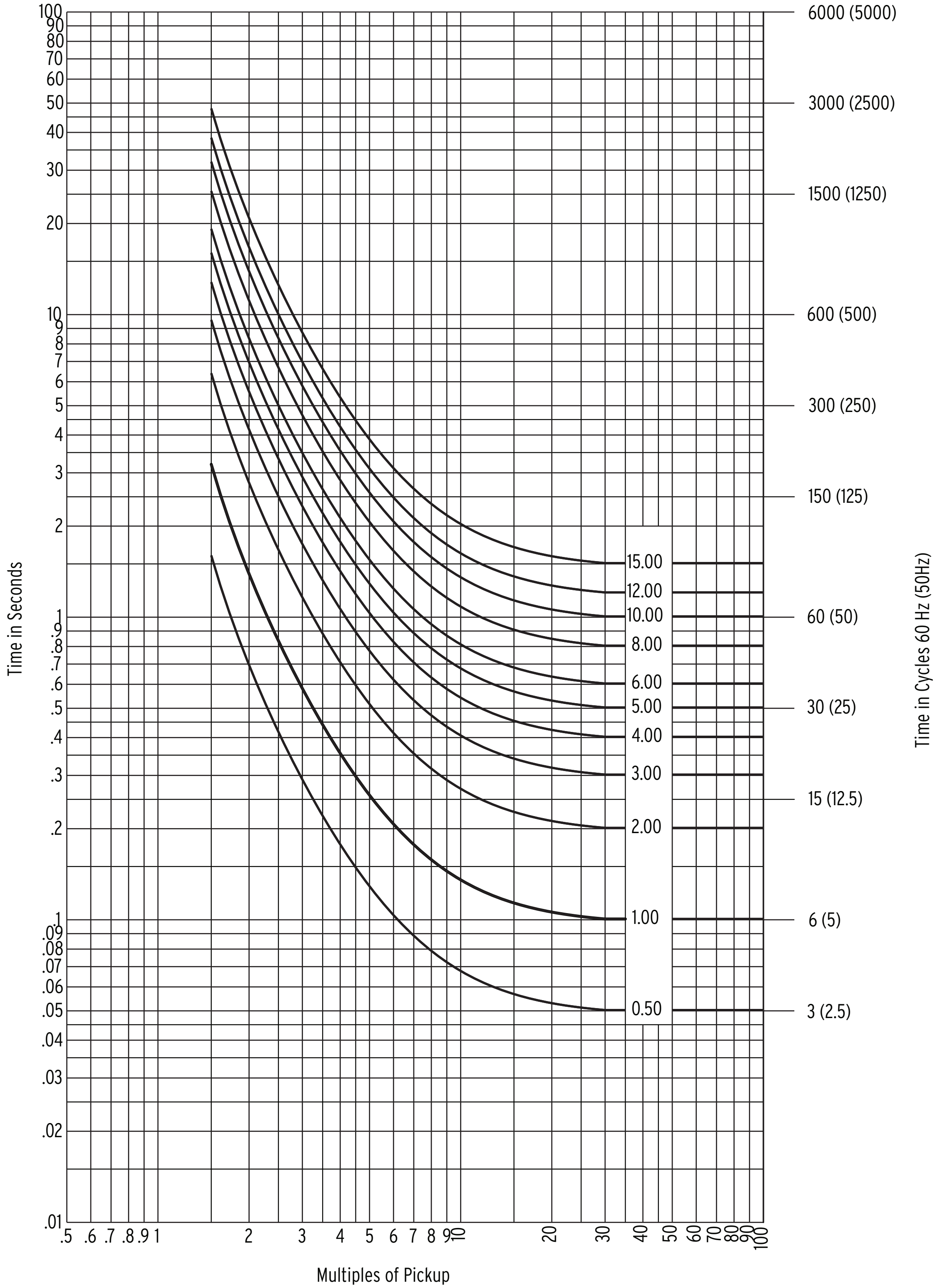

Figure 3.14 Time Curve U3

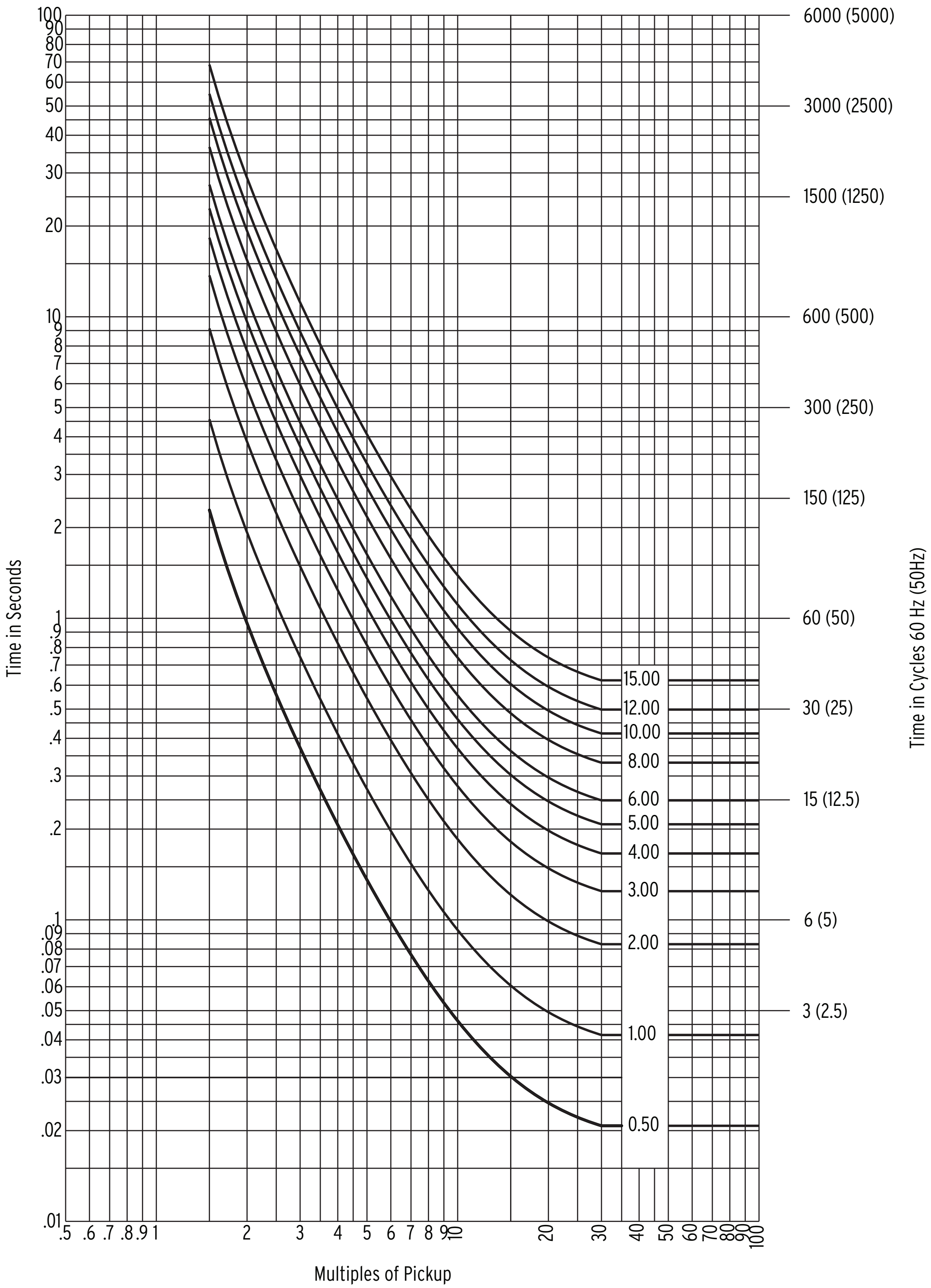

Figure 3.15 Time Curve U4

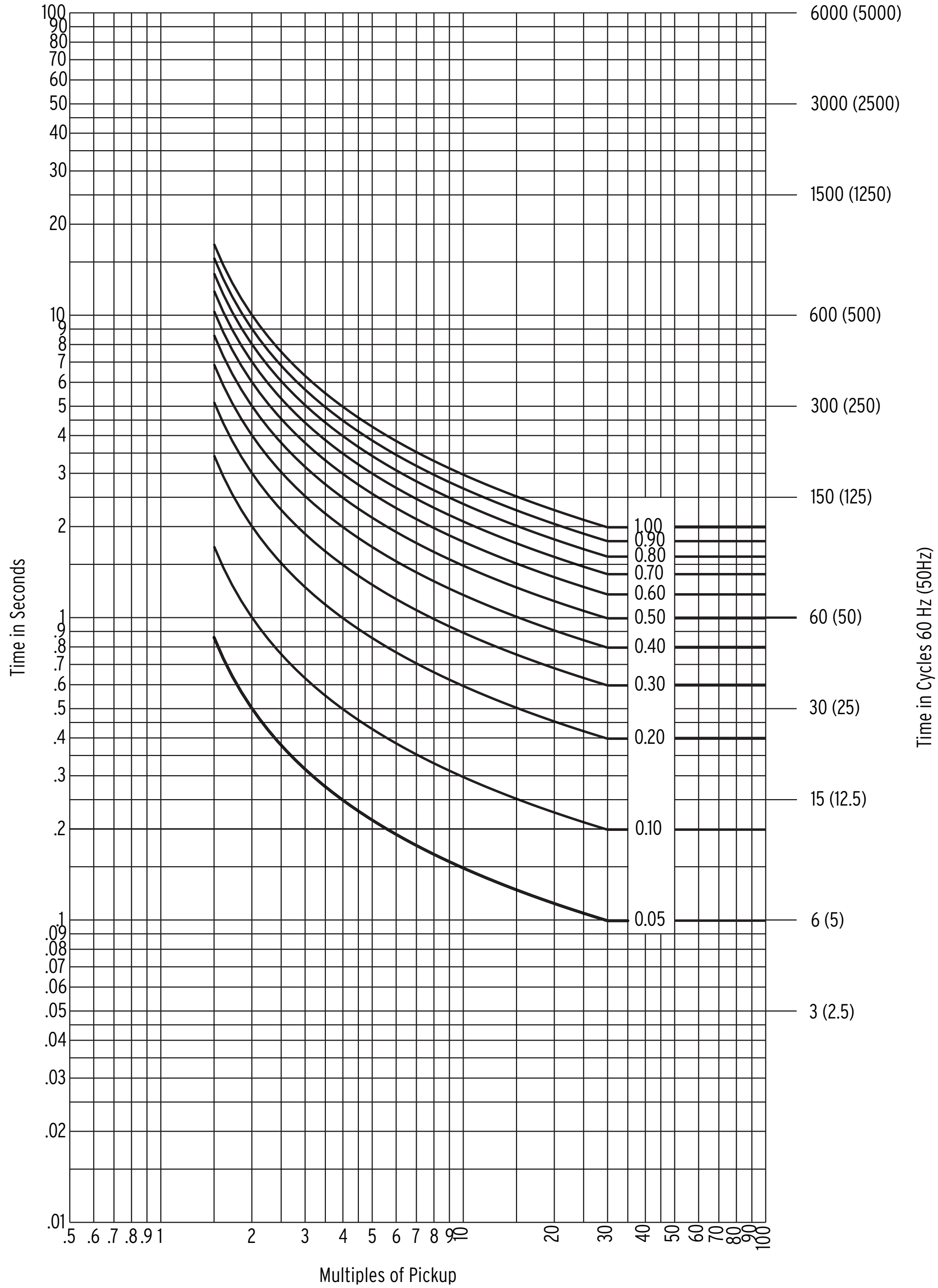

Figure 3.16 Time Curve C1

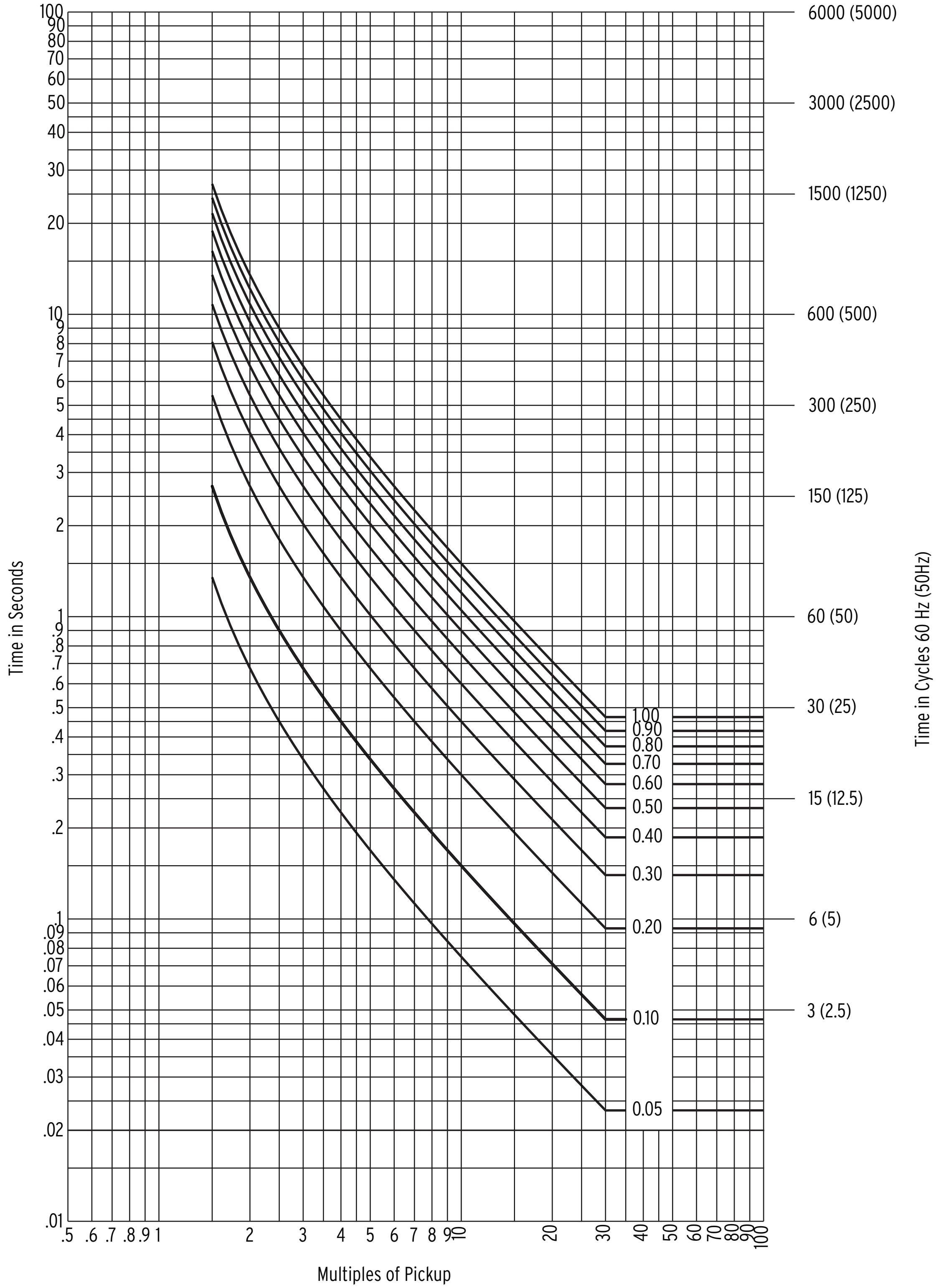

Figure 3.17 Time Curve C2

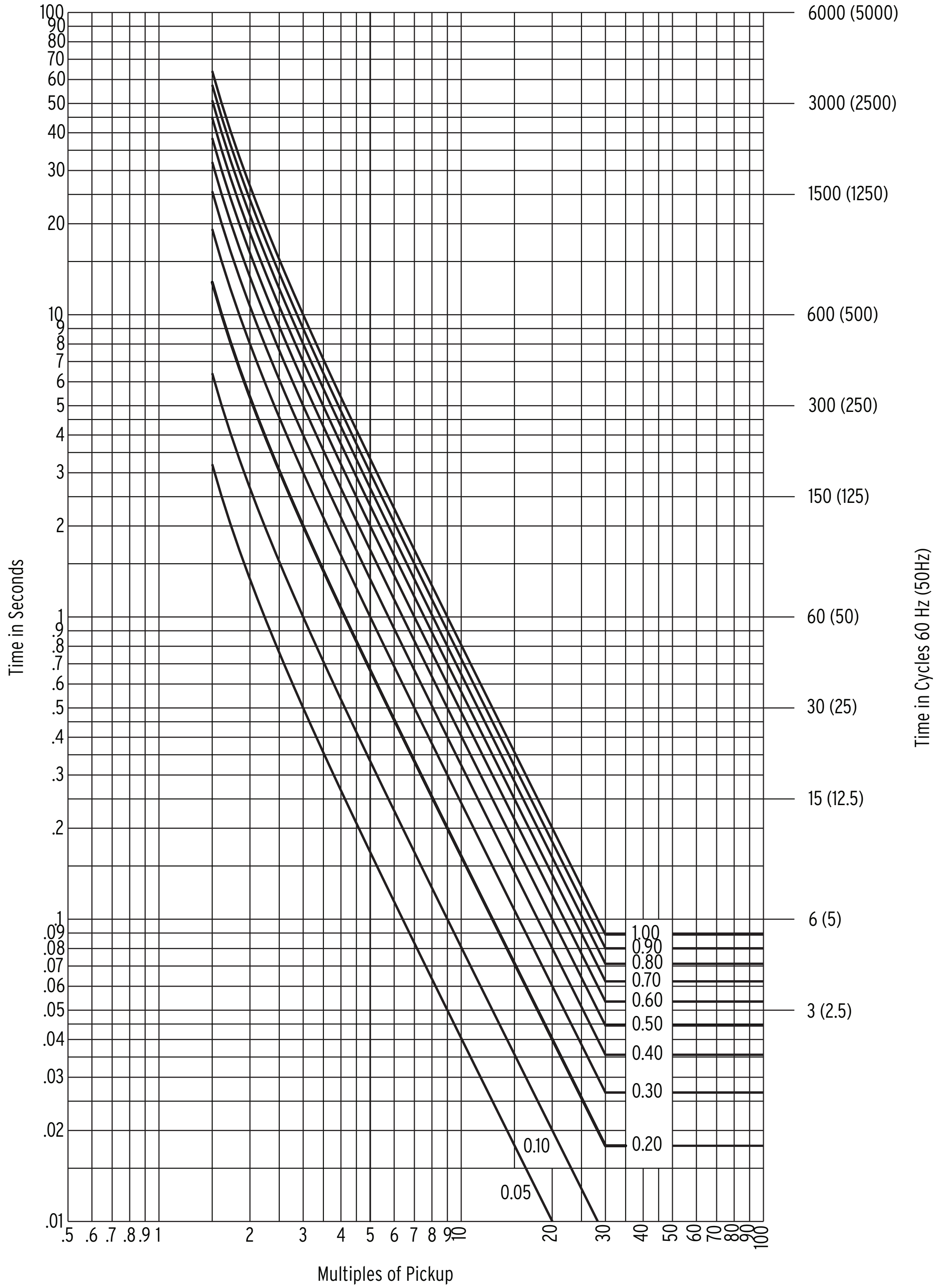

Figure 3.18 Time Curve C3

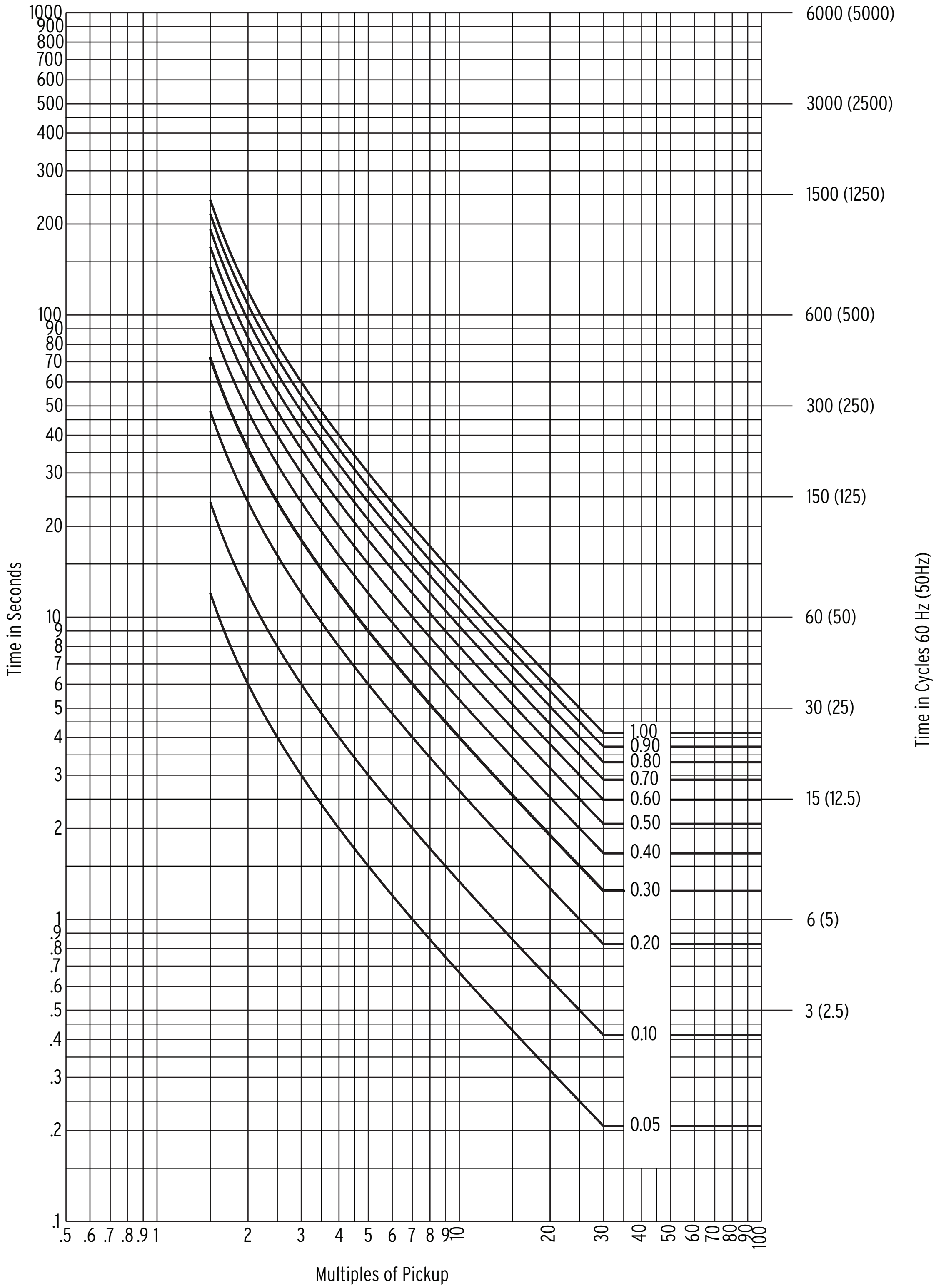

Figure 3.19 Time Curve C4

Section 4

Tripping, Closing, and Targeting Logic

Introduction

This section describes the Relay Word and the programmable settings used to configure the relay output contacts for tripping and closing operation. This section also discusses the relay front-panel target functions and provides a logic setting example.

The Relay Word

The SEL-587 performs digital filtering eight times per power system cycle by using data sampled from the six connected current inputs. The relay contains three different digital filters tuned to particular signal frequencies: the fundamental, second harmonic, and fifth harmonic. Using the filtered current information and present state of the relay control inputs, the relay executes all the magnitude estimation, differential algorithms, and logic functions.

To make the element and logic information accessible to other parts of the relay, the information is stored in a common area called the Relay Word. The Relay Word contains placeholders, called Relay Word bits, for each of the protection elements and logic conditions in the SEL-587. Each Relay Word bit is updated every eighth-cycle.

Relay Word bits contained in Rows 1 through 8 and Row 10 are defined by the relay specification and cannot be changed. Relay Word bits in Rows 9 and 11 (excluding ALARM) are defined using SELOGIC® control equations. SELOGIC control equations are discussed later in this section.

Table 4.1 lists the SEL-587 Relay Word. *Table 4.2* defines the Relay Word bits and describes their principal applications. Note that the Relay Word bits can be used in many ways; the principal applications listed in *Table 4.2* are merely suggestions.

Table 4.1 SEL-587 Relay Word Bit Summary (Sheet 1 of 2)

Row	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1	51P1P	51Q1P	51N1P	51P1T	51Q1T	51N1T	*	RB1
2	50P1P	50Q1P	50N1P	50P1T	50Q1T	50N1T	50P1H	50N1H
3	51P2P	51Q2P	51N2P	51P2T	51Q2T	51N2T	*	RB2
4	50P2P	50Q2P	50N2P	50P2T	50Q2T	50N2T	50P2H	50N2H
5	87U1	87U2	87U3	87U	87R1	87R2	87R3	87R
6	2HB1	2HB2	2HB3	5HB1	5HB2	5HB3	87BL	RB3
7	TH5P	TH5T	PDEM	NDEM	QDEM	TRP1	TRP2	TRP3

Table 4.1 SEL-587 Relay Word Bit Summary (Sheet 2 of 2)

Row	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
8	OC1	OC2	CC1	CC2	IN1	IN2	52A1	52A2
9	MTU3	MTU2	MTU1	MER	YT	Y	XT	X
10	51P1R	51Q1R	51N1R	51P2R	51Q2R	51N2R	*	RB4
11	*	*	*	ALARM	OUT1	OUT2	OUT3	OUT4
12	*	*	*	*	*	*	*	*

Table 4.2 SEL-587 Relay Word Bit Definitions (Sheet 1 of 3)

Row	Bit	Description	Application
1	51P1P	Winding 1 Phase Time-Overcurrent Pickup	Event Triggering, Testing
	51Q1P	Winding 1 Negative-Sequence Time-Overcurrent Pickup	
	51N1P	Winding 1 Residual Time-Overcurrent Pickup	
	51P1T	Winding 1 Phase Time-Overcurrent Trip	Tripping
	51Q1T	Winding 1 Negative-Sequence Time-Overcurrent Trip	
	51N1T	Winding 1 Residual Time-Overcurrent Trip	
	RB1	Remote Bit 1	User-Definable
2	50P1P	Winding 1 Phase Definite-Time Pickup	Event Triggering, Testing
	50Q1P	Winding 1 Negative-Sequence Definite-Time Pickup	
	50N1P	Winding 1 Residual Definite-Time Pickup	
	50P1T	Winding 1 Phase Definite-Time Trip	Tripping
	50Q1T	Winding 1 Negative-Sequence Definite-Time Trip	
	50N1T	Winding 1 Residual Definite-Time Trip	
	50P1H	Winding 1 Phase Instantaneous Trip	
	50N1H	Winding 1 Residual Instantaneous Trip	
3	51P2P	Winding 2 Phase Time-Overcurrent Pickup	Event Triggering, Testing
	51Q2P	Winding 2 Negative-Sequence Time-Overcurrent Pickup	
	51N2P	Winding 2 Residual Time-Overcurrent Pickup	
	51P2T	Winding 2 Phase Time-Overcurrent Trip	Tripping
	51Q2T	Winding 2 Negative-Sequence Time-Overcurrent Trip	
	51N2T	Winding 2 Residual Time-Overcurrent Trip	
	RB2	Remote Bit 2	User-Definable
4	50P2P	Winding 2 Phase Definite-Time Pickup	Event Triggering, Testing
	50Q2P	Winding 2 Negative-Sequence Definite-Time Pickup	
	50N2P	Winding 2 Residual Definite-Time Pickup	
	50P2T	Winding 2 Phase Definite-Time Trip	Tripping
	50Q2T	Winding 2 Negative-Sequence Definite-Time Trip	
	50N2T	Winding 2 Residual Definite-Time Trip	
	50P2H	Winding 2 Phase Instantaneous Trip	
	50N2H	Winding 2 Residual Instantaneous Trip	

Table 4.2 SEL-587 Relay Word Bit Definitions (Sheet 2 of 3)

Row	Bit	Description	Application
5	87U1	Phase 1 Unrestrained Differential Element	Testing, Indication
	87U2	Phase 2 Unrestrained Differential Element	
	87U3	Phase 3 Unrestrained Differential Element	
	87U	87U = 87U1 + 87U2 + 87U3	Tripping
	87R1	Phase 1 Restrained Differential Element	Testing, Indication
	87R2	Phase 2 Restrained Differential Element	
	87R3	Phase 3 Restrained Differential Element	
	87R	Percentage-Restrained Differential Element, Including Harmonic Blocking	Tripping
6	2HB1	Phase 1 Second-Harmonic Block (SEL-587-0) Phase 1 Second- or Fourth-Harmonic Block (SEL-587-1)	Testing, Indication
	2HB2	Phase 2 Second-Harmonic Block (SEL-587-0) Phase 2 Second- or Fourth-Harmonic Block (SEL-587-1)	
	2HB3	Phase 3 Second-Harmonic Block (SEL-587-0) Phase 3 Second- or Fourth-Harmonic Block (SEL-587-1)	
	5HB1	Phase 1 Fifth-Harmonic Block	
	5HB2	Phase 2 Fifth-Harmonic Block	
	5HB3	Phase 3 Fifth-Harmonic Block	
	87BL	87BL = 2HB1+5HB1+2HB2+5HB2+2HB3+5HB3	
	RB3	Remote Bit 3	User-Definable
7	TH5P	Fifth-Harmonic Alarm Pickup	Event Triggering, Testing
	TH5T	Fifth-Harmonic Alarm	Tripping, Indication
	PDEM	Phase Demand Threshold Exceeded	Indication
	NDEM	Residual Demand Threshold Exceeded	
	QDEM	Negative-Sequence Demand Threshold Exceeded	
	TRP1	Trip 1, initiated by MTU1	Trip Output
	TRP2	Trip 2, initiated by MTU2	
	TRP3	Trip 3, initiated by MTU3	
8	OC1	**OPEN** command, Breaker 1 (can only be used in MTU*n* SELOGIC control equation)	Tripping
	OC2	**OPEN** command, Breaker 2 (can only be used in MTU*n* SELOGIC control equation)	
	CC1	**CLOSE** command, Breaker 1	Closing
	CC2	**CLOSE** command, Breaker 2	
	IN1	Logic Input 1	Testing, Indication
	IN2	Logic Input 2	
	52A1	Breaker 1 Auxiliary Contact Status	
	52A2	Breaker 2 Auxiliary Contact Status	

Table 4.2 SEL-587 Relay Word Bit Definitions (Sheet 3 of 3)

Row	Bit	Description	Application
9	MTU3	SELOGIC Control Equation Variable	TRP3 Trip Initiation
	MTU2	SELOGIC Control Equation Variable	TRP2 Trip Initiation
	MTU1	SELOGIC Control Equation Variable	TRP1 Trip Initiation
	MER	SELOGIC Control Equation Variable	Event Triggering
	YT	Time-Delayed Pickup/Dropout Y Variable	User-Definable
	Y	SELOGIC Control Equation Variable	
	XT	Time-Delayed Pickup/Dropout X Variable	
	X	SELOGIC Control Equation Variable	
10	51P1R	Winding 1 Phase Time-Overcurrent Element Reset	Testing, Indication
	51Q1R	Winding 1 Negative-Sequence Time-Overcurrent Element Reset	
	51N1R	Winding 1 Residual Time-Overcurrent Element Reset	
	51P2R	Winding 2 Phase Time-Overcurrent Element Reset	
	51Q2R	Winding 2 Negative-Sequence Time-Overcurrent Element Reset	
	51N2R	Winding 2 Residual Time-Overcurrent Element Reset	
	RB4	Remote Bit 4	User-Definable
11	ALARM	Relay ALARM Output	Testing, Indication
	OUT1	Relay OUT1 Output	
	OUT2	Relay OUT2 Output	
	OUT3	Relay OUT3 Output	
	OUT4	Relay OUT4 Output	

SELOGIC Control Equations

SELOGIC control equations allow you to define the conditions to operate a Relay Word bit, trigger an event report, or close an output contact. Build the logic equation by using the Relay Word bits that are eligible for use in the equation (see *Table 4.3*) and the logic operators listed.

- * for the AND operator
- + for the OR operator
- ! for the INVERT operator

If you want to shut off a SELOGIC control equation variable, type NA at the setting prompt for the variable.

The SEL-587 logic settings are shown in *Table 4.3*. To change the SEL-587 logic settings, use the Access Level 2 **SET L** command while communicating with the relay serial port. The SELOGIC control equation setting rules are shown in the following list:

- Count the number of Relay Word bits entered in all 10 SELOGIC control equations. The sum must be less than 124.
- You are not required to type spaces between the bits and operators as you enter the equation.

- When entering the SELOGIC control equation, you can enter a maximum of 80 characters per line. If you need to enter an equation containing more than 80 characters, type **<\>** as your 80th character, press **<Enter>**, and continue the equation on the next line.
- No single equation can be longer than 160 characters.

Table 4.3 Logic Settings

Setting	Eligible Relay Word Bits
X	Relay Word bits from Row 1 through Row 8. Do not use TRP1, TRP2, or TRP3 in the X equation.
Y	Relay Word bits from Row 1 through Row 8, plus X and XT. Do not use TRP1, TRP2, or TRP3 in the Y equation.
MTU1	Relay Word bits from Row 1 through Row 8, plus X, XT, Y, and YT. Do not use TRP1, TRP2, or TRP3 in the MTU1 equation.
MTU2	Relay Word bits from Row 1 through Row 8, plus X, XT, Y, and YT. Do not use TRP1, TRP2, or TRP3 in the MTU2 equation.
MTU3	Relay Word bits from Row 1 through Row 8, plus X, XT, Y, and YT. Do not use TRP1, TRP2, or TRP3 in the MTU3 equation.
MER	Relay Word bits from Row 1 through Row 8, plus X, XT, Y, and YT.
OUT1	Relay Word bits from Row 1 through Row 10.
OUT2	Relay Word bits from Row 1 through Row 10.
OUT3	Relay Word bits from Row 1 through Row 10.
OUT4	Relay Word bits from Row 1 through Row 10.

Tripping, Closing, Timer, and Output Contact Functions

The SEL-587 evaluates the SELOGIC control equations eight times per power system cycle. When the control equation assigned to an output contact is true, the relay operates the contact. The tripping, closing, and output contact functions are discussed individually below.

Tripping Functions (MTU1, MTU2, MTU3, TDURD, LTRP)

Use the MTU1, MTU2, and MTU3 SELOGIC control equations to define the conditions that cause Relay Word bits TRP1, TRP2, and TRP3, respectively, to assert. Set the TRP1, TRP2, and TRP3 Relay Word bits to control any of the relay output contacts for tripping purposes. Include OC1 and OC2 in MTU1 and MTU2 to enable **OPEN** command.

The LTRP (Latch Trip) setting determines latching and unlatching of the TRP1, TRP2, and TRP3 bits. This setting, therefore, affects whether the relay trip contacts remain closed after removal of the trip condition. *Figure 4.1* illustrates the effect of LTRP on TRP1 logic. Logic schemes for TRP2 and TRP3 are similar but use MTU2 and MTU3, respectively, as inputs.

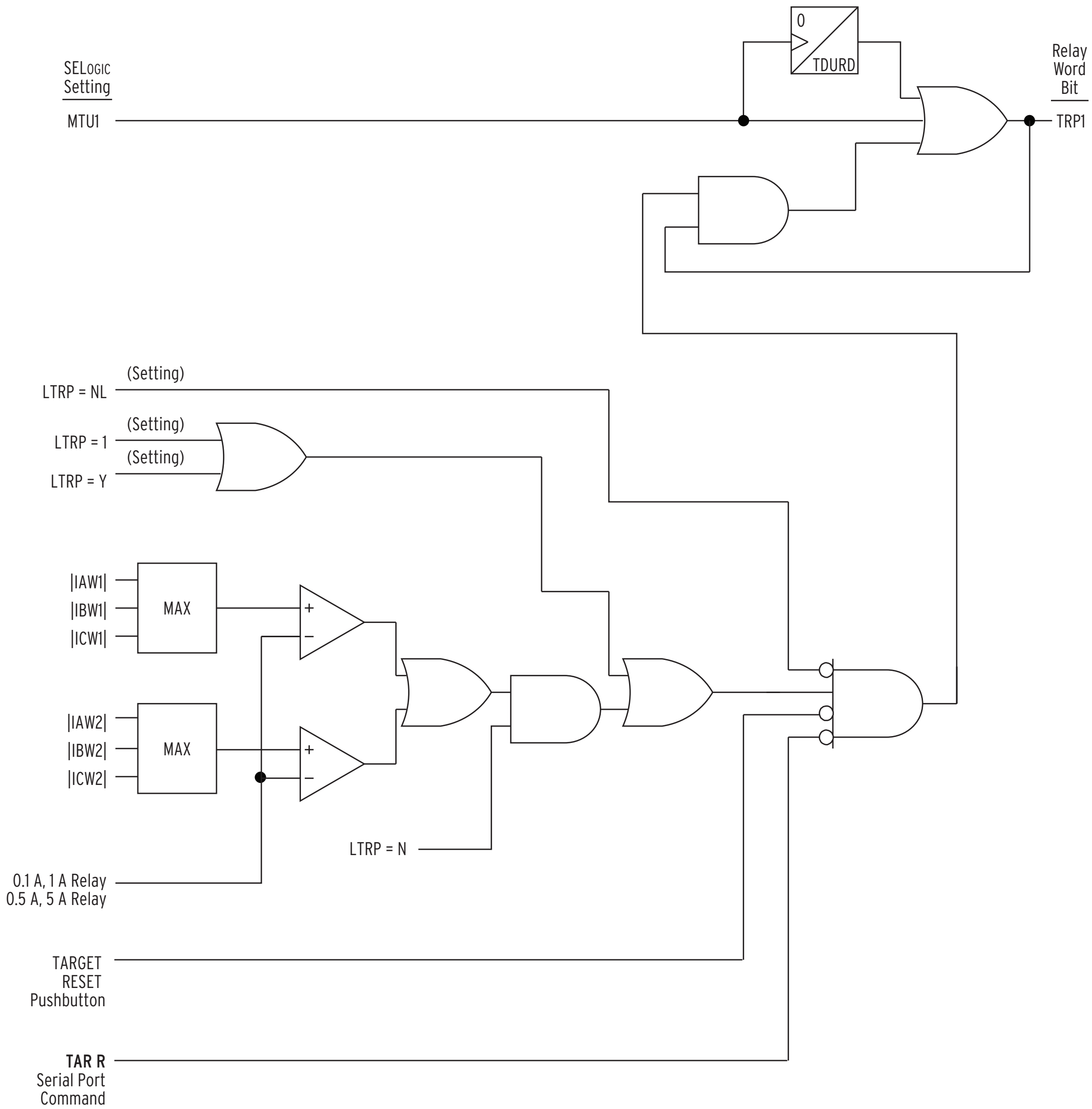

Figure 4.1 Trip Logic (TRP1)

To prevent latching, set LTRP = NL (not latched). Do this if you want TRP1 to deassert after the tripping condition vanishes or after TDURD cycles, whichever is longer. Use this setting for breaker bypass applications. This feature is only available in the SEL-587-1.

To latch TRP1, so it remains asserted after the tripping condition vanishes and the timer expires, set LTRP according to one of the following two cases:

- Set LTRP = Y, 1, 2, or 3 to enable latching regardless of current magnitude. Setting LTRP = Y will latch all trip contacts, while setting LTRP = 1, 2, or 3 allows you to latch a specific trip contact. Reset by pressing either the TARGET RESET button or executing the **TARGET R** command.
- Set LTRP = N to enable latching if current magnitude exceeds a threshold ($0.1 \bullet I_{nom}$). The relay resets when current magnitude decreases below the threshold. When current magnitude is equal to or greater than the threshold, reset by pressing either the TARGET RESET button or executing the **TARGET R** command.

Closing Functions (IN1, IN2)

The serial port **CLOSE *n*** (where *n* = 1 or 2) command controls the CC1 and CC2 Relay Word bits. If you want to use a relay output contact to close a high- or low-side circuit breaker by using the **CLOSE** command, set the SELOGIC control equation for the desired output contact equal to CC1 or CC2. Also, set IN1 = 52A1 or !52A1 to enable CLOSE 1 and set IN2 = 52A2 or !52A2 to enable CLOSE 2. Further, main board jumper JMP24 must be installed to enable the **CLOSE *n*** command (see *Circuit Board Jumpers and Battery on page 2.11*).

When you execute the **CLOSE 1** command, the CC1 Relay Word bit asserts for 60 cycles or until the 52A1, TRP1, TRP2, or TRP3 Relay Word bit asserts.

When you execute the **CLOSE 2** command, the CC2 Relay Word bit asserts for 60 cycles or until the 52A2, TRP1, TRP2, or TRP3 Relay Word bit asserts.

Figure 4.2 shows the CC1 logic.

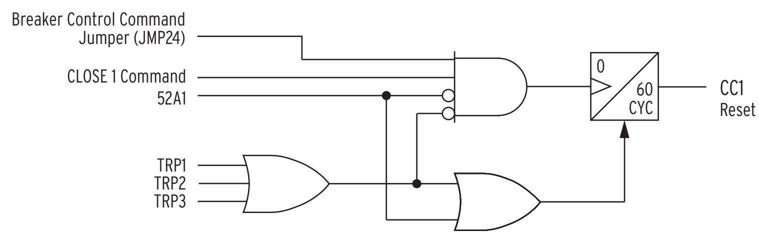

Figure 4.2 Close Logic Diagram

Timer Functions (X, XT, TXPU, TXDO, Y, YT, TYPU, TYDO)

Two SELOGIC control equation variables (X and Y) are available. Both of these variables have timer outputs (XT and YT).

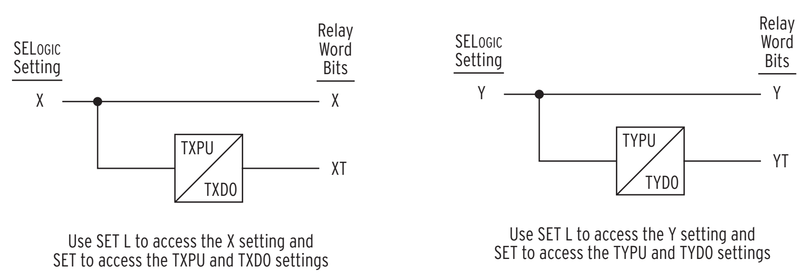

Figure 4.3 X and Y Variables

Output Contact Functions (OUT1, OUT2, OUT3, OUT4)

SELOGIC control equation settings control Relay Word bits having the same names. These Relay Word bits in turn control the output contacts. Alarm logic/circuitry controls the ALARM output contact.

Factory Settings Example

In the factory SELOGIC control equation settings, all four standard main board output contacts are used:

OUT1	=	TRP1	Used to trip Breaker 1
OUT2	=	TRP2	Used to trip Breaker 2
OUT3	=	TRP3	Used to energize 86 device for tripping Breakers 1–2
OUT4	=	87R + 87U + 50P1T + 51P1T + 50Q1T + 51Q1T + 50P2T + 51P2T + 51N2T	Tripping Alarm

SELOGIC Control Equation Setting Examples

Use the X and Y variables along with the output contact settings to define versatile testing and indication functions. *Table 4.4* shows several examples of relay logic settings that you can use to perform specific tasks.

Table 4.4 SELOGIC Control Equation Setting Examples

SELOGIC Control Equation Setting	Application
OUT3 = 51N1P	Testing: Output 3 closes when Winding 1 Residual current exceeds the 51N1P pickup setting.
MTU1 = PDEM * 52A1 + ..., OUT1 = TRIP	Overload Tripping: Output 1 closes when either winding phase demand current exceeds the PDEM setting while Breaker 1 is closed. Set the PDEM relay setting equal to or slightly greater than the maximum transformer load rating. Add other tripping conditions to the MTU1 equation by using the + operator.
MER = TH5P * !TH5T + ...	Event Triggering: MER asserts every time the Fifth-Harmonic Alarm Pickup (TH5P) asserts, causing the relay to generate an event report. ANDing TH5P with !TH5T prevents MER from remaining asserted for an extended period due to continuous presence of Fifth Harmonic. Add other event triggering conditions to the MER equation by using the + operator.
Y = 87U OUT4 = YT TYPU = 0 cycles TYDO = 60 cycles	Indication: Output 4 closes when the Unrestrained Current Differential Element picks up and remains closed for 60 cycles after the element drops out.

Instructions for Setting the Relay Outputs

Step 1. Select the output contacts for each of the tripping, closing, and indication functions required by your application.

Step 2. If you need to use the X or Y SELOGIC control equation variables to provide a time-delayed pickup or time-delayed dropout to a Relay Word bit you want to use for tripping or indication, write the X or Y equation defining those conditions. If you do not need to use X or Y, set them equal to NA.

Step 3. For each tripping function, write a SELOGIC control equation containing the necessary protection and logic Relay Word bits.

Step 4. The MER equation is for triggering event reports. Write a SELOGIC control equation containing the instantaneous pickup condition of each of the time-delayed tripping functions used above. Also include any additional desired event triggering conditions, except those already set in MTU1, MTU2, or MTU3. Elements set in MTU1, MTU2, and MTU3 always generate an event report.

Step 5. For each tripping output, set the output to the name of the TRP1, TRP2, or TRP3 Relay Word bit used to control the output.

Step 6. For each closing output, set the output to CC1 or CC2 (to control Breaker 1 or Breaker 2, respectively).

Step 7. For each testing or indication output, set the output to the Relay Word bit of the function under test, or the SELOGIC control equation defining the indication.

Step 8. Using a computer, terminal emulation software, and the appropriate cable (described in *Section 6: Operator Interface*), communicate with the SEL-587. Using the **ACCESS** and **2ACCESS** commands, along with the appropriate passwords, enter Access Level 2. Execute the **SET L** command and enter the logic settings defined in the previous steps.

Logic Setting Example

Table 4.5 shows the function of each relay output contact in the example application.

Table 4.5 Example Application Output Contact Functions

Output	Function
OUT1	Trip Winding 1 Breaker
OUT2	Trip Winding 2 Breaker
OUT3	Trip Transformer Lockout Relay
OUT4	Indicate Differential Element Operations

We will use the SELOGIC control equation X variable time-delayed dropout timer to add a dropout delay to the differential element. The TXDO time-delayed dropout time will be set long enough to ensure that the substation data acquisition system can acquire the indication.

X = 87U + 87R

[TXDO = 60 cycles]

The SELOGIC control equation Y variable is not used in this example.

Y = NA

Winding 1 overcurrent elements are used to trip the high-side breaker. The elements used are the phase definite-time overcurrent element, 50P1T, phase inverse-time overcurrent element, 51P1T, negative-sequence definite-time element, 50Q1T, inverse-time overcurrent element, 51Q1T, and the Breaker 1 OPEN command bit, OC1.

MTU1 = 50P1T + 51P1T + 50Q1T + 51Q1T + OC1

Winding 2 overcurrent elements are used to trip the low-side breaker. The elements used are the phase definite-time overcurrent element, 50P2T, phase inverse-time overcurrent element, 51P2T, residual definite-time and inverse-time overcurrent elements, 50N2T and 51N2T, and the Breaker 2 OPEN command bit, OC2.

MTU2 = 50P2T + 51P2T + 50N2T + 51N2T + OC2

The restrained and unrestrained transformer differential elements, 87R and 87U, are used to trip the transformer lockout relay.

MTU3 = 87R + 87U

The time-delayed elements used for tripping in this example are shown in *Table 4.6* along with their instantaneous pickup indications.

Table 4.6 Time-Delayed Overcurrent Elements and Their Instantaneous Pickup Indications

Time-Delayed Element	Element Pickup
50P1T	50P1P
51P1T	51P1P
50Q1T	50Q1P
51Q1T	51Q1P
50P2T	50P2P
51P2T	51P2P
50N2T	50N2P
51N2T	51N2P

The instantaneous element pickups and the fifth-harmonic alarm pickup are used to trigger an event report.

MER = TH5P * !TH5T + 50P1P + 51P1P + 50Q1P + 51Q1P + 50P2P + 51P2P + 50N2P + 51N2P

Output 1 is used to trip Breaker 1, Output 2 is used to trip Breaker 2, and Output 3 is used to trip the transformer lockout relay.

OUT1 = TRP1

OUT2 = TRP2

OUT3 = TRP3

Output 4 provides the time-delayed dropout indication of a differential element operation by using the XT Relay Word bit.

OUT4 = XT

The example SELOGIC control equations are summarized below.

X = 87U + 87R

Y = NA

MTU1 = 50P1T + 51P1T + 50Q1T + 51Q1T + OC1

MTU2 = 50P2T + 51P2T + 50N2T + 51N2T + OC2

MTU3 = 87R + 87U

MER = TH5P * !TH5T + 50P1P + 51P1P +50Q1P + 51Q1P + 50P2P + 51P2P + 50N2P + 51N2P

OUT1 = TRP1

OUT2 = TRP2

OUT3 = TRP3

OUT4 = XT

Relay Targets

The SEL-587 has eight LEDs on the front panel. The **EN** LED indicates the operating condition of the relay; the LED remains illuminated unless one of the following occurs:

- The front-panel targets have been reassigned using the **TARGET** command
- Power is removed from the relay
- A relay self-test failure has been detected

The remaining front-panel targets update to indicate trip and fault type information at the rising edge of the trip and again one cycle later. The resulting targets are the ORed combination of targets at the rising edge of the trip and one cycle later.

Table 4.7 Relay Targets

Target	Illuminates if:
87	A differential element is picked up at, or one cycle after, rising edge of trip
50	An instantaneous or definite-time O/C element is picked up at, or one cycle after, rising edge of trip
51	An inverse-time O/C element is timed out at, or one cycle after, rising edge of trip
A	A-phase is selected by target logic at, or one cycle after, rising edge of trip
B	B-phase is selected by target logic at, or one cycle after, rising edge of trip
C	C-phase is selected by target logic at, or one cycle after, rising edge of trip
N	A residual O/C element is tripped at, or one cycle after, rising edge of trip

The SEL-587 selects phase targets by using the following criteria. A particular phase target is illuminated if:

- The differential element operation indicates involvement of the phase
- A phase overcurrent element tripped and the phase current magnitude is greater than the pickup setting of the tripping element
- A residual or negative-sequence overcurrent element tripped and the phase current magnitude is the largest of the three phases

The relay stores the front-panel targets in nonvolatile memory each time they change. If power is removed from the relay, the relay restores the targets when relay power is reapplied.

Clear the targets by pressing the front-panel **TARGET RESET** button or by executing the serial port **TARGET R** command. If you press the **TARGET RESET** button and the targets do not clear, the tripping condition is still present.

In general, the relay targets indicate the phases involved in the fault. One exception is a phase-to-phase fault cleared by the operation of a negative-sequence overcurrent element. In this case, the relay targets indicate only one of the two involved phases: the phase carrying the greater current magnitude.

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Section 5
Setting the Relay

Introduction

Change or view settings with the **SET** and **SHOWSET** serial port commands and the front-panel **SET** pushbutton. *Table 5.1* lists the serial port **SET** commands.

Table 5.1 Serial Port SET Commands

Command	Settings Type	Description	Settings Sheets[a]
SET	Relay	Differential elements, overcurrent elements, timers, etc.	1–5
SET L	Logic	SELOGIC® control equations	6
SET P 1 **SET P F**	Port	Serial port protocol settings	7

[a] Located at the end of this section.

View settings with the respective serial port **SHOWSET** commands (**SHO**, **SHO L**, **SHO P**). See *SHOWSET on page 6.12*.

Settings Changes Via the Front Panel

The relay front-panel **SET** pushbutton provides access to the relay and port settings only. Thus, the corresponding relay and port settings sheets that follow in this section can also be used when making these settings via the front panel. Refer to *Figure 6.1* for information on front-panel communications.

Settings Changes Via the Serial Port

NOTE: In this instruction manual, commands you type appear in bold/uppercase: **SHOWSET**. You need to type only the first three letters of a command, for example, **SHO**. Computer keys you press appear in bold/brackets: **<Enter>**.

See *Section 6: Operator Interface* for information on serial port communications and relay access levels. To change a specific setting, enter the command:

SET *n s* <Enter>

where

n = L or P (parameter n is not entered for the Relay settings)

s = the name of the specific setting you want to jump to and begin setting. If s is not entered, the relay starts at the first setting.

When you execute the **SET** command, the relay presents a list of settings, one at a time. Enter a new setting, or press **<Enter>** to accept the existing setting. Editing keystrokes are shown in *Table 5.2*.

Table 5.2 Set Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains setting and moves to the next
^ <Enter>	Returns to previous setting
< <Enter>	Returns to previous setting
> <Enter>	Moves to next setting
END <Enter>	Exits editing session, then prompts you to save the settings
<Ctrl + X>	Aborts editing session without saving changes

The relay checks each entry to ensure that it is within the setting range. If it is not, an `Out of Range` message is generated, and the relay prompts for the setting again.

When settings are complete, the relay displays the new settings and prompts for approval to enable them. Answer **Y <Enter>** to enable the new settings. For about one second, while the active settings are updated, the relay is disabled, and the ALARM contact closes.

ACSELERATOR QuickSet SEL-5030 Software

The SEL-587 and SEL-587-1 relays with firmware version R702 and later are compatible with ACSELERATOR QuickSet® SEL-5030 Software. Use this software to read, set, and save relay settings, as well as monitor and control relay functions. QuickSet also provides automated help for the relay settings, and the ability to retrieve event reports from the relay. QuickSet communicates via the front serial port of the relay by using SEL ASCII communications.

Settings Explanations

The following explanations are for relay settings (accessed under the **SET** command) that do not have reference information anywhere else in the instruction manual.

Relay ID (RID) and Terminal ID (TID)

The SEL-587 has two identifier labels: the Relay Identifier (RID) and the Terminal Identifier (TID). The Relay Identifier typically is used to identify the relay or the type of protection scheme. Typical Terminal Identifiers include an abbreviation of the substation name and line terminal.

The relay tags each report (event report, meter report, etc.) with the Relay Identifier and Terminal Identifier. This allows you to distinguish the report as one generated for a specific breaker and substation.

RID and TID settings can include the following characters: 0–9, A–Z, -, /, ., space.

Demand Ammeter (DATC, PDEM, QDEM, NDEM)

The relay provides demand ammeters for Winding 1 phase, negative-sequence, and residual currents. The relay saves peak demand readings for each of the quantities. View this information by using the relay front panel or serial port **METER** commands (see *Section 6: Operator Interface*).

The demand ammeters behave much like low-pass filters, responding to gradual trends in the current magnitude. The relay uses the demand ammeter time constant setting, DATC, for all three demand ammeter calculations. The time constant is settable from 5 to 60 minutes.

The demand ammeters operate such that if demand current is reset and a constant input current is applied, the demand current output will be 90 percent of the constant input current value DATC minutes later.

Settable demand ammeter thresholds are available for all three demand ammeters in units of amperes secondary. The thresholds are PDEM, QDEM, and NDEM for the phase, negative-sequence, and residual demand ammeters, respectively.

If demand currents exceed the set threshold, the respective Relay Word bit PDEM, QDEM, or NDEM asserts. You can use these Relay Word bits to alarm for phase overload and negative-sequence or residual current unbalance.

System Frequency (NFREQ) and Phase Rotation (PHROT)

The relay settings NFREQ and PHROT allow you to configure the SEL-587 to your specific system.

Set NFREQ equal to your nominal power system frequency, either 50 Hz or 60 Hz.

Set PHROT equal to your power system phase rotation, either ABC or ACB.

Settings Sheets

The settings sheets that follow include the definition and input range for each setting in the relay.

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SEL-587 Relay Settings Sheets

SET Command

General Data

Relay Identifier (12 characters)	**RID**	= ____________________
Terminal Identifier (12 characters)	**TID**	= ____________________
Maximum Power Transformer Capacity (OFF, 0.2–5000 MVA in 0.1 steps)	**MVA**	= __________
Winding 1 Line-to-Line Voltage (1–1000 kV)	**VWDG1**	= __________
Winding 2 Line-to-Line Voltage (1–1000 kV)	**VWDG2**	= __________
Transformer Connection (YY, YDAC, YDAB, DACDAC, DABDAB, DABY, DACY, OTHER)	**TRCON**	= __________
CT Connection (DACDAC, DABDAB, DACY, DABY, YY, YDAB, YDAC)	**CTCON**	= __________
Remove I0 from Wye Connection Compensation (SEL-587-1 only) (Y, N)	**RZS**	= __________
Winding 1 CT Ratio (1–50000)	**CTR1**	= __________
Winding 2 CT Ratio (1–50000)	**CTR2**	= __________
Demand Ammeter Time Constant (OFF, 5–255 min)	**DATC**	= __________
Phase Demand Ammeter Threshold (0.5–16 A, 5 A) (0.1–3.2 A, 1 A)	**PDEM**	= __________
Negative-Sequence Demand Ammeter Threshold (0.5–16 A, 5 A) (0.1–3.2 A, 1 A)	**QDEM**	= __________
Residual Demand Ammeter Threshold (0.5–16 A, 5 A) (0.1–3.2 A, 1 A)	**NDEM**	= __________

Current TAPs

Winding 1 Current TAP	**TAP1**	= __________
Winding 2 Current TAP	**TAP2**	= __________

Input Assignment

IN1 or IN2 set to TCEN or TCBL enables torque-control settings.

Input 1 (NA, 52A1, !52A1, TCEN, TCBL)	**IN1**	= __________
Input 2 (NA, 52A2, !52A2, TCEN, TCBL)	**IN2**	= __________

Differential Elements

Restrained Element Operating Current Pickup (0.1–1.0 in per unit of tap)	**O87P**	= __________
Restraint Slope 1 Percentage (5–100%)	**SLP1**	= __________
Restraint Slope 2 Percentage (OFF, 25–200%)	**SLP2**	= __________
Restraint Current Slope 1 Limit (1–16 in per unit of tap)	**IRS1**	= __________

Unrestrained Operating Current Pickup (1–16 in per unit of tap)	**U87P**	= ________
Second-Harmonic Blocking Percentage (OFF, 5–100%)	**PCT2**	= ________
Fourth-Harmonic Blocking Percentage (SEL-587-1 Relay only) (OFF, 5–100%)	**PCT4**	= ________
Fifth-Harmonic Blocking Percentage (OFF, 5–100%)	**PCT5**	= ________
Fifth-Harmonic Alarm Threshold (0.1–3.2 in per unit of tap)	**TH5**	= ________
Fifth-Harmonic Alarm Time-Delay Pickup (0.00–8000.00 cycles)	**TH5D**	= ________
DC Ratio Blocking (SEL-587-1 Relay only) (Y, N)	**DCRB**	= ________
Harmonic Restraint (SEL-587-1 Relay only) (Y, N)	**HRSTR**	= ________
Independent Harmonic Blocking (Y, N)	**IHBL**	= ________

Winding 1 Phase Overcurrent Elements

Phase Definite-Time Overcurrent Pickup (OFF, 0.5–80 A, 5 A) (OFF, 0.1–16 A, 1 A) **50P1P** = ________

Phase Definite-Time Overcurrent Delay (0–16000.00 cycles) **50P1D** = ________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Phase Definite-Time Overcurrent External Torque-Control (Y, N) **50P1TC** = ________

Phase Instantaneous Overcurrent Pickup (OFF, 0.5–80 A, 5 A) (OFF, 0.1–16 A, 1 A) **50P1H** = ________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Phase Instantaneous Overcurrent External Torque-Control (Y, N) **50P1HC** = ________

Phase Inverse-Time Overcurrent Pickup (OFF, 0.5–16 A, 5 A) (OFF, 0.1–3.2 A, 1 A) **51P1P** = ________

Phase Inverse-Time Overcurrent Curve (U1–U4, C1–C4) **51P1C** = ________

Phase Inverse-Time Overcurrent Time-Dial (U.S. 0.5–15 in .01 increments) (IEC 0.05–1 in .01 increments) **51P1TD** = ________

Phase Inverse-Time Overcurrent Electromechanical Reset (Y, N) **51P1RS** = ________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Phase Inverse-Time Overcurrent External Torque-Control (Y, N) **51P1TC** = ________

Winding 1 Negative-Sequence Overcurrent Elements

Negative-Sequence Definite-Time Overcurrent Pickup (OFF, 0.5–80 A, 5 A) (OFF, 0.1–16 A, 1 A) **50Q1P** = ________

Negative-Sequence Definite-Time Overcurrent Delay (0.5–16000.00 cycles) **50Q1D** = ________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Negative-Sequence Definite-Time Overcurrent External Torque-Control (Y, N) **50Q1TC** = ________

Negative-Sequence Inverse-Time Overcurrent Pickup (OFF, 0.5–16 A, 5 A) (OFF, 0.1–3.2 A, 1 A) **51Q1P** = ________

Negative-Sequence Inverse-Time Overcurrent Curve (U1–U4, C1–C4)	**51Q1C**	=__________
Negative-Sequence Inverse-Time Overcurrent Time-Dial (U.S. 0.5–15 in .01 increments) (IEC 0.05-1 in .01 increments)	**51Q1TD**	=__________
Negative-Sequence Inverse-Time Overcurrent Electromechanical Reset (Y, N)	**51Q1RS**	=__________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Negative-Sequence Inverse-Time Overcurrent External Torque-Control (Y, N)	**51Q1TC**	=__________

Winding 1 Residual Overcurrent Elements

Residual Definite-Time Overcurrent Pickup (OFF, 0.5–80 A, 5 A) (OFF, 0.1–16 A, 1 A)	**50N1P**	=__________
Residual Definite-Time Overcurrent Delay (0–16000.00 cycles)	**50N1D**	=__________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Residual Definite-Time Overcurrent External Torque-Control (Y, N)	**50N1TC**	=__________
Residual Instantaneous Overcurrent Pickup (OFF, 0.5–80 A, 5 A) (OFF, 0.1–16 A, 1 A)	**50N1H**	=__________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Residual Instantaneous Overcurrent External Torque-Control (Y, N)	**50N1HC**	=__________
Residual Inverse-Time Overcurrent Pickup (OFF, 0.5–16 A, 5 A) (OFF, 0.1–3.2 A, 1 A)	**51N1P**	=__________
Residual Inverse-Time Overcurrent Curve (U1–U4, C1–C4)	**51N1C**	=__________
Residual Inverse-Time Overcurrent Time-Dial (U.S. 0.5–15 in .01 increments) (IEC 0.05–1 in .01 increments)	**51N1TD**	=__________
Residual Inverse-Time Overcurrent Electromechanical Reset (Y, N)	**51N1RS**	=__________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Residual Inverse-Time Overcurrent External Torque-Control (Y, N)	**51N1TC**	=__________

Winding 2 Phase Overcurrent Elements

Phase Definite-Time Overcurrent Pickup (OFF, 0.5–80 A, 5 A) (OFF, 0.1–16 A, 1 A)	**50P2P**	=__________
Phase Definite-Time Overcurrent Delay (0–16000.00 cycles)	**50P2D**	=__________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Phase Definite-Time Overcurrent External Torque-Control (Y, N)	**50P2TC**	=__________
Phase Instantaneous Overcurrent Pickup (OFF, 0.5–80 A, 5 A) (OFF, 0.1–16 A, 1 A)	**50P2H**	=__________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Phase Instantaneous Overcurrent External Torque-Control (Y, N)	**50P2HC**	=__________

Phase Inverse-Time Overcurrent Pickup **51P2P** = ________
(OFF, 0.5–16 A, 5 A)
(OFF, 0.1–3.2 A, 1 A)

Phase Inverse-Time Overcurrent Curve (U1–U4, C1–C4) **51P2C** = ________

Phase Inverse-Time Overcurrent Time-Dial **51P2TD** ________
(U.S. 0.5–15 in .01 increments)
(IEC 0.05–1 in .01 increments)

Phase Inverse-Time Overcurrent Electromechanical Reset (Y, N) **51P2RS** = ________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Phase Inverse-Time Overcurrent External Torque-Control (Y, N) **51P2TC** = ________

Winding 2 Negative-Sequence Overcurrent Elements

Negative-Sequence Definite-Time Overcurrent Pickup **50Q2P** = ________
(OFF, 0.5–80 A, 5 A)
(OFF, 0.1–16 A, 1 A)

Negative-Sequence Definite-Time Overcurrent Delay **50Q2D** = ________
(0.5–16000.00 cycles)

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Negative-Sequence Definite-Time Overcurrent External Torque-Control (Y, N) **50Q2TC** = ________

Negative-Sequence Inverse-Time Overcurrent Pickup **51Q2P** = ________
(OFF, 0.5–16 A, 5 A)
(OFF, 0.1–3.2 A, 1 A)

Negative-Sequence Inverse-Time Overcurrent Curve (U1–U4, C1–C4) **51Q2C** = ________

Negative-Sequence Inverse-Time Overcurrent Time-Dial **51Q2TD** = ________
U.S. 0.5–15 in .01 increments)
(IEC 0.05-1 in .01 increments)

Negative-Sequence Inverse-Time Overcurrent Electromechanical Reset (Y, N) **51Q2RS** = ________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Negative-Sequence Inverse-Time Overcurrent External Torque-Control (Y, N) **51Q2TC** = ________

Winding 2 Residual Overcurrent Elements

Residual Definite-Time Overcurrent Pickup **50N2P** = ________
(OFF, 0.5–80 A, 5 A)
(OFF, 0.1–16 A, 1 A)

Residual Definite-Time Overcurrent Delay **50N2D** = ________
(0–16000.00 cycles)

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Residual Definite-Time Overcurrent External Torque-Control (Y, N) **50N2TC** = ________

Residual Instantaneous Overcurrent Pickup **50N2H** = ________
(OFF, 0.5–80 A, 5 A)
(OFF, 0.1–16 A, 1 A)

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Residual Instantaneous Overcurrent External Torque-Control (Y, N) **50N2HC** = ________

Residual Inverse-Time Overcurrent Pickup (OFF, 0.5–16 A, 5 A) (OFF, 0.1–3.2 A, 1 A)	**51N2P**	=__________
Residual Inverse-Time Overcurrent Curve (U1–U4, C1–C4)	**51N2C**	=__________
Residual Inverse-Time Overcurrent Time-Dial (U.S. 0.5–15 in .01 increments) (IEC 0.05–1 in .01 increments)	**51N2TD**	=__________
Residual Inverse-Time Overcurrent Electromechanical Reset (Y, N)	**51N2RS**	=__________

Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

Residual Inverse-Time Overcurrent External Torque-Control (Y, N)	**51N2TC**	=__________

Miscellaneous Timers

Latch Trips (Y, N, 1, 2, 3 [SEL-587-0]) (Y, N, NL, 1, 2, 3 [SEL-587-1])	**LTRP**	=__________
Minimum Trip Duration Time (0–2000.00 cycles)	**TDURD**	=__________
Timer X Pickup Delay (0–8000.00 cycles)	**TXPU**	=__________
Timer X Dropout Delay (0–8000.00 cycles)	**TXDO**	=__________
Timer Y Pickup Delay (0–8000.00 cycles)	**TYPU**	=__________
Timer Y Dropout Delay (0–8000.00 cycles)	**TYDO**	=__________

Power System Data

Nominal Frequency (50, 60 Hz)	**NFREQ**	=__________
Phase Rotation (ABC, ACB)	**PHROT**	=__________

SET L Command Logic

Logic Variables

X =____________________

Y =____________________

Tripping Logic

MTU1 =____________________

MTU2 =____________________

MTU3 =____________________

Event Report Trigger Condition Logic

MER =____________________

Output Contact Logic

OUT1 =____________________

OUT2 =____________________

OUT3 =____________________

OUT4 =____________________

SET P Command (Port Settings)

Protocol and Communications Settings

Front Port (SET P F)

Serial Port Protocol (SEL, LMD)	**PROTO**	=__________

Rear Port (SET P 1)

Serial Port Protocol (SEL, LMD, MOD)	**PROTO**	=__________

If PROTO = SEL

Serial Port Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400)	**SPEED**	=__________
Serial Port Data Bits (7, 8)	**DATA_BITS**	=__________
Serial Port Parity (N, E, O)	**PARITY**	=__________
Serial Port Stop Bits (1, 2)	**STOP**	=__________
Serial Port Time Out (0–30 minutes)	**TIMEOUT**	=__________
Send Automessage to Port (Y, N)	**AUTO**	=__________
Enable RTS/CTS Handshaking (Y, N)	**RTS_CTS**	=__________
Fast Operate Enable (Y, N)	**FAST_OP**	=__________

If PROTO = LMD

LMD Prefix (#, $, %, &, @)	**PREFIX**	=__________
LMD Address (1–99)	**ADDRESS**	=__________
LMD Settling Time (0–30 seconds)	**SETTLE_TIME**	=__________
Serial Port Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400)	**SPEED**	=__________
Serial Port Data Bits (7, 8)	**DATA_BITS**	=__________
Serial Port Parity (N, E, O)	**PARITY**	=__________
Serial Port Stop Bits (1, 2)	**STOP**	=__________
Serial Port Time Out (0–30 minutes)	**TIMEOUT**	=__________
Send Automessage to Port (Y, N)	**AUTO**	=__________
Fast Operate Enable (Y, N)	**FAST_OP**	=__________

If PROTO = MOD (SEL-587-1 Relay)

Serial Port Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400)	**SPEED**	=__________
Serial Port Parity (N, E, O)	**PARITY**	=__________
Serial Port Stop Bits (1, 2)	**STOP**	=__________
Slave ID (1–99)	**SLAVEID**	=__________
Send Automessage to Port (Y, N)	**AUTO**	=__________

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Section 6
Operator Interface

Introduction

This section describes operator interface with the SEL-587 from the serial port or front panel. Serial port communication provides complete relay control locally or remotely. The front panel provides convenient access to an abbreviated set of relay commands, settings, and information.

In this instruction manual, keys you press appear in bold/brackets: **<Enter>**. Front-panel pushbuttons you press appear in bold/uppercase san serif font: **CNTRL**. Commands you type appear in bold/uppercase: **SHOWSET**. You need to type only the first three letters of a command, for example, **SHO**. The instruction manual shows commands in uppercase letters, but you can enter commands also with lowercase letters.

Serial Port Operation

Establish communication with the SEL-587 through a serial port by using standard "off-the-shelf" software and cable connections appropriate for the device to which you connect the relay.

The SEL-587 is equipped with two serial communications ports located on the on the front and rear panels of the relay. Connect one of the serial ports to a computer serial port for local communications or to a modem for remote communications. Other devices useful for communications include the SEL-2020 and the SEL-2030.

You can use a variety of terminal emulation programs on your personal computer to communicate with the relay.

The SEL-587 comes with an EIA-232 front serial port and can be ordered with either an EIA-232 or EIA-485 (4-wire) rear serial port. The default settings for the serial port are the following:

NOTE: If you do not enter a serial port command after a set time (0–30 minutes), the relay serial port will time out and the relay will return to the lowest access level. Use the **SET P** command to determine the length of time before the relay serial port times out.

Baud Rate = 2400

Data Bits = 8

Parity = N

Stop Bits = 1

To change the port settings, use the serial port **SET P F** or **SET P 1** command (see *Section 5: Setting the Relay*) or the front-panel **SET** pushbutton.

Hardware Protocol

The SEL-587 relays equipped with the EIA-232 port support RTS/CTS hardware handshaking. Relays equipped with the EIA-485 port do not support RTS/CTS handshaking.

To enable hardware handshaking, use the **SET P** command (or front-panel **SET** pushbutton) to set RTS_CTS = Y. Disable hardware handshaking by setting RTS_CTS = N.

If RTS_CTS = N, the relay permanently asserts the RTS line.

If RTS_CTS = Y, the relay deasserts RTS when it is unable to receive characters.

If RTS_CTS = Y, the relay does not send characters until the CTS input is asserted.

Software Protocol

Software protocols consist of standard SEL ASCII, SEL Distributed Port Switch (LMD), Modbus® RTU, SEL Fast Meter, and SEL Compressed ASCII. Based on the Set P port PROTOCOL setting, the relay activates SEL ASCII, SEL LMD, or Modbus RTU. SEL Fast Meter and SEL Compressed ASCII commands are always active.

SEL ASCII

The following software protocol applies to both manual and automatic communications.

1. All commands the relay receives must be of the form:

   <command><CR> or <command><CR><LF>

   A command transmitted to the relay should consist of the following:

   ➢ A command followed by either a carriage return or a carriage return and line feed.

   ➢ You must separate arguments from the command by spaces, commas, semicolons, colons, or slashes.

   ➢ You can truncate commands to the first three characters. **EVENT 1 <Enter>** would become **EVE 1 <Enter>**.

   ➢ Upper- and lowercase characters can be used without distinction, except in passwords.

2. The relay transmits all messages in the following format:

   <STX><CR><LF>

   <MESSAGE LINE 1><CR><LF>

   <MESSAGE LINE 2><CR><LF>

   •

   •

   •

   <LAST MESSAGE LINE><CR><LF>

   <ETX> <PROMPT>

   Each message begins with the start of transmission character STX (ASCII character 02) and ends with the end of transmission character ETX (ASCII character 03).

3. The relay uses an XON/XOFF protocol to indicate the level of content in the relay receive buffer.

   The relay transmits XON (ASCII hex 11) when the buffer drops below 40 percent full.

   The relay transmits XOFF (ASCII hex 13) when the buffer is more than 80 percent full. Automatic transmission sources should monitor for the XOFF character, to prevent overwriting of the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and can resume when the relay sends XON.

4. You can use an XON/XOFF procedure to control the relay during data transmission. When the relay receives an XOFF command during transmission, it pauses until it receives an XON command. If there is no message in progress when the relay receives an XOFF command, it blocks transmission of any message the buffer receives.

   The CAN character (ASCII hex 18) aborts a pending transmission. This is useful in terminating an unwanted transmission.

5. Send control characters from most keyboards with the following keystrokes:

   XON: **<Ctrl + Q>** (hold down the Control key and press Q)

   XOFF: **<Ctrl + S>** (hold down the Control key and press S)

   CAN: **<Ctrl + X>** (hold down the Control key and press X)

SEL Distributed Port Switch Protocol

The SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. Select the protocol by setting the SET P setting (PROTOCOL = LMD). See *Appendix C: SEL Distributed Port Switch Protocol* for more information on Distributed Port Switch Protocol (LMD).

SEL Fast Meter Protocol

SEL Fast Meter protocol supports binary messages to transfer metering messages. SEL Fast Meter protocol is always available on any serial port. *Appendix D: Configuration, Fast Meter, and Fast Operate Commands* describes the protocol.

SEL Fast Operate Protocol

SEL Fast Operate protocol supports binary messages to control Relay Word bits. SEL Fast Operate protocol is available on any serial port. Set the SET P setting FAST_OP = N to turn off SEL Fast Operate protocol. *Appendix D: Configuration, Fast Meter, and Fast Operate Commands* describes the protocol.

SEL Compressed ASCII Protocol

SEL Compressed ASCII protocol provides compressed versions of some of the relay ASCII commands. SEL Compressed ASCII protocol is always available on any serial port. *Appendix E: Compressed ASCII Commands* describes this protocol.

Modbus RTU Protocol

Modbus RTU protocol provides binary multidrop communication with the SEL-587-1. The protocol is described in *Appendix I: Modbus RTU Communications Protocol*.

SEL ASCII Protocol Details

Serial Port Automatic Messages

When the serial port AUTO setting is Y, the relay sends automatic messages to indicate specific conditions. *Table 6.1* describes the automatic messages.

Table 6.1 Serial Port Automatic Messages

Condition	Description
Turn On	The relay sends a message containing the present date and time, Relay and Terminal Identifiers, and the Access Level 0 prompt when you turn the relay on.
Event Trigger	The relay sends an event summary upon the triggering of each event report. See *Section 7: Event Reports*.
Self-Test Warning or Failure	The relay sends a status report each time it detects a self-test warning or failure condition. See *STATUS on page 6.12*.

Serial Port Password Security

⚠**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 is not responsible for any damage resulting from unauthorized access.

The relay serial port includes a password security function to prevent unauthorized access to relay information and settings (see *Table 6.2*). When main board jumper **JMP22** is not installed, the relay prompts you to enter passwords to enter Access Level 1 and Access Level 2. See *Section 2: Installation* for jumper location and detail. You can use the Access Level 2 password command to change the password for either access level to any six-digit, or fewer, alphanumeric combination. Valid characters are numbers, letters, dash, or period. Relay passwords are case sensitive; the relay treats uppercase and lowercase letters as different characters.

NOTE: The factory-default passwords are shown under PASSWORD n on page 6.10.

Table 6.2 Serial Port Security Function

Access Level	Prompt	Description
0	=	When the relay turns on, it is in Access Level 0, from which you must enter the **ACCESS** command and corresponding password to enter Access Level 1.
1	=>	Allows access to Access Level 1 commands. From this level you must enter the **2ACCESS** command and corresponding password to enter Access Level 2.
2	=>>	Allows access to all commands, including **PASSWORD**, **SET**, and breaker control commands.

The primary differences between the serial port commands available at Access Level 1 and those available at Access Level 2 are the following:

- The Access Level 1 commands allow the user to look at information (e.g., settings, metering, etc.), not change it.
- The Access Level 2 commands allow the user to change settings or operate relay parameters and output contacts.

Setting Changes Via the Serial Port

To set the relay by using serial port commands, first establish serial communications with the relay. Next, execute the **ACCESS** and **2ACCESS** commands to enter Access Level 2. Enter the command **SET**, **SET L**, **SET P 1**, or **SET P F**. To change a specific setting, enter **SET *n s***, where *n* is L or P (*n* parameter is ignored for the regular **SET** command) and *s* is the name of the setting you want to change.

When you execute the **SET** command, the relay presents a list of settings, one at a time. Enter a new setting, or press **<Enter>** to accept the existing setting. The relay shows only the settings you need for your application. *Table 6.3* shows editing keystrokes.

Table 6.3 Editing Keys for SET Command

Press Key(s)	Results
<Enter>	Retains setting and moves to the next
^ <Enter>	Returns to previous setting
< <Enter>	Moves up one setting subgroup
> <Enter>	Moves down one setting subgroup
END <Enter>	Exits editing session, then prompts you to save the settings
<Ctrl + X>	Aborts editing session without saving changes

The relay checks each entry to ensure that it is within the setting range. If it is not, the relay generates an `Out of Range` message and prompts for the setting again.

When settings are complete, the relay displays the new settings and prompts for approval to enable them. Answer Y <Enter> to enable the new settings. For about one second, while the active settings are updated, the relay is disabled and the ALARM output contact closes.

ACSELERATOR QuickSet SEL-5030 Software

The SEL-587 and SEL-587-1 Relays with firmware version R702 and later are compatible with ACSELERATOR QuickSet® SEL-5030 Software. Use this software to read, set, and save relay settings, as well as monitor and control relay functions. QuickSet also provides automated help for the relay settings, and the ability to retrieve event reports from the relay. QuickSet communicates via the front serial port of the relay by using SEL ASCII communications.

Command Definitions

ACCESS

Access Level 0

Entry of the **ACCESS** command from the serial port moves you from Access Level 0 to Access Level 1, from which you can view, but not change, relay information.

When Main Board jumper JMP22 is not installed, the relay prompts you to enter a password. The factory-default password is listed under *PASSWORD n on page 6.10*. See *Section 2: Installation* for jumper locations and detail.

2ACCESS

Access Level 1

Entry of the **2ACCESS** command from the serial port moves you from Access Level 1 to Access Level 2, from which you can view relay information and change relay parameters.

When Main Board jumper JMP22 is not installed, the relay prompts you to enter a password. The factory-default password is listed under *PASSWORD n*.

BREAKER

Access Level 1

Use the **BREAKER *n*** command to view breaker monitor trip counter and trip current data for Breaker *n* (*n* = 1, 2). The SEL-587 can monitor as many as two circuit breakers. When IN1 and/or IN2 are set to monitor the breaker auxiliary contact, the relay counts the number of times each monitored breaker trips as a result of SEL-587 operations (Internal Trips) and as a result of other operations (External Trips). The breaker monitor also records a running sum of the current (in primary kiloamperes, kA) that each breaker pole interrupts.

BREAKER n R

Access Level 2

Reset Breaker *n* monitor trip counters and trip current data with the **BREAKER *n* R** command, where *n* = 1, 2. Following a reset, use the **BREAKER *n*** command to verify resetting of the data.

CALIBRATION

Access Level 2

Use the **CALIBRATION** command to enter the calibration access level. A password is required to access this level. The default password for this level is set to **332** at the factory; use the **PASSWORD** command to change this password. Use the calibration access level only under the direction of SEL.

CLOSE n

Access Level 2

Issuing the **CLOSE *n*** command from the serial port asserts the CLOSE Relay Word bit (CC*n*) in the relay close logic and causes a relay output contact to close a high- or low-side circuit breaker *n* (*n* = 1, 2). You can enable the **CLOSE *n*** command only if the main board jumper **JMP24** is in place. See *Section 4: Tripping, Closing, and Targeting Logic* for more details.

CONTROL n

Access Level 2

The **CONTROL** command is a two-step, Access Level 2 command that allows you to control Relay Word bits RB1 through RB4. At the Access Level 2 prompt, type **CONTROL**, a space, and the number of the bit you want to control (1–4). The relay responds by repeating your command followed by a colon. At the colon, type the **CONTROL** subcommand you want to perform (see *Table 6.4*).

The following example shows the steps necessary to pulse Remote Bit 2 (RB2) for three seconds.

```
=>>CONTROL 2 <Enter>
CONTROL RB2: PRB 2 3 <Enter>
=>>
```

Table 6.4 SEL-587 CONTROL Subcommands

Subcommand	Description
SRB *n*	Set Remote Bit *n*
CRB *n*	Clear Remote Bit *n*
PRB *n t*	Pulse Remote Bit *n* for *t* seconds (*t* = 1 if not otherwise specified) **Note:** *n* must match the **CONTROL** command bit number.

DATE

Access Level 1

NOTE: After setting the date, allow at least 60 seconds before powering down the relay or the new setting may be lost.

The relay stores the date in an internal calendar/clock. Type **DATE <Enter>** to display the date via the serial port. Set the date from the serial port by typing **DATE *mm/dd/yy* <Enter>**, where *m* = month, *d* = day, and *y* = year. Front-panel operations are **MAINT** > DATE and **MAINT** > DATE > SET to view and set the date, respectively.

EVENT n

Access Level 1

The **EVENT *n*** command causes the relay to display one of as many as 10 event reports, where *n* = 1–10. Additional parameters specify the type and format of event report that the relay displays. See *Section 7: Event Reports* for more details.

EVENT n, EVENT L n, EVENT R n, EVENT L C n, EVENT R C n

EVENT *n*	Causes the relay to display a standard 15-cycle event report with quarter-cycle sampling
EVENT L *n*	Causes the relay to display a standard event report with 1/16-cycle sampling
EVENT R *n*	Causes the relay to display an unfiltered event report with 1/16-cycle sampling
EVENT L C *n* or **EVENT R C *n***	Causes the relay to add digital data at the end of the EVENT L *n* and EVENT R *n* reports, respectively

HISTORY n

Access Level 1

The **HISTORY *n*** command causes the relay to display the *n* latest standard 15-cycle event reports, where *n* = 1–20 event reports. These brief summaries contain the date and time of each event, event type, and relay targets. See *Section 7: Event Reports* for more details.

HIS C

Access Level 1

The **HISTORY C** command clears the history and associated events from nonvolatile Flash memory. See *Section 7: Event Reports* for more details. Under normal operation, the clearing process can take as long as 30 seconds. This time may be longer if the relay is processing a fault or other protection logic.

IRIG

Access Level 1

The **IRIG** command directs the relay to read the demodulated IRIG-B time code at the serial port input.

To force the relay to synchronize to IRIG-B, enter the following command:

=>IRIG <Enter>

If the relay successfully synchronizes to IRIG-B, it sends the following header:

```
FEEDER 1                    Date:  03/05/96    Time:  10:15:09.609
STATION A

=>
```

If no IRIG-B code is present at the serial port input or if the code cannot be read successfully, the relay responds:

```
IRIG-B DATA ERROR

=>
```

If an IRIG-B signal is present, the relay continuously synchronizes its internal clock with IRIG-B. It is not necessary to issue the **IRIG** command to synchronize the relay clock with IRIG-B. Use the **IRIG** command to determine if the relay is properly reading the IRIG-B signal.

METER

Access Level 1

Table 6.7 shows how to display or reset metering information via the serial port or front panel. Via the front panel, the display automatically scrolls through the selected metering values. Stop the scrolling by pressing the **SELECT** button. Resume scrolling by the **SELECT** button again. While scrolling is stopped, move through the data by using the up- and down-arrow buttons.

METER, METER D, and METER P

These commands display instantaneous, demand, and peak demand currents (in primary amperes), respectively, for the following:

Winding 1 (W1)

IAW1	Current connected to input IAW1
IBW1	Current connected to input IBW1
ICW1	Current connected to input ICW1
3I2W1	Magnitude 3I2 negative-sequence current derived from IAW1, IBW1, and ICW1
IRW1	Residual (ground) current derived from IAW1, IBW1, and ICW1

Winding 2 (W2)

IAW2	Current connected to input IAW2
IBW2	Current connected to input IBW2
ICW2	Current connected to input ICW2
3I2W2	Magnitude 3I2 negative-sequence current derived from IAW2, IBW2, and ICW2
IRW2	Residual (ground) current derived from IAW2, IBW2, and ICW2

Reset the accumulated demand values by using the **MET RD** command. Reset the peak demand values by using the **MET RP** command.

METER DIF

This command displays the instantaneous magnitudes of differential operate, differential restraint, second-harmonic, and fifth-harmonic current (in secondary amperes, referenced to Winding 1):

IOP1	Operate current for differential element 1
IOP2	Operate current for differential element 2
IOP3	Operate current for differential element 3
IRT1	Restraint current for differential element 1
IRT2	Restraint current for differential element 2
IRT3	Restraint current for differential element 3
I1F2	Second-harmonic current in differential element 1
I2F2	Second-harmonic current in differential element 2
I3F2	Second-harmonic current in differential element 3

I1F5	Fifth-harmonic current in differential element 1
I2F5	Fifth-harmonic current in differential element 2
I3F5	Fifth-harmonic current in differential element 3

Use this command at relay installation time to help verify correct CT connections, under load current conditions.

METER PH

This command displays the instantaneous magnitudes of peak second-harmonic and peak fifth-harmonic current (in secondary amperes, referenced to Winding 1):

I1F2	Second-harmonic current in differential element 1
I2F2	Second-harmonic current in differential element 2
I3F2	Second-harmonic current in differential element 3
I1F5	Fifth-harmonic current in differential element 1
I2F5	Fifth-harmonic current in differential element 2
I3F5	Fifth-harmonic current in differential element 3

METER SEC

This command displays the magnitude and angle (in secondary amperes) for the same instantaneous values that the relay displays with the **METER** command.

OPEN n

Access Level 2

Issuing the **OPEN *n*** command from the serial port asserts the TRIP Relay Word bit (OC*n*) in the relay trip logic and causes a relay output contact to open a high- or low-side circuit breaker *n* (*n* = 1, 2). You can enable the **OPEN *n*** command only if TDURD exceeds 0. See *Section 4: Tripping, Closing, and Targeting Logic* for more details.

PASSWORD n

⚠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 is not responsible for any damage resulting from unauthorized access.

Access Level 2

The **PASSWORD *n*** command lets you inspect or change the existing password for Access Level *n*, where *n* = 1, 2, or C.

Table 6.5 Default Passwords

Access Level	Default Password
Access Level 1 password (**PAS 1** command)	587
Access Level 2 password (**PAS 2** command)	587
Access Level C password (**PAS C** command)[a]	332

[a] Use Access Level C only under the direction of SEL.

Change a password by entering the command, the access level you want, and a new alphanumeric password with between one and six characters. These characters can include any combination of letters, numbers, periods, or hyphens. Syntax is as follows:

PAS *n xxxxxx* **<Enter>**

where:

n equals the access level, either 1 or 2

x equals a password character

Relay passwords are case sensitive; the relay treats uppercase and lowercase letters as different characters. Strong passwords consist of six characters, with at least one special character or digit and mixed case sensitivity, but do not form a name, date, acronym, or word. Passwords formed in this manner are less susceptible to password guessing and automated attacks. Examples of valid, distinct, strong passwords include:

NOTE: If you lose passwords or want to operate the relay without password protection, install main board jumper JMP22. See Section 2: Installation for jumper location and detail.

- Ot3579
- A24.68
- Ih2dcs
- 4u-Iwg
- .351r.

PULSE n m

Access Level 2

From the serial port use the **PULSE *n m*** command to trigger an event report and pulse an output contact *n* for *m* seconds, where *n* = 1, 2, 3, 4, and ALARM and *m* = 1–30 (seconds). Lack of a time parameter causes the relay to pulse an output contact for 1 second. Use the **PULSE** command from the front panel to trigger an event report and pulse 1, 2, 3, 4, or ALARM for 1 second.

QUIT

Access Level 1

The **QUIT** command returns the relay to Access Level 0 from Level 1 or 2. The command causes the relay to display the relay settings RID, TID, date, and time of **QUIT** command execution. Prevent unauthorized access to the relay by using the **QUIT** command after you finish relay communication.

Note that the relay automatically returns to Access Level 0 after a set time of relay inactivity. The front panel times out after 5 minutes of inactivity, and the serial port times out after a settable inactivity time ranging from 0–30 minutes. There is no user setting allowing change of this time period for the front panel. For the serial port, you can use the **SET P 1**, or **SET P F** command to set the serial port time-out from 0 to 30 minutes.

RESET n

Access Level 2

The **RESET *n*** command clears time-overcurrent element accumulators (phase, negative-sequence, and residual) for Winding *n*, where *n* = 1 or 2. You can use this command to test inverse-time elements; the command causes the relay to mimic the action of returning an electromechanical disk immediately to the starting position.

SET

Access Level 2

With the **SET** command, depending upon the parameter you include, you can view and change relay settings, SELOGIC® control equation settings, or serial port protocol settings. By entering the command name (**SET**, **SET L**, **SET P 1**, or **SET P F**), a space, and the name of a particular setting, you can avoid having to scroll through an entire setting family to see the setting you want. Otherwise, the relay default is to display the first setting within a setting family. *Table 5.2* lists the editing keystrokes necessary for viewing or changing relay settings.

SET, SET L, SET P

SET	View or change relay settings
SET L	View or change SELOGIC control equation settings
SET P 1 **SET P F**	View or change serial port communication and protocol settings. These settings include baud rate; data bits; parity; LMD prefix, address, and settling time; serial port time-out; and whether to enable automessaging, RTS/CTS handshaking, or Fast Operate.

SHOWSET

Access Level 1

With the **SHOWSET** command you can view, but not change, relay settings, SELOGIC control equation settings, or serial port protocol settings. By entering the command name (**SHOWSET**, **SHOWSET L**, or **SHOWSET P**), a space, and the name of a particular setting, you can avoid having to scroll through an entire setting family to see the setting you want. Otherwise, the relay default is to display the first setting within a setting family.

SHOWSET, SHOWSET L, SHOWSET P

SHOWSET	View all relay settings
SHOWSET L	View SELOGIC control equation settings
SHOWSET P	View serial port protocol settings

STATUS

Access Level 1

Self-test functions monitor the operation of several major relay subsystems. Execute the serial port **STATUS** command, or press the front-panel **STATUS** button to inspect the most recent results of the relay self-tests. Below is an example of the STATUS report. *Table 6.6* provides further description.

```
XFMR 1                                  Date: 12/28/94   Time: 19:22:11.745
STATION A
FID=SEL-587-R100-V65X1XX-D941205
SELF TESTS
W=Warn    F=Fail
       IAW1     IBW1     ICW1     IAW2     IBW2     ICW2     MOF
OS      2        2        2        3        2        2        0
       +5V_PS   +5V_REG   5V_REG  +10V_PS  -10V_PS   VBAT
PS      4.94     5.11     -4.96    10.12   -10.07    2.92
       TEMP     RAM      ROM      CR_RAM   EEPROM   FLASH
        23.4    OK       OK       OK       OK       OK
```

Table 6.6 Self-Test Status Report Description

Parameter	Description
OS: IAW1–ICW2, MOF	DC offset voltages in millivolts for the analog channels (IAW1, IBW1, ICW1, IAW2, IBW2, ICW2) and master offset (MOF). W (Warning) or F (Failure) indicates an out-of-tolerance condition.
PS: +5V_PS–VBAT	Power supply and voltage regulator output voltages. W (Warning) or F (Failure) indicates out-of-tolerance condition.
TEMP	Temperature inside the relay in degrees Celsius. W (Warning) or F (Failure) indicates out-of-tolerance condition.
RAM, ROM, CR_RAM	Memory functions. Status is either OK or FAIL.
EEPROM	Checksums of the settings in EEPROM are checked. If they agree with an initial checksum, OK is displayed. If not, FAIL is displayed.
FLASH	Checksums of the nonvolatile event report data in FLASH are checked. If there is agreement, OK is displayed. If not, FAIL is displayed.

TARGET

Access Level 1

Table 6.6 shows the present state of relay elements, optoisolated inputs, output contacts, and programmable logic in the 11-row Relay Word. With the **TARGET** command, you can view the rows of the Relay Word via the front panel or through the serial port.

Executing the **TARGET # *n*** command (as given in *Table 6.8*) displays Relay Word row "#" on the computer screen with a list of the elements and corresponding status (logical 1 = asserted; logical 0 = not asserted). If number *n* is entered with the **TARGET # *n*** command, the logic status is reported *n* times, about a quarter second between reports. This feature is useful when testing elements-state changes can be observed on the computer screen (element state goes from 1 to 0 or 0 to 1).

The front-panel target LEDs are also reassigned to display the state of elements in the selected Relay Word row (LED illuminated = asserted; LED off = not asserted). The front-panel target LEDs are updated each quarter cycle.

Table 6.7 SEL-587 Relay Word and Correspondence of the Relay Word to the Target Command and Front-Panel LEDs

Target 0 (Front-Panel LEDs)	EN	87	50	51	A	B	C	N
Target 1	51P1P	51Q1P	51N1P	51P1T	51Q1T	51N1T	*	RB1
Target 2	50P1P	50Q1P	50N1P	50P1T	50Q1T	50N1T	50P1H	50N1H
Target 3	51P2P	51Q2P	51N2P	51P2T	51Q2T	51N2T	*	RB2
Target 4	50P2P	50Q2P	50N2P	50P2T	50Q2T	50N2T	50P2H	50N2H
Target 5	87U1	87U2	87U3	87U	87R1	87R2	87R3	87R
Target 6	2HB1	2HB2	2HB3	5HB1	5HB2	5HB3	87BL	RB3
Target 7	TH5P	TH5T	PDEM	NDEM	QDEM	TRP1	TRP2	TRP3
Target 8	OC1	OC2	CC1	CC2	IN1	IN2	52A1	52A2
Target 9	MTU3	MTU2	MTU1	MER	YT	Y	XT	X
Target 10	51P1R	51Q1R	51N1R	51P2R	51Q2R	51N2R	*	RB4
Target 11	*	*	*	ALARM	OUT1	OUT2	OUT3	OUT4

See *Table 4.2* for SEL-587 Relay Word bit definitions.

TIME

Access Level 1

NOTE: After setting the time, allow at least 60 seconds before powering down the relay or the new setting may be lost.

To view the time presently on the internal clock/calendar of the relay, use the **TIME** command. Change this time by entering the command **TIME *hh*:*mm*:*ss***, where *h* = hours, *m* = minutes, and *s* = seconds.

TRIGGER

Access Level 1

Use the **TRIGGER** command to trigger an event report, which the relay logs in the event report history and which you can view by entering an **EVENT** command. The **TRIGGER** command offers you a convenient way to record all inputs and outputs from the relay at any time you want (e.g., testing or commissioning). The relay records the event type as TRIG any time you issue the **TRIGGER** command.

Front-Panel Operation

Front-panel pushbuttons provide you convenient access to an abbreviated set of the relay commands available from the serial port. Use the front-panel pushbuttons to obtain much of the same information available through use of the serial port commands.

Use *Figure 6.1* and *Table 6.8* as guides to SEL-587 front-panel operation. *Figure 6.1* illustrates front-panel pushbutton functions. *Table 6.8* lists the serial port commands alphabetically within a given access level, front-panel operation equivalents, and a brief description of each command.

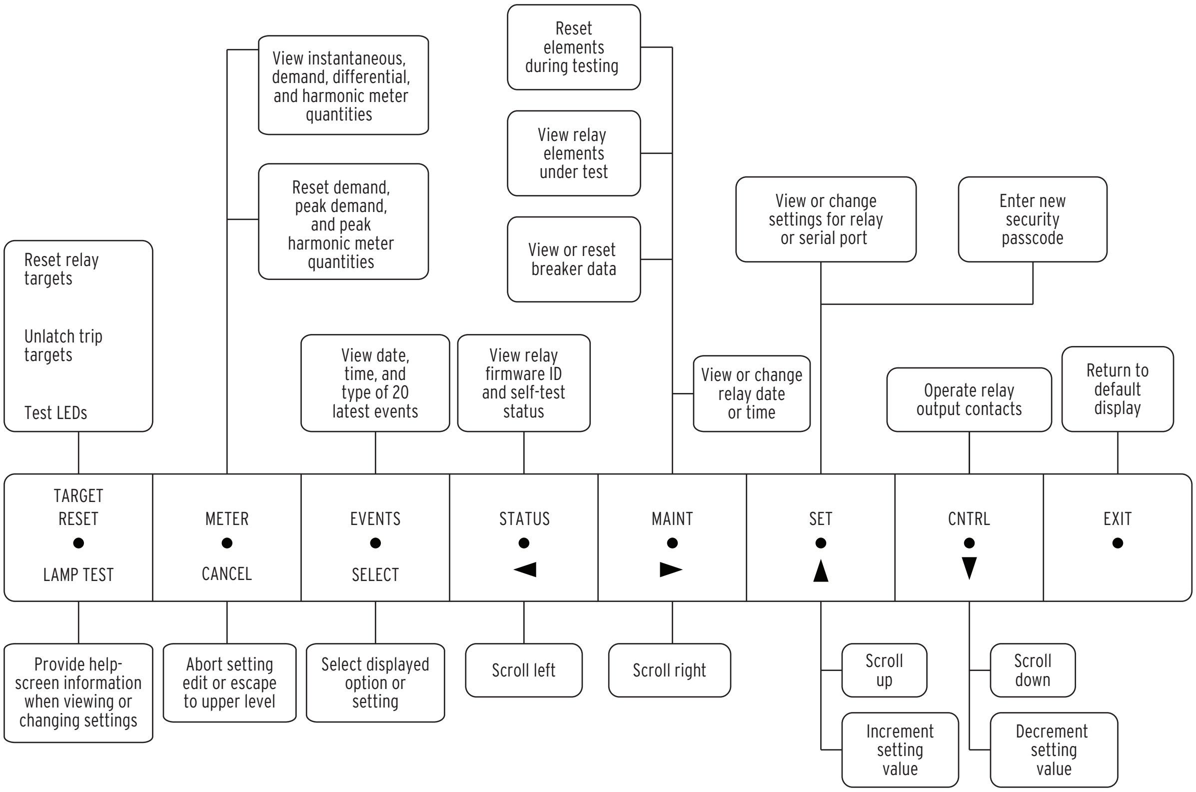

Figure 6.1 Front-Panel Function Drawing

Table 6.8 Serial Port Commands and Front-Panel Operation Equivalents (Sheet 1 of 2)

Access Level	Serial Port Command	Front-Panel Operations	Command Description
0	**ACCESS**	–	Move to Access Level 1
1	**2ACCESS**	–	Move to Access Level 2
1	**BREAKER**	**MAINT** > OTHER > BKRn > SHOW	View breaker monitor trip counter and trip current data for Breaker *n* (*n* = 1, 2)
1	**DATE**	**MAINT** > DATE	View date
1	**DATE *mm/dd/yy***	**MAINT** > DATE > SET	Change date
1	**EVENT #**	–	View event report (# = 1–10)
1	**HISTORY**	**EVENTS**	View latest 20 event summaries
1	**HISTORY C**	–	Clear event history
1	**IRIG**	–	Synchronize to IRIG-B
1	**METER *n*, METER D *n***	**METER** > Wn > SHOW	View instantaneous or demand (D) currents for Windings 1 and 2. Repeat *n* times.
1	**METER P *n***	**METER** > Wn > PEAK	View peak demand (P) currents for Windings 1 and 2. Repeat *n* times.
1	**METER RD *n* METER RP *n***	**METER** > Wn > RESET	Reset demand (RD) and peak demand (RP) values for Winding *n* (*n* = 1, 2)
1	**METER DIF *n***	**METER** > DIF > SHOW	View differential element quantities. Repeat *n* times.
1	**METER PH *n***	**METER** > DIF > PEAK	View peak harmonic (PH) current. Repeat *n* times.
1	**METER RPH**	**METER** > DIF > RESET	Reset peak harmonic (RPH) values
1	**METER SEC *n***	**METER** > PHA	View secondary magnitude and angle for phase, negative-sequence, and residual currents
1	**QUIT**	–	Move to Access Level 0

Table 6.8 Serial Port Commands and Front-Panel Operation Equivalents (Sheet 2 of 2)

Access Level	Serial Port Command	Front-Panel Operations	Command Description
1	**SHOWSET**	SET > RELAY > SHOW	View relay settings
1	**SHOWSET L**	–	View relay SELOGIC control equation settings
1	**SHOWSET P**	SET > PORT > SHOW	View serial port protocol settings
1	**STATUS**	STATUS	View relay self-test status
1	**TARGET # *n***	MAINT > OTHER > TAR	View Relay Word row # (# = 0–11). Repeat *n* times.
1	**TARGET R**	TARGET RESET	Reset tripping targets and return targets to TARGET 0 (display front-panel targets)
1	**TIME**	MAINT > TIME	View time
1	**TIME hh:mm:ss**	MAINT > TIME > SET	Change time
1	**TRIGGER**	–	Trigger a relay event report
2	**BREAKER *n* R**	MAINT > OTHER > BRKn > RESET	Reset breaker monitor trip counters and trip current data
2	**CLOSE *n***	–	Assert Relay Word bit CC*n* (*n* = 1, 2)
2	**CONTROL *n***	–	Assert, deassert or pulse Relay Word bit RB*n* (*n* = 1, 2, 3, 4)
2	**OPEN** *n* (valid only if TDURD > 0)	–	Assert Relay Word bit OC*n* (*n* = 1, 2)
2	**PASSWORD**	–	View Access Level 1 and 2 passwords
2	**PASSWORD 1**	–	View Access Level 1 password
2	**PASSWORD 2**	–	View Access Level 2 password
2	**PASSWORD 1 *######***	–	Change Access Level 1 password to *######*
2	**PASSWORD 2 *######***	SET > PASS	Change Access Level 2 password to *######*
2	**PULSE *n m***	CNTRL > PULSE:OUTn	Trigger an event report and assert output contact *n* (*n* = 1, 2, 3, 4) for *m* seconds (*m* = 1–30). One-second pulse for front panel or if not specified.
2	**RESET *n***	MAINT > OTHER > EL	Reset time-overcurrent elements for Winding *n* (*n* = 1, 2)
2	**SET**	SET > RELAY > SET	View or change relay settings
2	**SET L**	–	View or change SELOGIC control equation settings
2	**SET P 1** **SET P F**	SET > PORT > SET	View or change serial port protocol settings

Front-Panel Command Execution

Execute a front-panel command by pressing the desired control button. Use the left- and right-arrow buttons to underline the desired function, and then press the **SELECT** button.

Press the **EXIT** button to end a command and return to the default display. Press the **CANCEL** button to undo the last selection and return to the previous display.

Default and Automatic Messages

The front panel normally displays Winding 1 and Winding 2 current magnitudes scaled in primary amperes.

The normal display clears and new information shows when:

- The relay triggers an event report.
- The relay self tests detect a warning or failure state.

The relay displays the automatic message until a new condition occurs, or you press any front-panel button.

Front-Panel Password Security

Relay front-panel password security prevents unauthorized personnel from entering Access Level 2. From Access Level 2 you can enter all Access Level 1 commands, change settings, and operate relay parameters and output contacts. When the relay turns on, the front panel is at Access Level 1, from which you can view but not change relay information. If the Main Board Jumper **JMP22** is not in place, the relay prompts for entry of a password before allowing you to enter Access Level 2. See *Section 2: Installation* for jumper locations and detail.

⚠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 is not responsible for any damage resulting from unauthorized access.

The password is a six-digit, or fewer, alphanumeric combination that can include numbers, letters, a dash, or period. To enter the password from the front panel, use the left- and right-arrow buttons to underline and select a digit. Use the up- and down-arrow buttons to change the digit. Unused digits to the right of the password appear as spaces. Press the **SELECT** button when you have entered the correct alphanumeric character for each digit. Note that relay passwords are case sensitive; the relay treats uppercase and lowercase letters as different characters.

Setting Changes Via the Front Panel

Press the front-panel **SET** button. Use the left- or right-arrow buttons to underline:

- `Relay` (relay differential and overcurrent settings)
- `Port` (communications-port settings)
- `Pass` (security password)

Press the **SELECT** button to indicate your choice. For example, to change relay settings, underline `RELAY` and press the **SELECT** button, then underline `SET` and press the **SELECT** button.

The relay prompts you to enter the Access Level 2 password, if password security is enabled. When you have correctly entered the password, press the **SELECT** button. The relay displays the first setting subgroup title, `GENERAL DATA`. Refer to the settings sheets at the end of *Section 5: Setting the Relay*.

Use the up-, down-, left-, or right-arrow buttons to scroll through the setting subgroup titles. When the relay displays a setting subgroup you want to modify, press the **SELECT** button to enter that subgroup.

Use the up- and down-arrow buttons to scroll through the settings within a subgroup. When the relay displays a setting you want to change, press the **SELECT** button and make the changes. The **TARGET RESET** button provides help-screen information when viewing or changing settings.

- Change the RID (Relay Identifier) and TID (Terminal Identifier) settings in the GENERAL DATA subgroup by using the left- and right-arrow buttons to underline the digit you want to change. Use the up- and down-arrow buttons to scroll through the available alphanumeric characters. Press the **SELECT** button after you enter the character you want for each digit (digits can be left blank). The relay then displays the next setting.
- Change numeric settings (e.g., CT ratios, restraint percentages, taps, pickups, timers, etc.) by using the left- and right-arrow buttons to underline the digit you want to change. Some numeric settings have an OFF setting option that can also be selected

with the left- and right-arrow buttons. Use the up- and down-arrow buttons to enter the correct number. Press the **SELECT** button after you enter the number you want for each digit (or after selecting OFF). The relay then displays the next setting.

- Change yes/no (Y/N) settings or settings that provide a given selection of setting values (i.e., transformer connections, CT connections, input assignments, curve type, system frequency, or phase rotation) by using the up- and down-arrow buttons to scroll through the available settings. Press the **SELECT** button after you select the setting you want. The relay then displays the next setting.

Press the **CANCEL** button if you decide not to change a setting. The relay then displays the next setting.

When you have entered all the setting changes you want, press the **EXIT** button. The relay prompts you to save changes. To save the new settings, underline `Yes` and press the **SELECT** button. To reject the new settings, underline `No` and press the **SELECT** button.

You cannot set logic settings via the front panel. Set logic settings via the rear-panel serial port, with the **SET L** command. The relay has logic settings for programmable timer inputs, tripping conditions, event report triggering conditions, and output contacts. *Section 4: Tripping, Closing, and Targeting Logic* discusses logic settings in more detail.

Front-Panel Reset

If the relay does not detect a front-panel button-press for five minutes, the relay takes the following actions:

- The front-panel LCD resets to the default display.
- The LCD backlight extinguishes.
- Any routine being executed via a front-panel command is interrupted.
- The target LEDs display the tripping targets.

Operation Details

Breaker Command From the Front Panel

Table 6.8 shows how to display or reset breaker monitor information via the serial port or front panel. Via the front panel, the display scrolls automatically through the accumulated trips and interrupted kiloamperes pole by pole for the selected breaker. Stop the scrolling by pressing the **SELECT** button, and resume scrolling by pressing the **SELECT** button again. While scrolling is stopped, move through the data by using the up- and down-arrow buttons.

To reset the data via the front panel, select `RESET` instead of `SHOW`. If password security is in effect, you must enter the password before resetting the breaker monitor data.

Target Command From the Front Panel

After accessing the Relay Word with the front-panel operations given in *Table 6.8*, use the up- and down-arrow buttons to scroll between the different Relay Word rows. The front-panel target LEDs are also reassigned to display the state of elements in the selected Relay Word row (LED illuminated = corresponding element asserted; LED off = corresponding element not asserted). The front-panel target LEDs are updated each quarter cycle.

If any element is asserted, the element name is also displayed on the front-panel LCD. Use the left- and right-arrow buttons to view the names of the asserted elements. If an element is not asserted, the element name is not displayed on the front-panel LCD. The displayed element names are updated every two seconds on the LCD.

Relay Alarm Conditions

The relay asserts the ALARM output when dc power is removed or when any diagnostic test fails. In addition, the ALARM output pulses with the commands and conditions shown below.

Table 6.9 Commands With Alarm Conditions

Command	Condition
2ACCESS	Entering Access Level 2 or three wrong password attempts
ACCESS	Three wrong password attempts
PASSWORD	Any password is changed
SET commands	The relay setting changes are accepted

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Section 7
Event Reports

Introduction

Analyze events with event report summaries and event reports. Enable automatic messaging to allow the SEL-587 to send event report summaries out the serial port. These summaries are not stored; you cannot retrieve them later from the relay. The relay stores event reports in nonvolatile memory for later retrieval. Use the **HISTORY** command to obtain an index of these stored reports.

Event Report Triggering (MER)

The relay triggers (generates) an event report summary (if automessaging is enabled) and a 15-cycle event report when any of the following occurs:

- You execute the serial port **TRIGGER** command.
- You execute the front-panel or serial port **PULSE** command.
- Any of the programmable trip conditions (TRP1, TRP2, TRP3) assert.
- Any of the elements selected in the programmable MER equation assert.

Select elements to trigger event reports with the MER SELOGIC® control equation. The relay evaluates each element in the MER setting individually.

The relay triggers an event report at the rising edge of any element set in the MER equation, unless a report is already in progress. Three cycles of pre-fault data are recorded prior to the event.

Event Report Summary

If you have enabled relay automessaging (use **SET P *n*** to set AUTO = Y), the relay sends an event report summary to the serial port a few seconds after the occurrence of an event. You can connect the serial port to a printer, computer, or other SEL device.

Note that automessaging must be on for the relay to send an event report summary, the summary is specific only to the latest occurring event, and the summary is volatile; the relay sends the summary to the serial port but does not store this information in memory.

Event report summaries contain the following information:

- Relay identifier and terminal identifier (settings RID and TID)
- Date and time when the event was triggered
- Event type and duration
- Front-panel tripping target LEDs
- Phase (each phase), negative-sequence ($3 \bullet I_2$), and residual current magnitudes in amperes secondary measured at the largest phase current magnitude in the triggered event report for Windings 1 and 2. The Event Report Summary shows the maximum phase current magnitude calculated by the bipolar peak detector or cosine filter and displays that result. When the relay uses the bipolar peak detector value (when an instantaneous pickup setting is greater than 8 times nominal phase current, and the harmonic distortion index is greater than a fixed threshold) the relay displays “pk” as shown in the Event Summary portion of the Example 15-Cycle Event Report at the end of this section (for more information on the cosine filter and bipolar peak detector see *CT Saturation Protection on page 1.5*).

Event Type

The “Event:” field shows the event type. *Table 7.1* shows the possible types of events and corresponding descriptions.

Table 7.1 Event Types

Event	Event Triggered by:
TRP1	TRP1 tripping element assertion
TRP2	TRP2 tripping element assertion
TRP3	TRP3 tripping element assertion
MER	Element assertion in the MER equation assertion
PULSE	**PULSE** command execution
TRIG	**TRIGGER** command execution

Event Duration

The “Duration:” field shows the number of cycles that fault-detecting elements selected in MTU1, MTU2, MTU3, and MER were picked up during the event report. If elements are picked up at the beginning or end of the event report, the relay adds a “+” to the duration. This indicates that actual duration of the fault is longer than the figure reported.

Event Report History (HIS)

Review a brief summary of as many as 20 of the latest events by using the front-panel display and the **EVENTS** pushbutton or the serial port **HISTORY** command (see *Section 6: Operator Interface*). This summary contains the event report number, the date and time the event occurred, the event type, and relay targets. Use the event report history as an event report index, from which you can identify an event report for further examination.

Event Reports

The relay acquires data every sixteenth cycle, filters the data, processes these data every eighth or quarter cycle, and provides you the option of displaying either a standard, cosine-filtered event report or a raw, unfiltered event report. Filtered event report row data are always the output of the cosine filter; the relay reports the bipolar peak detector output value only in the Event Summary. With standard event reports, you have the option of displaying event data at either a standard four samples per cycle or at 16 samples per cycle. The relay displays raw event reports at 16 samples per cycle.

The relay stores event reports for the 10 latest events in nonvolatile memory. Each event report contains detailed current, relay element, input, and output data associated with the event. Use the information contained in the relay event reports to review relay operation during faults and tests.

Obtain event reports with the serial port **EVENT** command. You can cause the relay to display any one of five different event formats, depending upon the arguments you enter with the **EVENT** command.

Quarter-Cycle Event Reports (EVE)

Use quarter-cycle event reports to simplify calculation of RMS current values. One quarter cycle represents 90 electrical degrees, so two consecutive samples are effectively perpendicular to each other. You can treat the two samples as rectangular components of the phasor quantity and extract the magnitude of the phasor by taking the square root of the sum of the squares of the samples. Each row shows the instantaneous value of the current signals each quarter cycle, after analog and digital filtering.

Overcurrent element status is reported without modification since it is processed at a quarter-cycle rate. Differential element, optoisolated input, and contact output status is displayed after taking the OR of two consecutive eighth-cycle values. As a result, the quarter-cycle report may indicate that two elements asserted at the same time when the elements actually asserted an eighth cycle apart. Use the sixteenth-cycle report for a complete detailed report.

Sixteenth-Cycle Event Reports (EVE L)

Use the sixteenth-cycle event report for oscillography and more complete event analysis. Overcurrent element status is repeated in four consecutive rows since it is processed at a quarter-cycle rate. Differential element, optoisolated input, and contact output status is repeated in two consecutive rows since it is processed at an eighth-cycle rate.

Event Commands

The listing below shows the event commands and report formats.

Command	Format
EVENT	For this standard 15-cycle event report, the relay samples ac current and optoisolated inputs four times per power cycle and filters these inputs to remove transient signals. The relay operates on filtered values and reports cosine-filtered values every quarter cycle in the event report row data. The relay reports the bipolar peak detector output value only in the Event Summary. The relay lists two separate 15-cycle reports, with the relay settings printed in between them. The two separate reports contain the following information: ➤ First report: input currents (currents connected to the rear-panel terminals from Windings 1 and 2), resultant residual current, overcurrent elements, general differential elements, inputs, and output contacts. ➤ Second report: operating and restraint current magnitudes, maximum second- and fifth-harmonic current magnitudes, more detailed differential element information, and remaining elements.
EVENT L	The relay samples ac current and optoisolated inputs 16 times per power cycle and filters these inputs to remove transient signals. The relay operates on filtered values and reports cosine-filtered values every sixteenth cycle in the event report row data. The relay reports the bipolar peak detector output value only in the Event Summary.
EVENT R	This command causes the relay to provide an event report, like the first of the two reports in the standard event report, but with a line of information listed each sixteenth cycle and the “raw” input currents displayed (current information that has not passed through digital filtering). The report contains secondary phase currents for each of the winding inputs as well as the status of digital outputs and optoisolated inputs. The report is 16.25 cycles long, with settings added on at the end.
EVENT L C and **EVENT R C**	The relay adds digital data in hexadecimal format to the end of the EVENT L version or EVENT R version, respectively, of the event report. These data are machine readable.

The time reported at the top of the EVENT standard event report corresponds to the end of the third event report cycle. The time reported at the top of the EVENT L, EVENT L C, EVENT R, and EVENT R C format event reports corresponds to the row with the “>” symbol between the current and relay element columns.

Relay Current Data

Current From Connected Winding 1 and Winding 2 CT Secondaries

The first eight columns of data in the first of the two reports in the standard event report show the currents from connected Winding 1 and Winding 2 CT secondaries (see example event report at the end of this section). The columns are:

IRW1	Residual current from Winding 1
IAW1	A-phase current from Winding 1
IBW1	B-phase current from Winding 1
ICW1	C-phase current from Winding 1
IRW2	Residual current from Winding 2

IAW2	A-phase current from Winding 2
IBW2	B-phase current from Winding 2
ICW2	C-phase current from Winding 2

Each row shows the instantaneous samples of the current signals, after analog and digital filtering, scaled in secondary amperes, RMS. The data in a single row correspond to a single point in time. The rows are a quarter cycle, or 90 degrees, apart in time.

Event report current values can be used to represent the signals as phasors and analyze the fault. Choose any row of data:

The value of the current in the previous row is the Q component.

The value of the current in the chosen row is the P component.

To construct a phasor diagram of the currents, select two consecutive rows from an area of interest in the event report. On Cartesian coordinates, plot the lower row (P-component) on the X (horizontal) axis and the upper row (Q-component) on the Y (vertical) axis.

Use any two consecutive samples to calculate the magnitude and phase angle of the measured current. Calculate the magnitude of the current phasors by taking the square root of $P^2 + Q^2$. Calculate the phase angle of the signal by taking the arctangent of (Q/P).

Current Seen by Relay Differential Elements

The first eight columns of data in the second of the two reports in the standard event report format show the operate, restraint, and harmonic currents seen by the relay differential elements. The columns are:

IOP1	Magnitude of operate current for differential element 1
IOP2	Magnitude of operate current for differential element 2
IOP3	Magnitude of operate current for differential element 3
IRT1	Magnitude of restraint current for differential element 1
IRT2	Magnitude of restraint current for differential element 2
IRT3	Magnitude of restraint current for differential element 3
IF2	Magnitude of maximum second-harmonic current seen by the differential elements
IF5	Magnitude of maximum fifth-harmonic current seen by the differential elements

Each row shows the magnitude of the current signals each quarter (1/4) cycle, after analog and digital filtering. The magnitudes are scaled in secondary amperes, RMS, and no phasor information can be derived.

Relay Column Headings

The columns adjacent to the current data in the standard event report format contain information on the state of relay elements, inputs, and outputs each quarter-cycle during the event.

Each column shows a letter or symbol to indicate the condition of protection elements during that quarter-cycle. Read the column labels vertically.

Table 7.2 Columns in the First of the Two Reports in the Standard Event Report (Sheet 1 of 2)

Column	Symbol	Definition
All	.	Element/output/input not picked up or asserted
51P1	p	Winding 1 Phase time-overcurrent element picked up
	T	Winding 1 Phase time-overcurrent element trip
51Q1	q	Winding 1 Negative-sequence time-overcurrent element picked up
	T	Winding 1 Negative-sequence time-overcurrent element trip
51N1	n	Winding 1 Residual time-overcurrent element picked up
	T	Winding 1 Residual time-overcurrent element trip
50P1	p	Winding 1 Phase definite-time overcurrent element picked up
	T	Winding 1 Phase definite-time overcurrent element trip
	H	Winding 1 Phase instantaneous overcurrent element trip
50Q1	q	Winding 1 Negative-sequence definite-time overcurrent element picked up
	T	Winding 1 Negative-sequence definite-time overcurrent element trip
50N1	n	Winding 1 Residual definite-time overcurrent element picked up
	T	Winding 1 Residual definite-time overcurrent element trip
	H	Winding 1 Residual instantaneous overcurrent element trip
51P2	p	Winding 2 Phase time-overcurrent element picked up
	T	Winding 2 Phase time-overcurrent element trip
51Q2	q	Winding 2 Negative-sequence time-overcurrent element picked up
	T	Winding 2 Negative-sequence time-overcurrent element trip
51N2	n	Winding 2 Residual time-overcurrent element picked up
	T	Winding 2 Residual time-overcurrent element trip
50P2	p	Winding 2 Phase definite-time overcurrent element picked up
	T	Winding 2 Phase definite-time overcurrent element trip
	H	Winding 2 Phase instantaneous overcurrent element trip
50Q2	q	Winding 2 Negative-sequence definite-time overcurrent element picked up
	T	Winding 2 Negative-sequence definite-time overcurrent element trip
50N2	n	Winding 2 Residual definite-time overcurrent element picked up
	T	Winding 2 Residual definite-time overcurrent element trip
	H	Winding 2 Residual instantaneous overcurrent element trip
87U	*	Unrestrained differential element trip
87R	*	Restrained differential element trip
87BL	*	Second- or fifth-harmonic block
OUT1&2	1	Output contact OUT1 asserted
	2	Output contact OUT2 asserted
	b	Both output contacts OUT1 and OUT2 asserted

Table 7.2 Columns in the First of the Two Reports in the Standard Event Report (Sheet 2 of 2)

Column	Symbol	Definition
OUT3&4	3	Output contact OUT3 asserted
	4	Output contact OUT4 asserted
	b	Both output contacts OUT3 and OUT4 asserted
ALRM	*	ALARM output contact asserted
IN1&2	1	Input IN1 asserted
	2	Input IN2 asserted
	b	Both inputs asserted

Table 7.3 Columns in the Second of the Two Reports in the Standard Event Report

Column	Symbol	Definition
All	.	Element/output/input not picked up or asserted
87U1	*	Unrestrained differential element 1 trip
87U2	*	Unrestrained differential element 2 trip
87U3	*	Unrestrained differential element 3 trip
87R1	*	Restrained differential element 1 trip
87R2	*	Restrained differential element 2 trip
87R3	*	Restrained differential element 3 trip
2HB1	*	Second-harmonic block asserted for differential element 1
2HB2	*	Second-harmonic block asserted for differential element 2
2HB3	*	Second-harmonic block asserted for differential element 3
5HB1	*	Fifth-harmonic block asserted for differential element 1
5HB2	*	Fifth-harmonic block asserted for differential element 2
5HB3	*	Fifth-harmonic block asserted for differential element 3
TRP1	*	Trip logic output for programmable equation MTU1
TRP2	*	Trip logic output for programmable equation MTU2
TRP3	*	Trip logic output for programmable equation MTU3
XT	T	Output of X programmable timer
YT	T	Output of Y programmable timer
CC	1	Breaker 1 **CLOSE** command execution
	2	Breaker 2 **CLOSE** command execution
OC	1	Breaker 1 **OPEN** command execution
	2	Breaker 2 **OPEN** command execution
TH5	p	Fifth-harmonic threshold exceeded
	T	Fifth-harmonic threshold exceeded for longer than time setting TH5D
PDEM	*	Phase demand current threshold exceeded
QDEM	*	Negative-sequence demand current threshold exceeded
NDEM	*	Residual demand current threshold exceeded

Inputs and outputs are identical to the first report.

Relay Settings

Relay settings are included with each standard event report unless the settings have changed since the report was triggered. The event report shows a message (instead of the settings) if relay settings have been changed since the event was triggered.

ACSELERATOR QuickSet SEL-5030 Software

The SEL-587 and SEL-587-1 relays with firmware version R702 and later are compatible with ACSELERATOR QuickSet® SEL-5030 Software. Use this software to read, set, and save relay settings, as well as monitor and control relay functions. QuickSet also provides automated help for the relay settings, and the ability to retrieve event reports from the relay. QuickSet communicates via the front serial port of the relay by using SEL ASCII communications.

Example 15-Cycle Event Report

The following standard event report was generated by an SEL-587 in response to a laboratory-staged fault on C-phase of the secondary of a delta-wye transformer. A high-side breaker is closed, energizing the transformer and the bolted fault. There is no source on the secondary side. The C-phase secondary fault on the wye winding translates to B-C primary current flowing into the primary delta winding (see IBW1 and ICW1 current columns).

NOTE: For the Long Event Report (16 samples/cycle), the arrow (>) in the column following the ICW2 current column identifies the "trigger" row. This is the row that corresponds to the Date and Time values at the top of the event report. The trigger row indication (>) is only shown in Long and Raw event reports.

The example standard event report has been edited to fit on one page.

The asterisk (*) in the column following the ICW2 current column identifies the row with the maximum phase current. The maximum phase current is calculated from the row identified with the asterisk and the row one-quarter cycle previous. If the "trigger" row (>) and the maximum phase current row (*) are the same row, the > symbol takes precedence and is displayed.

```
Xfmr 1                             Date: 01/12/95   Time: 18:33:44.796
Station L

FID=SEL 587 X104 V5a D950106
                                                        Relay Elements    OUT IN

           Winding 1                  Winding 2         555555 555555 888   A
           Amps Sec                   Amps Sec          111000 111000 777 13L 1
                                                        PQNPQN PQNPQN URB &&R &
  IRW1   IAW1   IBW1   ICW1   IRW2   IAW2   IBW2   ICW2 111111 222222   L 24M 2
                                                 .
[Two cycles of data not shown in this example]   .
                                                 .

 11.43   0.66  10.10   0.66  11.44   0.67  10.09   0.68 ...... p..... ..* ... 1
-11.72  -2.56  -6.60  -2.57 -11.69  -2.57  -6.56  -2.56 ...... p.n... ..* ... .
-14.15  -1.37 -11.41  -1.37 -14.08  -1.38 -11.31  -1.39 p..p.. p.np.n ..* ... .
  9.60   3.76   2.08   3.77   9.54   3.77   2.01   3.77 pq.p.. p.np.n *.* .b. .

 17.27   1.35  14.56   1.36  17.33   1.35  14.61   1.37 pq.p.. p.np.n *.. .b. .
 -5.60  -3.80   2.00  -3.80  -5.65  -3.81   1.97  -3.81 pq.H.. p.np.n *.. .b. .
-19.54  -1.24 -17.05  -1.24 -19.35  -1.24 -16.86  -1.25 pq.H.. p.np.n *.. .b. .
  3.30   3.84  -4.38   3.84   3.34   3.85  -4.36   3.85 pq.H.. p.np.n *.. .b. .

 20.51   1.13  18.26   1.13  20.33   1.13  18.08   1.13 pq.H.. p.np.n **. .b. .
  2.01  -3.87   9.76  -3.88   1.86  -3.88   9.63  -3.88 pq.Hq. p.np.n *** .b. .
-23.86  -1.01 -21.84  -1.01 -23.87  -1.01 -21.84  -1.01 pq.Hq. p.np.n **. .b. .
 -2.99   3.90 -10.80   3.91  -2.88   3.91 -10.71   3.91 pq.Hq. p.np.n **. .b. .

                                                 .
[10 cycles of data not shown in this example]    .
                                                 .
Event: TRP1 TRP2 TRP3    Targets: 87 50 A B C N         Duration:   9.13 cyc
Winding 1 Currents (A Sec), ABCQN:   4.03     31.08 pk   4.04     16.84  19.81
Winding 2 Currents (A Sec), ABCQN:   4.05     31.00 pk   4.05     15.64  20.46

[Settings listed here, but not shown in this example]
                                                     Relay Elements       OUT IN

   Operating Qty     Restraint_Qty   Max Hrm    888888 222555 TTT      PQN   A
     Amps Sec          Amps Sec      Amps Sec   777777 HHHHHH RRRXYCO TDDD 13L 1
                                                UUURRR BBBBBB PPPTTCC HEEE &&R &
 IOP1  IOP2  IOP3  IRT1  IRT2  IRT3  IF2   IF5  123123 123123 123     5MMM 24M 2
                                                 .
[Two cycles of data not shown in this example]   .
                                                 .
 5.00  15.6  0.96  3.22  7.80  0.48  8.43  0.96 ...... ***.*. ....... p*** ... 1
 4.78  17.9  2.64  4.27  8.98  1.32  15.3  4.83 ...... *****. ....... p*** ... .
 4.37  19.3  2.91  4.53  9.67  1.45  14.9  4.81 ...... ****.. ....... p*** ... .
 6.46  17.1  4.01  4.90  8.70  2.00  18.3  4.02 .*.... ****.. ..*.... p*** .b. .

 7.90  22.2  4.00  5.85  11.2  2.00  19.5  4.04 .*.... **.... ..*.... p*** .b. .
 9.51  22.8  4.04  6.19  11.5  2.02  18.9  3.00 .*.... **.... ..*.... p*** .b. .
 10.5  26.6  4.00  6.80  13.3  2.00  18.2  3.12 .*.... **.... ..*.... p*** .b. .
 11.5  27.6  4.04  7.10  13.8  2.02  19.3  3.30 **.... **.... ..*.... p*** .b. .

 12.1  29.4  4.00  7.43  14.8  2.00  20.1  3.58 **...* **.... ..*.... p*** .b. .
 14.5  33.0  4.04  8.27  16.6  2.02  16.9  2.11 **...* **.... ..*.... p*** .b. .
 17.6  43.5  4.01  10.1  21.8  2.00  15.4  3.06 **...* **.... ..*.... p*** .b. .
 18.0  44.2  4.04  10.2  22.1  2.02  15.4  3.03 **...* **.... ..*.... p*** .b. .
                                                 .
[10 cycles of data not shown in this example]    .
```

Relay and Terminal Identifier Settings

First Report

Event Summary

Second Report (Note correspondence with above first report)

One Cycle of Data

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Section 8

Testing and Troubleshooting

Introduction

This section should be used for determining and establishing test routines for the SEL-587. Included are discussions on testing philosophies, methods, and tools. Example test procedures are shown for the time-overcurrent element pickup thresholds, time-overcurrent element timing, differential element pickup, restrained differential element slope characteristic, and the harmonic blocking functions. Relay troubleshooting procedures are shown at the end of the section.

Testing Philosophy

⚠CAUTION
Before performing any tests, verify that the injected test signals do not exceed the maximum specified current levels and times. See Specifications on page 1.7 for details.

Protective relay testing can be divided into two categories: commissioning and maintenance testing. The categories are differentiated by when they take place in the life cycle of the relay, as well as in the test complexity.

The paragraphs below describe when each type of test is performed, the goals of testing at that time, and the relay functions that you need to test at each point. This information is intended as a guideline for testing SEL relays.

Commissioning Testing

When: When installing a new protection system.

Goal:

1. Ensure that all system ac and dc connections are correct.
2. Ensure that the relay functions as intended using your settings.
3. Ensure that all auxiliary equipment operates as intended.

What to test: All connected or monitored inputs and outputs; polarity and phase rotation of ac current connections; simple check of protection elements.

SEL performs a complete functional check and calibration of each relay before it is shipped. This helps ensure that you receive a relay that operates correctly and accurately. Commissioning tests should verify that the relay is properly connected to the power system and all auxiliary equipment. Verify control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection check to verify that the relay current inputs are of the proper magnitude and phase rotation.

Brief fault tests ensure that the relay settings are correct. It is not necessary to test every relay element, timer, and function in these tests.

At commissioning time, use the relay **METER DIF *n*** command to record the measured operate and restraint values for through-load currents. Use the **PULSE** command to verify relay output contact operation.

Use *Appendix H: SEL-587 Relay Commissioning Test Worksheet* to verify correct CT connections and settings when placing the relay in service. The worksheet shows how using software commands or the front-panel display can replace the need for the traditional phase angle meter and ammeter.

Maintenance Testing

When: At regularly scheduled intervals, or when there is an indication of a problem with the relay or system.

Goals:

1. Ensure that the relay is measuring ac quantities accurately.
2. Ensure that scheme logic and protection elements are functioning correctly.
3. Ensure that auxiliary equipment is functioning correctly.

What to test: Anything not shown to have operated during an actual fault within the past maintenance interval.

SEL relays use extensive self-testing capabilities and feature detailed metering and event reporting functions that lower the utility's dependence on routine maintenance testing.

Use the SEL relay reporting functions as maintenance tools. Periodically verify that the relay is making correct and accurate current measurements by comparing the relay METER output to other meter readings on that line. Review relay event reports in detail after each fault. Using the event report current and relay element data you can determine that the relay protection elements are operating properly. Using the event report input and output data you can determine that the relay is asserting outputs at the correct instants and that auxiliary equipment is operating properly. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

The basis of this testing philosophy is simple: If the relay is correctly set and connected, is measuring properly, and no self-test has failed, there is no reason to test it further.

Each time a fault occurs the protection system is tested. Use event report data to determine areas requiring attention. Slow breaker auxiliary contact operations and increasing or varying breaker operating time can be detected through detailed analysis of relay event reports.

Because SEL relays are microprocessor-based, their operating characteristics do not change over time. Time-overcurrent and current differential element operating times are affected only by the relay settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

At SEL, we recommend that maintenance tests on SEL relays be limited under the guidelines provided above. The time saved can be spent analyzing event data and thoroughly testing those systems that require more attention.

Testing Methods and Tools

Test Features Provided by the Relay

The following features assist you during relay testing.

METER Command	The **METER** command shows the currents presented to the relay in primary values. Compare these quantities against other devices of known accuracy.
EVENT Command	The relay generates a 15-cycle event report in response to faults or disturbances. Each report contains current information, relay element states, and input/output contact information. If you question the relay response or your test method, use the event report for more information.
TARGET Command	Use the **TARGET *n*** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test.
Programmable Outputs	Programmable outputs allow you to initiate individual relay elements. Refer to the **SET** command.

For more information on these features and commands, see *Section 6: Operator Interface*.

Low-Level Test Interface

The SEL-587 has a low-level test interface between the calibrated input module and the separately calibrated processing module. You can test the relay in either of two ways: conventionally, by applying ac current signals to the relay inputs; or by applying low magnitude ac voltage signals to the low-level test interface. Access the test interface by removing the relay front panel.

Figure 8.1 shows the low-level interface connections. This drawing also appears on the inside of the relay front panel. Remove the ribbon cable between the two modules to access the outputs of the input module and the inputs to the processing module (relay main board).

⚠**CAUTION**
The relay contains devices sensitive to electrostatic discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

You can test the relay processing module by using signals from the SEL RTS Low-Level Relay Test System. Never apply voltage signals greater than 6.2 volts peak-peak to the low-level test interface. *Figure 8.1* shows the signal scaling factors.

You can test the input module two different ways:

1. Measure the outputs from the input module with an accurate voltmeter, and compare the readings to accurate instruments in the relay input circuits, or
2. Replace the ribbon cable, press the front-panel **METER** button, and compare the relay readings to other accurate instruments in the relay input circuits.

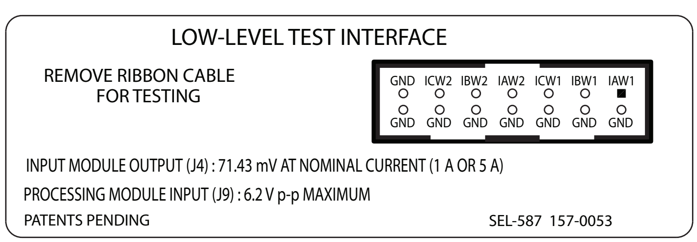

Figure 8.1 Low-Level Test Interface

Test Methods

Test the pickup and dropout of relay elements by using one of two methods: front-panel LCD/LED indication and output contact closure.

Testing Via Target LED Illumination

During testing use target LED illumination to determine relay element status. Using the **TARGET** command, set the front-panel targets to display the element under test. Monitor element pickup and dropout by observing the target LEDs.

Be sure to reset the front-panel targets to the default targets after testing before returning the relay to service. This can be done by pressing the front-panel TARGET RESET button, or by issuing the **TAR R** command from the serial port.

Review the **TARGET** command description in *Section 6: Operator Interface* for further details.

Testing Via Output Contact Operation

The relay can be set to operate an output contact for testing a single element. Use the **SET L** command to set an output contact (OUT1 through OUT4) to the element under test.

Use this method to verify definite-time delays and delays associated with time-current elements. Do not forget to re-enter the correct relay settings when you are ready to place the relay in service.

Test Procedures

Winding 1 Overcurrent Element Pickup Test: 50P1P, 50P1H, 50Q1P, 50N1P, 50N1H, 51P1P, 51Q1P, 51N1P

This example tests the Winding 1 50P1P phase overcurrent element. Use the same procedure to test the Winding 1 50P1H phase overcurrent element and the residual and negative-sequence overcurrent elements 50N1P, 50N1H, 51N1P, 50Q1P, and 51Q1P.

Step 1. Execute the **SHOW** command via the relay front panel or serial port and verify the setting for the Winding 1 50P1P overcurrent element.

Step 2. Execute the **TARGET 2** command. The SEL-587 now displays the state of several Winding 1 overcurrent elements on the front-panel LED and LCD, as shown below. When testing the time-overcurrent element pickup settings, use the **TARGET 1** command to display the status of 51P1P, 51N1P, and 51Q1P elements. See *Table 6.8* for more information on the **TARGET** command.

Target Label	EN	87	50	51	A	B	C	N
TARGET 2 Indicates:	• 50P1P	• 50Q1P	• 50N1P	• 50P1T	• 50Q1T	• 50N1T	• 50P1H	• 50N1H

Step 3. Connect a single current source to terminals 101 and 102, IAW1.

Step 4. Turn on the current test source and slowly increase the magnitude of current applied until the 50P1P element asserts, causing the EN (50P1P) LED to illuminate. Note the magnitude of the current applied. It should equal the 50P1P setting.

Residual Time-Overcurrent Element: 51N1T

The steps taken in the example test for the Winding 1 51N1T residual time-overcurrent element operating time can be applied to test the Winding 1 51P1T and 51Q1T time-overcurrent elements.

Step 1. Execute the **SHOW** command and verify the relay settings for the residual time-overcurrent element. Settings of interest are: 51N1P, 51N1C, 51N1TD, 51N1RS, and 51N1TC.

Step 2. Using the **SET L** command, set OUT1 = 51N1T. Connect **OUT1** to an external timer. Configure the timer to start on application of current and stop on operation of the **OUT1** contact. Note that any one of the four output contacts, **OUT1** through **OUT4**, can be used for this test.

Step 3. Connect a single current source to terminals **101** and **102**, IAW1.

Step 4. Calculate the expected operating time (tp) of the element. Use the element settings and the operating time equations shown in *Section 3: Relay Elements*. TD is the time-dial setting, 51N1TD, and M is the applied multiple of pickup current.

NOTE: If the time-overcurrent element induction-disk reset emulation is enabled (51N1RS, 51P1RS, or 51Q1RS = Y), the element under test may take some time to reset fully. If the element is not fully reset when you run a second test, the time to trip will be lower than expected. To reset an element before running additional tests, enter the **RESET** command from the relay serial port or the **EL** command under the **MAINT** pushbutton from the relay front panel.

For example, if 51N1P = 2.2 A, 51N1C = U3, and 51N1TD = 4.0, we can use the equation below to calculate the expected operating time for M = 3 (applied current equals M • 51N1P = 6.6 A):

$$tp = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$$

tp = 2.33 seconds

Step 5. Set the current source to deliver M • 51N1P amperes and turn the current source on. The timer should start. When the time-overcurrent element times out, OUT1 should close, stopping the timer. The time recorded should be approximately equal to the time you calculated in *Step 4*.

Winding 2 Overcurrent Element Pickup Test: 50P2P, 50P2H, 50Q2P, 50N2P, 50N2H, 51P2P, 51Q2P, 51N2P

To test Winding 2 elements, use the same procedure as that outlined for Winding 1 elements, substituting the appropriate Winding 2 settings and target indications.

Differential Element Pickup Test: 87U, 87R

This example tests the 87U unrestrained differential element. Use the same procedure to test the 87R restrained differential element. When testing the 87R element, monitor 87R with the **TARGET 5** command and use the 087P setting to calculate pickup value.

When testing a relay with the ability to provide harmonic restraint (HRSTR setting), make sure this setting is set to OFF for these tests (HRSTR = N). Failure to set the harmonic restraint setting to off during these tests could cause incorrect 87 element assertion levels due to the presence of harmonics, even in small quantities, in the generated waveforms. See *Harmonic Restraint Function Test: PCT2 and PCT4 Setting (HRSTR = Y) on page 8.9* for instruction on testing the harmonic restraint setting.

Step 1. Execute the **SHOW** command via the relay front panel or serial port and verify the instantaneous unrestrained operating current element (U87P) setting.

Step 2. Calculate the expected pickup for the 87U element by multiplying the U87P setting by the TAP1 setting and the appropriate connection constant, as shown in *Table 8.1*. Use constant A when testing winding 1, and constant B when testing winding 2. TRCON and CTCON settings determine the A and B constants for the calculations.

For RZS = Y, the relay subtracts zero-sequence current from the applied current.

For single-phase tests:

$$I0 = \frac{1}{3}(Ia + Ib + Ic)$$

If Ib = 0 and Ic = 0, then

$$I0 = \frac{1}{3}(Ia)$$

Therefore, for single-phase tests, the applied test current must be increased to account for subtracted zero-sequence current. The Current Connection Constants for RZS = Y reflect this requirement.

Table 8.1 Current Connection Compensation for Testing

TRCON Setting	CTCON Setting	A RZS = Y	A RZS = N	B RZS = Y	B RZS = N
YY[a]	YY	$\sqrt{3}$	$\sqrt{3}$	$\sqrt{3}$	$\sqrt{3}$
YDAC	YY	$\sqrt{3}$	$\sqrt{3}$	1.5	1
YDAB	YY	$\sqrt{3}$	$\sqrt{3}$	1.5	1
DABY	YY	1.5	1	$\sqrt{3}$	$\sqrt{3}$
DACY	YY	1.5	1	$\sqrt{3}$	$\sqrt{3}$
All other connections		1.5	1	1.5	1

[a] RZS setting hidden for TRCON = YY.

Step 3. Execute the **TARGET 5** command. The SEL-587 now displays the state of several differential elements on the front panel as follows:

Target Label	EN	87	50	51	A	B	C	N
	•	•	•	•	•	•	•	•
TARGET 5 Indicates:	87U1	87U2	87U3	87U	87R1	87R2	87R3	87R

Step 4. Connect a single current source to terminals 101 and 102, IAW1.

Step 5. Turn on the current test source and slowly increase the magnitude of current applied until the 87U element asserts, causing the **51** (87U) LED to illuminate. The LED illuminates when the applied current equals the calculated value in *Step 2*.

Restrained Differential Element Slope Test: SLP1 and SLP2 Setting

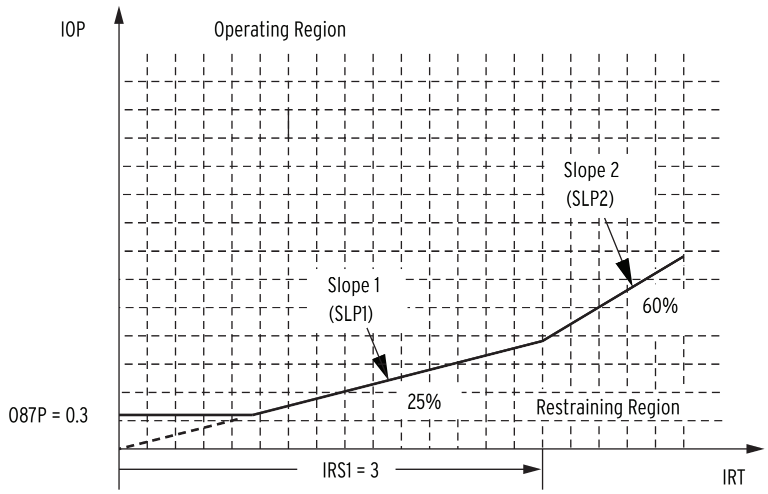

Figure 8.2 Percentage Restraint Differential Characteristic and Slope Test

Restraint Slope 1 Percentage: SLP1 Setting (HRSTR = N)

Step 1. Execute the **SHOW** command via the relay front panel or serial port and verify the Restraint Slope 1 Percentage (SLP1) setting, the TAP1 setting, the TAP2 setting, and the restraint current slope 1 limit (IRS1) setting.

Step 2. Execute the **TARGET 5** command. The SEL-587 now displays the state of several differential elements on the front panel as follows:

Target Label	EN	87	50	51	A	B	C	N
	•	•	•	•	•	•	•	•
TARGET 5 Indicates:	87U1	87U2	87U3	87U	87R1	87R2	87R3	87R

Step 3. Connect a current source to the IAW1 input, polarity to terminal 101 and nonpolarity to terminal 102. Connect a second current source to the IAW2 input, polarity to terminal 107 and nonpolarity to terminal 108.

Step 4. Calculate the Winding 1 input current for the test:

$$\mathrm{IAW1} = 0.8 \bullet \mathrm{IRS1} \bullet \left(1 + \frac{\mathrm{SLP1}}{200}\right) \bullet \mathrm{TAP1} \bullet \mathrm{A}$$

This calculation makes the test cross the differential characteristic at 80 percent of the IRS1 setting. See *Figure 8.2*.

If SLP2 = OFF, use the following equation:

$$IAW1 = 2 \bullet 087P \bullet \left(\frac{100}{SLP1} + \frac{1}{2}\right) \bullet TAP1 \bullet A$$

This calculation makes the test cross the differential characteristic well above the intersect point of the 087P setting and SLP1. See *Figure 8.2*.

SLP1, IRS1, 087P, and TAP1 are relay settings and A is the connection constant shown in *Table 8.1*.

Step 5. Turn on the current test source connected to the Winding 1 input (IAW1) to current equal to the value calculated in *Step 4*. The A (87R1) LED will illuminate once current is applied to the Winding 1 input.

Step 6. Calculate the expected Winding 2 input (IAW2) current at the SLP1 threshold:

$$IAW2 = 0.8 \bullet IRS1 \bullet \left(1 - \frac{SLP1}{200}\right) \bullet TAP2 \bullet B$$

If SLP2 = OFF, use the following equation:

$$IAW2 = 2 \bullet 087P \bullet \left(\frac{100}{SLP1} - \frac{1}{2}\right) \bullet TAP2 \bullet B$$

SLP1, IRS1, 087P, and TAP2 are relay settings and B is the connection constant shown in *Table 8.1*.

NOTE: IRS1 must be greater than [100 / (0.8 • SLP1)] • 087P if SLP2 is not set to OFF.

Step 7. Turn on the current test source connected to the Winding 2 input (IAW2) 180° out of phase with respect to IAW1. Slowly increase the magnitude of current applied to the Winding 2 input until the 87R1 element deasserts, causing the A (87R1) LED to completely extinguish. Note the value of current applied to the Winding 2 input. This should equal the calculated current in *Step 6*, ±5 percent.

Restraint Slope 2 Percentage: SLP2 Setting (HRSTR = N)

Step 1. Execute the **SHOW** command via the relay front panel or serial port and verify the following settings: Restraint Slope 2 Percentage (SLP2), TAP1, TAP2, and Restraint Current Slope 1 Limit (IRS1).

Step 2. Execute the **TARGET 5** command. The SEL-587 now displays the state of several differential elements on the front-panel display.

Step 3. Connect a current source to the IAW1 input, polarity to terminal 101 and nonpolarity to terminal 102. Connect a second current source to the IAW2 input, polarity to terminal 107 and nonpolarity to terminal 108.

Step 4. Calculate the Winding 1 input current for the test:

$$IAW1 = 1.2 \bullet IRS1 \bullet \left(1 + \frac{SLP1 + 0.2 \bullet SLP2}{1.2 \bullet 200}\right) \bullet TAP1 \bullet A$$

This calculation makes the test cross the differential characteristic at 120 percent of the IRS1 setting. See *Figure 8.2*.

IRS1, SLP1, SLP2, and TAP1 are relay settings and A is the connection constant shown in *Table 8.1*.

Step 5. Turn on the current test source connected to the Winding 1 input (IAW1) to current equal to the value calculated in *Step 4*. The **A** (87R1) LED will illuminate once current is applied to the Winding 1 input.

Step 6. Calculate the expected Winding 2 input (IAW2) current at the SLP2 threshold:

$$\mathrm{IAW2} = 1.2 \bullet \mathrm{IRS1} \bullet \left(1 - \frac{\mathrm{SLP1} + 0.2 \bullet \mathrm{SLP2}}{1.2 \bullet 200}\right) \bullet \mathrm{TAP2} \bullet \mathrm{B}$$

SLP1, SLP2, IRS1, and TAP2 are relay settings and B is the connection constant shown in *Table 8.1*.

Step 7. Turn on the current test source connected to the Winding 2 input (IAW2) 180° out of phase with respect to IAW1. Slowly increase the magnitude of current applied to the Winding 2 input until the 87R1 element deasserts, causing the **A** (87R1) LED to completely extinguish. Note the value of current applied to the Winding 2 input. This should equal the calculated current in *Step 6*, ±5 percent.

Harmonic Restraint Function Test: PCT2 and PCT4 Setting (HRSTR = Y)

This test requires a current source capable of generating second- and fourth-harmonic current. This example tests the second-harmonic restraint function. Use the same procedure to test the fourth-harmonic restraint function.

Step 1. Execute the **SHOW** command via the relay front panel or serial port and verify the Second-Harmonic Blocking Percentage (PCT2).

Step 2. Execute the **TARGET 5** command. The SEL-587 now displays the state of several differential elements on the front-panel LED and LCD, as follows:

Target Label	EN	87	50	51	A	B	C	N
	•	•	•	•	•	•	•	•
TARGET 5 Indicates:	87U1	87U2	87U3	87U	87R1	87R2	87R3	87R

Step 3. Connect a current source to the IAW1 input, terminals 101 and 102. Connect a second current source in parallel with the first source to the IAW1 input, terminals 101 and 102.

Step 4. Turn on the first current test source connected to the Winding 1 input (IAW1) equal to the TAP1 setting multiplied by the connection constant A shown in *Table 8.1*. The **N** (87R) LED will illuminate once current is applied to the relay.

Step 5. The following test applies to a single-harmonic injection at a time, i.e., only the second or the fourth harmonic, not both. Set HRSTR = Y (SEL-587-1). Set the second current source for second-harmonic current (120 Hz for NFREQ = 60 and 100 Hz for NFREQ = 50). Turn on the second current test source connected to the Winding 1 input (IAW1). Starting at zero current, slowly increase the magnitude of applied current until the 87R element deasserts, causing the **N** (87R) LED to completely extinguish. Note the value of the applied current from the second test source. Calculate the percentage of harmonic content for a single slope with the following equation (±5% ±0.10 A (5 A relay) or ±5% ±0.02 A (1 A relay)):

$$I1F2 = (IOP1 - IRT1 \bullet f(SLP)) \bullet \frac{PCT2}{100}$$

where f(SLP) is the value of the slope for the chosen value of IRT1 and

$$\%\ \text{harmonic} = \frac{I1F2}{IOP1} \bullet 100\ \text{(percent)}$$

For inrush conditions, current is normally applied to one side of the transformer, and the equation simplifies to the following:

$$\%\ \text{harmonic} = PCT2\left(1 - \frac{SLP1}{200}\right)$$

For example, SLP1 = 50 percent, PCT2 = 20 percent.

$$\%\ \text{harmonic} = 20\left(1 - \frac{50}{200}\right) = 15\ \text{percent}$$

For values on the second slope, use the following equation:

$$\%\ \text{harmonics} = \left(\frac{PCT2}{200}\right) \bullet \left(200 - SLP2 - \frac{IRSI}{IRT}(SLP1 - SLP2)\right)$$

NOTE: The second and fourth harmonics are combined to form the restraint quantity.

For example, slope 1 = 25 percent, slope 2 = 60 percent, PCT2 = 20 percent, IRS1 = 3, and choose IRT = 6.

$$\%\ \text{harmonic} = \left(\frac{20}{200}\right) \bullet \left(200 - 60 - \frac{3}{6}(25 - 60)\right) = 15.75\ \text{percent}$$

Harmonic Blocking Function Test: PCT2, PCT4, and PCT5 Setting (HRSTR = N)

This test requires a current source capable of generating second-, fourth-, and fifth-harmonic current. This example tests the second-harmonic blocking function. Use the same procedure to test the fourth- and fifth-harmonic blocking function.

Step 1. Execute the **SHOW** command via the relay front panel or serial port and verify the Second-Harmonic Blocking Percentage (PCT2).

Step 2. Execute the **TARGET 5** command. The SEL-587 now displays the state of several differential elements on the front-panel LED and LCD, as follows:

Target Label	EN	87	50	51	A	B	C	N
TARGET 5 Indicates:	• 87U1	• 87U2	• 87U3	• 87U	• 87R1	• 87R2	• 87R3	• 87R

Step 3. Connect a current source to the IAW1 input, terminals 101 and 102. Connect a second current source in parallel with the first source to the IAW1 input, terminals 101 and 102.

Step 4. Turn on the first current test source connected to the Winding 1 input (IAW1) equal to the TAP1 setting multiplied by the connection constant A shown in *Table 8.1*. The **N** (87R) LED will illuminate once current is applied to the relay.

Step 5. Set HRSTR = N (SEL-587-1). Set the second current source for second-harmonic current (120 Hz for NFREQ = 60 and 100 Hz for NFREQ = 50). Turn on the second current test source connected to the Winding 1 input (IAW1). Starting at zero current, slowly increase the magnitude of applied current until the 87R element deasserts, causing the **N** (87R) LED to completely extinguish. Note the value of the applied current from the second test source. The current from the second source divided by the current from the first source, multiplied by 100 should equal the setting for PCT2, ±5% ±0.10 A (5 A relay) or ±5% ±0.02 A (1 A relay).

$$\text{PCT2} = \frac{\text{IAW1 (second harmonic)}}{\text{IAW1 (fundamental)}} \bullet 100$$

Relay Self-Tests

The relay runs a variety of self-tests. The relay takes the following corrective actions for out-of-tolerance conditions (see *Table 8.2*):

- Protection Disabled: The relay disables overcurrent elements and trip/close logic. All output contacts are de-energized. The **EN** front-panel LED is extinguished.
- ALARM Output: The ALARM output contact signals an alarm condition by going to its de-energized state. If the ALARM output contact is a b contact (normally closed), it closes for an alarm condition or if the relay is de-energized. If the ALARM output contact is an a contact (normally open), it opens for an alarm condition or if the relay is de-energized. Alarm condition signaling can be five-second pulses (Pulsed) or permanent (Latched).
- The relay generates automatic STATUS reports at the serial port for warnings and failures.
- The relay displays failure messages on the relay LCD for failures.

Use the serial port **STATUS** command or front-panel **STATUS** pushbutton to view relay self-test status.

Table 8.2 Relay Self-Test (Sheet 1 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
IAW1, IBW1, ICW1, IAW2, IBW2, ICW2 Offset	Warning	30 mV	No	Pulsed	Measures the dc offset at each of the current input channels every 0.2 seconds.
Master Offset	Warning	20 mV	No	Pulsed	Measures the dc offset at the A/D every 0.2 seconds.
	Failure	30 mV	Yes	Latched	
+5V PS	Warning	+4.75 V +5.25 V	No	Pulsed	Measures the +5-volt power supply every 0.2 seconds.
	Failure	+4.70 V +5.50 V	Yes	Latched	
±5V REG	Warning	±4.65 V ±5.35 V	No	Pulsed	Measures the regulated 5-volt power supply every 0.2 seconds.

Table 8.2 Relay Self-Test (Sheet 2 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
	Failure	±4.50 V ±5.50 V	Yes	Latched	
±10V PS	Warning	±9.00 V ±11.00 V	No	Pulsed	Measures the 10-volt power supply every 0.2 seconds.
	Failure	±8.00 V ±12.00 V	Yes	Latched	
VBAT	Warning	+2.25 V +5.00 V	No	Pulsed	Measures the Real Time clock battery every 0.2 seconds.
	Failure	+2.10 V +6.00 V	No	Pulsed	
TEMP	Warning	–40°C +85°C	No		Measures the temperature at the A/D voltage reference every 0.2 seconds.
	Failure	–50°C +100°C	Yes	Latched	
RAM	Failure		Yes	Latched	Performs a read/write test on system RAM every 60 seconds.
ROM	Failure	checksum	Yes	Latched	Performs a checksum test on the relay program memory every 0.2 seconds.
CR_RAM	Failure	checksum	Yes	Latched	Performs a checksum test on the active copy of the relay settings every 0.2 seconds.
EEPROM	Failure	checksum	Yes	Latched	Performs a checksum test on the nonvolatile copy of the relay settings every 0.2 seconds.
The following self-tests are performed by dedicated circuitry in the microprocessor and the SEL-587 main board. Failures in these tests shut down the microprocessor and are not shown in the STATUS report.					
Microprocessor Crystal	Failure		Yes	Latched	The relay monitors the microprocessor crystal. If the crystal fails, the relay displays `CLOCK STOPPED` on the LCD. The test runs continuously.
Microprocessor	Failure		Yes	Latched	The microprocessor examines each program instruction, memory access, and interrupt. The relay displays `VECTOR nn` on the LCD upon detection of an invalid instruction, memory access, or spurious interrupt. The test runs continuously.
+5V PS Under/ Over Voltage	Failure	+4.65 V +5.95 V	Yes	Latched	A circuit on the SEL-587 main board monitors the +5-volt power supply. Upon detection of a failure, the circuit forces the microprocessor to reset.

Relay Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the relay. After you finish the inspection, proceed to *Troubleshooting Procedure*.

Step 1. Measure and record the power supply voltage at the power input terminals.

Step 2. Check to see that the power is on. Do not turn the relay off.

Step 3. Measure and record the voltage at all control inputs.

Step 4. Measure and record the state of all output relays.

Troubleshooting Procedure

All Front-Panel LEDs Dark

1. Input power not present or fuse is blown.
2. Self-test failure.

Cannot See Characters on Relay LCD Screen

1. Relay is de-energized. Check to see if the ALARM contact is closed.
2. LCD contrast is out of adjustment. Use the steps below to adjust the contrast.
    a. Remove the relay front panel by removing the three front-panel screws.
    b. Press any front-panel button. The relay should turn on the LCD backlighting.
    c. Locate the contrast adjust potentiometer directly adjacent to the **EN** LED.
    d. Use a small screwdriver to adjust the potentiometer.
    e. Replace the relay front panel.

Relay Does Not Respond to Commands From Device Connected to Serial Port

1. Communications device not connected to relay.
2. Relay or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.
3. Relay serial port has received an XOFF, halting communications. Type **<Ctrl + Q>** to send relay an XON and restart communications.

Relay Does Not Respond to Faults

1. Relay improperly set.
2. Improper test source settings.
3. CT input wiring error.
4. Analog input cable between transformer secondary and main board loose or defective.
5. Failed relay self-test.

Relay Calibration

The SEL-587 is factory calibrated. If you suspect that the relay is out of calibration, contact the factory.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, contact us at:

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Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

To determine the firmware version, view the status report by using the serial port **STATUS** command or the front-panel **STATUS** pushbutton. The status report displays the Firmware Identification (FID) number.

For firmware versions prior to date code 20010406, the status report displays the following FID number:

FID=SEL-587**-1-Rxxx-Vxb-Dxxxxxx**

NOTE: The hardware of the SEL-587 relays that originally shipped with firmware versions R704 and prior differs from the hardware of SEL-587 relays which have shipped with R800 firmware. Relays with firmware versions R704 and prior cannot be upgraded to R800 firmware.

For firmware versions with the date code of 20010406, or later, the status report displays the following FID number:

FID=SEL-587**-1-Rxxx-Vxb-Z001001-Dxxxxxxxx** (SEL-587-1)

FID=SEL-587**-0-Rxxx-Vxb-Z001001-Dxxxxxxxx** (SEL-587-0)

The firmware revisions number is after the R, and the date code is after the D. The single x after the V is a 1 for a 1 A relay and 5 for a 5 A relay.

Firmware series R101–R1*xx* and R401–R4*xx* are stored in through-hole EPROM. Firmware series R500–R7*xx* are stored in SMT (surface-mount technology) EPROM. Firmware series R8*xx* are stored in FLASH.

Table A.1 and *Table A.2* list the firmware versions, revision descriptions, and corresponding instruction manual date codes for the SEL-587-1 and SEL-587-0, respectively. The most recent firmware version is listed first.

Starting with revisions published after March 1, 2022, changes that address security vulnerabilities are marked with “[Cybersecurity]”. Other improvements to cybersecurity functionality that should be evaluated for potential cybersecurity importance are marked with “[Cybersecurity Enhancement]”.

Table A.1 SEL-587-1 Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Date Code
Conventional Terminal Blocks SEL-587-1-R801-Vxb-Z002001-D20220429	➤ Resolved an issue where Modbus communications would become unresponsive if the relay received a Modbus message containing a Slave ID that the relay did not recognize as its own.	20220429
Conventional Terminal Blocks SEL-587-1-R800-Vxb-Z002001-D20210406	➤ Added support for front-panel serial port.	20210406
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-1-R704-Vxb-Z001001-D20090227	➤ Improved sensitivity of DC Ratio Blocking element.	20090227
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-1-R703-Vxb-Z001001-D20061005	➤ Corrected problem with Modbus® message buffer overflow causing serial port to lock up whenever more than 256 characters were received.	20061005

Table A.1 SEL-587-1 Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Date Code
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-1-R702-Vxb-Z001001-D20040129	➤ CT Saturation Protection was enhanced to improve security with low set instantaneous values. ➤ Corrected fluctuations in relay IOP values reported using Modbus protocol.	20040129
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-1-R701-Vxb-Z001001-D20020828	➤ Updated ID message. ➤ Added CT Saturation Protection.	20020828
Supports PROTO = MOD 5 Amp SEL-587-1-R600-Vxb-D20010606 1 Amp SEL-587-1-R650-Vxb-D20010606 **Does Not Support PROTO = MOD** 5 Amp SEL-587-1-R502-Vxb-D20010606 1 Amp SEL-587-1-R552-Vxb-D20010606	➤ Added Modbus RTU protocol. ➤ Changed the FID string to use a four-digit year instead of a two-digit year. ➤ Changed the IHBL default setting to IHBL = N. ➤ Added DS1302 battery-backed clock support.	20010606
SEL-587-1-R501-D000505 (5 Amp) SEL-587-1-R551-D000505 (1 Amp)	➤ Fixed the LMD protocol (PROTO=LMD) so it properly handles applications with multiple devices. ➤ Fixed the Fast Meter protocol (PROTO=SEL) so it completes transmission of Fast Meter data after the Serial Port Time-Out (TIMEOUT) timer expires. ➤ Fixed the Fast Meter protocol so it responds to Fast Meter commands received shortly after transmission of Fast Meter data from an earlier command. ➤ Enhanced the previous target logic by displaying the ORed combination of the target status at the rising edge of TRIP and one cycle later, rather than just at the rising edge of TRIP. ➤ Fixed the initialization of the DC blocking element so it does not pick up after a series of setting changes.	20000505
SEL-587-1-R500-D991215 (5 Amp) SEL-587-1-R550-D991215 (1 Amp)	➤ Initial Version. ➤ Added harmonic restraint, trip unlatch, and zero-sequence removal.	991215

Table A.2 SEL-587-0 Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Date Code
Conventional Terminal Blocks SEL-587-0-R801-Vxb-Z002001-D20220429	➤ Resolved an issue where Modbus communications would become unresponsive if the relay received a Modbus message containing a Slave ID that the relay did not recognize as its own.	20220429
Conventional Terminal Blocks SEL-587-0-R800-Vxb-Z002001-D20210406	➤ Added support for front-panel serial port.	20210406
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-0-R704-Vxb-Z001001-D20090227	➤ Improved sensitivity of DC Ratio Blocking element.	20090227
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-0-R703-Vxb-Z001001-D20061005	➤ Corrected problem with Modbus message buffer overflow causing serial port to lock up whenever more than 256 characters were received.	20061005
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-0-R702-Vxb-Z001001-D20040129	➤ CT Saturation Protection was enhanced to improve security with low set instantaneous values.	20040129
Conventional Terminal Blocks and Plug-in Connectors (Connectorized) SEL-587-0-R701-Vxb-Z001001-D20020828	➤ Updated ID Message. ➤ Added CT Saturation Protection.	20020828

Table A.2 SEL-587-0 Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Date Code
SEL-587-0-R505-D000505 (5 Amp) SEL-587-0-R555-D000505 (1 Amp)	➤ Fixed the LMD protocol (PROTO = LMD) so it properly handles applications with multiple devices. ➤ Fixed the Fast Meter protocol (PROTO = SEL) so it completes transmission of Fast Meter data after the Serial Port Time-Out (TIMEOUT) timer expires. ➤ Fixed the Fast Meter protocol so it responds to Fast Meter commands received shortly after transmission of Fast Meter data from an earlier command. ➤ Enhanced the previous target logic by displaying the ORed combination of the target status at the rising edge of TRIP and one cycle later, rather than just at the rising edge of TRIP.	20000505
SEL-587-R503 (5 Amp) SEL-587-R553 (1 Amp)	➤ Corrected event type indication to include TRP1 when TRP1 asserts during an event, but does not trigger the event.	970528
SEL-587-R502 (5 Amp) SEL-587-R552 (1 Amp)	➤ Decreased power-up initialization time.	[a]
SEL-587-R501 (5 Amp) SEL-587-R551 (1 Amp)	➤ Fixed Fast Meter target data problem and system clock calibration problem.	[a]
SEL-587-R500 (5 Amp) SEL-587-R550 (1 Amp)	➤ Added IRIG. ➤ Added secondary metering with phase angle. ➤ Improved communications.	[a]
SEL-587-R105 (5 Amp) SEL-587-R405 (1 Amp)	➤ Password changed to allow up to six alphanumeric digits. ➤ Improved Fast Meter configuration.	[a]
SEL-587-R103 (5 Amp) SEL-587-R402 (1 Amp)	➤ Limited Multidrop (LMD) protocol. ➤ Fast Meter messages. ➤ Fast Operate messages ➤ Compressed ASCII commands. ➤ Added the **CONTROL** command, which allows the user to set, clear, or pulse the new relay elements RB1–RB4.	[a]
SEL-587-R102 (5 Amp)		[a]
SEL-587-R101 (5 Amp) SEL-587-R401 (1 Amp)	➤ Initial Version.	[a]

[a] Information about changes to earlier versions of the SEL-587-0 Instruction Manual is not available.

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.3 lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table A.3 Instruction Manual Revision History (Sheet 1 of 7)

Date Code	Summary of Revisions
20250131	Preface ➤ Updated *General Safety Marks*. Section 2 ➤ Updated *Clock Battery*.

Table A.3 Instruction Manual Revision History (Sheet 2 of 7)

Date Code	Summary of Revisions
	Section 3 ➤ Updated *Figure 3.6: SEL-587-0 Differential Element (87BL1 Blocking Logic)* and *Figure 3.7: SEL-587-1 Differential Element (87BL1) Blocking Logic*. Section 6 ➤ Updated *CALIBRATION*. ➤ Updated *Table 6.5: Default Passwords*. ➤ Updated *Figure 6.1: Front-Panel Function Drawing*. Appendix K ➤ Updated *Product Function*, *Secure Operation Recommendations*, *Local Accounts (or Access Levels)*, *Alarm Contact*, *Malware Protection Features*, and *Update Verification*.
20221103	Section 1 ➤ Added UKCA Mark in *Specifications*.
20221013	General ➤ Updated communication protocol description terminology to replace slave with server and master with client. Section 1 ➤ Updated *Processing* in *Specifications*. Section 3 ➤ Updated *Maximum Power Transformer Capacity (MVA)*. SEL-587 Relay Settings Sheets ➤ Updated *SET P Command (Port Settings)*. Section 6 ➤ Updated *Table 6.5: Default Passwords*. Section 7 ➤ Updated *Table 7.3: Columns in the Second of the Two Reports in the Standard Event Report*. Section 8 ➤ Updated *Testing Philosophy*. Appendix K ➤ Added new appendix.
20220630	Appendix A ➤ Added cybersecurity information to *Determining the Firmware Version in Your Relay*. ➤ Updated *Table A.1: SEL-587-1 Firmware Revision History* for R801, R800, R704, R703, R702, and R701. ➤ Updated *Table A.2: SEL-587-0 Firmware Revision History* for R801, R800, R704, R703, R702, and R701.
20220429	Appendix A ➤ Updated for firmware version R801. Appendix B ➤ Updated *Firmware Upgrade Instructions*.
20220113	Appendix B ➤ Updated *Firmware Upgrade Instructions*.
20211203	Section 1 ➤ Updated compliance information in *Specifications*.

Table A.3 Instruction Manual Revision History (Sheet 3 of 7)

Date Code	Summary of Revisions
20210406	Section 1 ➤ Added *Figure 1.2: SEL-587 Relay Front Panel With Front Serial Port*. ➤ Updated *Overcurrent Protection*. Section 2 ➤ Added *Figure 2.5: SEL-587 Relay With Front Serial Port Fitted With Mounting Bracket (SEL P/N 9100 for Mounting in 19-Inch Rack)*. ➤ Added *Figure 2.7: SEL-587 Relay Front Panel With Front Serial Port, Rack-Mount Version (Half-Rack Width)*. ➤ Added *Figure 2.9: SEL-587 Relay Front Panel With Front Serial Port, Panel-Mount Version*. ➤ Added *Figure 2.11: Rear Panel For SEL-587 With Front Serial Port (Conventional Terminal Blocks Option)*. ➤ Updated *EIA-232 Serial Communications Port Voltage Jumper (EIA-232 Option Only)*. ➤ Updated *Output Contact YOUT2 Control Jumper*. Section 3 ➤ Updated *Harmonic Restraint (HRSTR)*. ➤ Updated *Overcurrent Protection Overview*. Section 5 ➤ Updated to include **SET P 1** and **SET P F** serial port commands. Settings Sheets ➤ Added SET P F settings. Section 6 ➤ Updated *Serial Port Operation*. ➤ Added **SET P 1** and **SET P F** serial port commands. Appendix A ➤ Updated for firmware version R800.
20191107	Section 1 ➤ Updated *Specifications*.
20190809	Appendix H ➤ Added *Appendix H: PC Software*.
20151105	Section 1 ➤ Updated compliance information in *Specifications*.
20150126	Preface ➤ Added *Safety Information*. Section 1 ➤ Updated compliance information and tightening torque values in *Specifications*.
20120127	Section 6 ➤ Added **CALIBRATION** command.
20100813	Section 1 ➤ Updated *Relay Specifications*.
20090227	Section 2 ➤ Added terminal block information. Appendix A ➤ Updated for firmware version R704.
20071025	Section 1 ➤ Added 110 Vdc option to optoisolated inputs information in *Relay Specifications*.
20070927	Section 1 ➤ Added ACSELERATOR QuickSet® SEL-5030 Software information. Section 2 ➤ Added *Table 2.2: Jumper Designations*. ➤ Clarified jumper information.

Table A.3 Instruction Manual Revision History (Sheet 4 of 7)

Date Code	Summary of Revisions
	Section 5 ➤ Added ACSELERATOR QuickSet SEL-5030 Software information. Section 6 ➤ Added ACSELERATOR QuickSet SEL-5030 Software information. Section 7 ➤ Added ACSELERATOR QuickSet SEL-5030 Software information.
20061005	Appendix A ➤ Updated for firmware version R703. Appendix B ➤ Updated *Firmware Upgrade Instructions*.
20050725	Section 1 ➤ Changed the one-second thermal rating from 250 A to 500 A. Section 2 ➤ Updated *Figure 2.12: Output Contact OUT4 Control Jumper Location*. ➤ Updated *Table 2.2: Required Position of Jumper JMP13 for Desired Output Contact OUT4 Operation*. Section 4 ➤ Corrected *Figure 4.1: Trip Logic (TRP1)*. Section 7 ➤ Clarified *Event Report Triggering*. Appendix B ➤ Updated *Firmware Upgrade Instructions.*
20040129	Section 1 ➤ Updated *CT Saturation Protection*. Section 7 ➤ Updated *Event Report Summary*. Appendix A ➤ Updated for firmware version R702.
20021025	Section 1 ➤ Modified *Optoisolated Inputs* information in *General Specifications*. Section 2 ➤ Modified text in *Control Voltage Jumpers (Conventional Terminal Blocks Option Only)*.
20020828	Section 1 ➤ Added subsection *SELECT Saturation Protection or Cosine-peak Adaptive Filter*. ➤ Updated *Specifications*; added *Transient Overreach Specification*. Section 2 ➤ Inserted updated relay dimensions, panel cutout, and drill plan drawings. Section 3 ➤ Added CT Saturation information to CT sizing. Command Summary ➤ Removed phase angle information from the **METER** command. Section 7 ➤ Added phase magnitude information to *Event Report Summary*.

Table A.3 Instruction Manual Revision History (Sheet 5 of 7)

Date Code	Summary of Revisions
	Appendix A ➤ Changed the name of the appendix to *Firmware and Manual Versions*. ➤ Revised the firmware versions tables to include the corresponding instruction manual date code for firmware versions. ➤ Added *Table A.1*, *Table A.2*, and *Table A.3* to replace the Manual Change Information page previously included in the instruction manual. ➤ Updated for firmware version R701. Appendix B ➤ Changed *Firmware (EPROM) Upgrade Instructions* section and added reference to special service bulletin on upgrading from R600, R650, R502, and R552 firmware.
20010606	Section 4 ➤ Corrected *Figure 4.2: Close Logic Diagram*. Section 5 ➤ Updated serial port *Settings Sheets*. Section 6 ➤ Added references to Modbus® protocol. ➤ Added information about strong passwords. Section 8 ➤ Improved description of *Harmonic Blocking Function Test*. Appendix A ➤ Updated for firmware versions R502, R552, R600, and R650. Appendix E ➤ Included CHANNEL string in *CMETER PH Command*. Appendix I ➤ Added *Appendix I: Modbus® RTU Communications Protocol*.
20001110	Title Page ➤ Added cautions, warnings, and dangers in English and French to reverse of title page, including a warning to change default passwords to private passwords at relay installation. Section 1 ➤ Corrected power supply, processing, metering, and differential specifications. ➤ Added tightening torque and terminal connections specifications. Section 2 ➤ Added rack-mount and panel-mount discussion, rear-panel information, port connector and communication cables discussion, caution about replacing battery. ➤ Inserted updated relay dimensions, panel cutout, and drill plan drawings. Settings Sheets ➤ Clarified that the sheets apply to both the SEL-587-0 Relay and the SEL-587-1 Relay. Section 6 ➤ Removed port connector and communications cables discussion. ➤ Reorganized section to improve readability. ➤ Added serial port command details. ➤ Added a warning to change default passwords to private passwords at relay installation, and added notes. ➤ Added cautionary note about powering down the relay after setting the date and time. Section 7 ➤ Explained the **HIS** command. ➤ Explained the processing rate of the relay, quarter-cycle and eighth-cycle event reports. ➤ Explained the various options available with the **EVE** command. Section 8 ➤ Clarified *Differential Element Pickup Test*: 87U, 87R.

Table A.3 Instruction Manual Revision History (Sheet 6 of 7)

Date Code	Summary of Revisions
20000616	Section 3 ➤ Corrected *Figure 3.7: SEL-587-1 Differential Element (87BL1) Blocking Logic*. Section 6 ➤ Added descriptions of **DATE** and **TIME** commands. Appendix B ➤ Updated instructions. Appendix D ➤ Made corrections. Appendix E ➤ Inserted event description that had been inadvertently omitted.
20000505	Section 1 ➤ Updated *Specifications* subsection. Section 3 ➤ Reorganized section for consistency and to add 87U drawing, SEL-587-0 Differential Element (87BL1) Blocking Logic drawing, overcurrent logic drawings, and setting descriptions. Section 4 ➤ Fixed the *Close Logic Diagram* text, added *Output Contact Functions* subsection, modified *Relay Targets* subsection for target logic enhancements. Section 5 ➤ Removed *Current Transformer* subsection and extra MER setting from *Settings Sheet*. Section 8 ➤ Added clarifying information in Harmonic Blocking Function Test: PCT2, PCT4, and PCT5 Setting. Appendix A ➤ Updated for firmware versions R501, R505, R551, and R555.
991215	➤ Added SEL-587-1, reorganized manual, and reissued complete manual.
991115	Section 1 ➤ Made minor corrections throughout section. Section 2 ➤ Added *Figure 2.3* and renumbered following figures. ➤ Added sections *EIA-232 Serial Communications Port Voltage Jumper* and *Output Contact OUT4 Control Jumper*. ➤ Made minor corrections throughout section. Section 8 ➤ Added *Relay Self-Tests* section. Appendix B ➤ Inserted new *Appendix B: Firmware Upgrade Instructions*. ➤ Re-lettered appendices following Appendix B.
990715	➤ Added tabs to manual. Section 4 ➤ Combined 1 A and 5 A settings sheets.
990521	Section 2 ➤ Corrected output labels in *Figure 2.6*.
990423	Main Table of Contents ➤ Reissued.
990322	Section 1 ➤ Corrected printer symbol error. ➤ Replaced 0 (zero) with degree sign.

Table A.3 Instruction Manual Revision History (Sheet 7 of 7)

Date Code	Summary of Revisions
981019	Section 2 ➤ Updated drill plans and rear-panel drawings. ➤ Added information regarding part numbers. Section 4 ➤ Made clarifications.
980626	Section 1 ➤ Removed note to show availability of 250 V "Level-Sensitive" inputs. ➤ Changed 250 Vdc dropout from 200 to 150 Vdc. Section 2 ➤ Added "10 A for L/R = 20 ms at 250 Vdc." ➤ Removed note to show availability of 250 V "Level-Sensitive" inputs.
970725	Section 1 ➤ Reformatted extensively for clarification. ➤ Added the following to *Type Tests and Standards*: IEC 68-2-1-1990, IEC 68-2-2-1974, IEC 255-11-1979, IEC 255-22-2-1996, IEC 255-22-3-1989, IEC 255-22-4-1992, IEC 695-2-2-1991, UL 508 Listing ➤ Added 24-volt power supply ratings to *Output Contacts, Optoisolated Input Ratings, and Power Supply Ratings*. Section 3 ➤ Added/clarified constraints for settings 087P, U87P, and TH5 in *Table 3.1*. Section 4 ➤ Added/clarified constraints for settings 087P, U87P, and TH5. ➤ Deleted incorrect instruction.
970611	➤ Added *EC Declaration of Conformity* as addendum. Section 1 ➤ Made general corrections, clarification and consistency edits.
970528	Section 1 ➤ Corrected CT 1 second rating in *AC Input Currents* in *General Specifications*. Appendix A ➤ Corrected event type indication to include TRP1 when TRP1 asserts during an event, but does not trigger the event.
970414	➤ Removed *Instruction Manual Change Record* from Instruction Manual. ➤ Inserted *Manual Change Information* document in Instruction Manual before *Table of Contents*. Section 2 ➤ Clarified *Passcode and Breaker Control Command Jumpers*. Section 8 ➤ Revised steps to adjust LCD contract in *Troubleshooting Procedure*.

Information about changes to earlier versions of the SEL-587 Instruction Manual is not available.

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Appendix B
Firmware Upgrade Instructions

IMPORTANT: The firmware upgrade procedure may result in lost relay settings due to the addition of new features and changes in the way memory is used. It is imperative to have a copy of the original relay settings available in case they need to be re-entered. Carefully follow these upgrade instructions to minimize the chance of inadvertently losing relay settings.

NOTE: The hardware of SEL-587 relays that shipped with firmware version R704 and earlier differs from the hardware of SEL-587 relays that have shipped with firmware version R800 and later. Relays with firmware version R704 and earlier cannot be upgraded to firmware version R800 or later.

The SEL-587 includes two firmware configurations:

- EPROM
- Flash

EPROM and flash firmware may not be interchanged on a relay. To determine the type of firmware in your relay, display the firmware version by pressing the relay front-panel **STATUS** pushbutton or by using the serial port **STATUS** command. The relay displays the FID firmware version string as follows:

`FID=SEL-587-1-Rxxx-Vxb-Dxxxxxx` (for versions prior to April 6, 2001)

`FID=SEL-587-1-Rxxx-Vxb-Z001001-Dxxxxxxxx` (SEL-587-1 for firmware after April 6, 2001)

`FID=SEL-587-0-Rxxx-Vxb-Z001001-Dxxxxxxxx` (SEL-587-0 for firmware after April 6, 2001)

The SEL-587 relays with firmware versions R704 and earlier are EPROM-based firmware revisions.

EPROM Firmware Upgrades

Contact SEL for assistance with EPROM firmware upgrades.

Flash Firmware Upgrades

Required Equipment

The following equipment is required for performing flash firmware upgrades:

- Personal computer
- Terminal emulation software that supports XMODEM/CRC protocol
- Serial communications cable (SEL-234A or equivalent)
- Firmware upgrade file

Upgrade Procedure

NOTE: The hardware of SEL-587 relays that shipped with firmware version R704 and earlier differs from the hardware of SEL-587 relays that have shipped with firmware version R800 and later. Relays with firmware version R704 and earlier cannot be upgraded to firmware version R800 or later.

These instructions assume you have a working knowledge of your personal computer terminal emulation software. In particular, you must be able to modify your serial communications parameters (baud rate, data bits, parity, etc.), disable any hardware or software flow control in your computer terminal emulation software, select transfer protocol (i.e., XMODEM/CRC), and transfer files (e.g., send and receive binary files).

NOTE: If the SEL-587 contains History (HIS) data, Event (EVE) data, or Metering (MET) data that you want to retain, retrieve them prior to performing the firmware upgrade, because all these data may be erased in the upgrade procedure.

NOTE: If upgrading from firmware version R800 to a later release, issue a **HIS C** command prior to the firmware upgrade process. The **HIS C** command clears all event records from the relay. Gather any event record data prior to issuing the **HIS C** command.

NOTE: SELBOOT does not echo non-alphabetic characters as the first character of a line. This may make it appear that the relay is not functioning properly when just the **<Enter>** key is pressed on the connected PC, even though everything is okay.

NOTE: If relay power fails while receiving new firmware, and the old firmware has been erased, the relay will restart in SELBOOT with the default baud rate of 2400 baud. (If this happens, connect to the relay at 2400 baud and type **BAUD 38400 <Enter>** at the SELBOOT prompt. The firmware receive can be started again at *Step 14*.)

NOTE: The relay will display one or more "C" characters as it waits for your PC terminal emulation program to send the new firmware. If you do not start the transfer quickly enough (within about 18 seconds), it may time out and respond with `Remote system not responding`. If this happens, begin again in *Step 14*.

NOTE: The file transfer takes approximately 3 minutes at 38,400 baud when you use the 1k-XMODEM protocol.

Perform the following to upgrade your flash-based firmware:

Step 1. If the relay is in service, disable its control functions.

Step 2. Connect the personal computer to the relay serial port and enter Access Level 2 by issuing the **ACC** and **2AC** commands.

Step 3. Issue the Show Calibration (**SHO C**) command to retrieve the relay calibration settings.

Step 4. Record the displayed settings (or save them to a computer file) for possible reentry after the firmware upgrade.

Step 5. If you do not already have copies of the Global, Group, Logic, Port, SER, and Text label settings, use the following Show commands to retrieve them: **SHO**, **SHO L**, **SHO P**, **SHO R**, and **SHO T**.

Normally, the relay preserves settings during the firmware upgrade. However, depending on the firmware version previously installed and the use of relay memory, this cannot be ensured. Saving settings is always recommended.

Step 6. If upgrading from firmware version R800, issue the **HIS C** command after all events have been collected. Otherwise, proceed to *Step 7*.

Step 7. Configure your communication connection to use the highest possible baud rate. The relay supports speeds as high as 38,400 baud.

Step 8. Use the **SET P** command to change the SPEED setting to the desired baud rate.

Step 9. From Access Level 2, issue the **L_D** command to the relay to start the SELBOOT program.

Step 10. Type **Y <Enter>** at the `Disable relay to send or receive firmware (Y/N)?` prompt and **Y <Enter>** to the `Are you sure (Y/N)?` prompt. The relay will send the SELBOOT prompt (!>).

Step 11. Make a copy of the firmware currently in the relay in case the new firmware download is unsuccessful. To make a backup of the firmware, you need approximately 500 KB of free disk space. The procedure takes approximately 3 minutes at 38,400 baud.

Step 12. Issue the Send (**SEN**) command to the relay to initiate the firmware transfer from the relay to your computer. You will not see any activity on the PC screen because the relay waits for the PC to request the first XMODEM data packet.

Step 13. Select the Receive File function with the XMODEM protocol in your terminal emulation software.

Step 14. Give the file a unique name to clearly identify the firmware version (e.g., 551_R500.S19). After the transfer, the relay will respond as follows:

```
Download completed successfully
```

Step 15. Begin the transfer of the new firmware to the relay by issuing the Receive (**REC**) command to instruct the relay to receive new firmware.

Step 16. The relay will ask if you are sure you want to erase the existing firmware.

Type **Y** to erase the existing firmware and load new firmware, or press **Enter** to abort.

Step 17. The relay then prompts you to press a key and begin the transfer. Press a key (e.g., **<Enter>**).

Step 18. Start the file transfer by selecting the Send File function in your terminal emulation software. Use the XMODEM or 1k-XMODEM (fastest) protocol and send the file that contains the new firmware (e.g., Relay.S19). After the transfer completes, the relay will restart and return to Access Level 0. *Figure B.1* shows the entire process.

```
=>>L_D <Enter>
Disable the relay to send or receive firmware (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
Relay Disabled
!>SEN <Enter>
Download completed successfully!

!>REC <Enter>
Caution! - This command erases the relay's firmware.
If you erase the firmware, new firmware must be loaded into the relay
before it can be put back into service.

Are you sure you wish to erase the existing firmware? (Y/N) Y <Enter>
Erasing
Erase Successful
Press any key to begin transfer, then start transfer at the PC <Enter>

Upload completed successfully. Attempting a restart.
```

Figure B.1 Flash-Based Firmware Upgrade Process

Step 19. The relay illuminates the **EN** front-panel LED if the original relay settings were retained through the download.

Step 20. If the **EN** LED is illuminated, proceed to *Step 22*; otherwise, the relay may display various self-test failures because of changes in the way memory is used.

Step 21. If the **EN** LED is extinguished, the relay baud rate has changed back to the factory default of 2400 baud. Perform the following:

a. Set your communications software settings to 2400 baud, 8 data bits, 1 stop bit.

b. Enter Access Level 2 by issuing the **ACC** and **2AC** commands (the factory-default passwords will be in effect).

c. Issue the Restore Settings (**R_S**) command to restore the factory-default settings in the relay. This takes about two minutes, after which the **EN** LED will illuminate.

d. Enter Access Level 2 by issuing the **ACC** and **2AC** commands (the factory-default passwords will be in effect).

e. Restore the original settings as necessary with each of the following commands: **SET**, **SET L**, **SET P**, **SET R**, and **SET T**.

f. Set the relay passwords via the **PAS** command. Passwords are case-sensitive, so the lower- and uppercase letters are treated differently.

g. If there are still any FAIL codes on the relay LCD, refer to *Section 8: Testing and Troubleshooting*.

Step 22. Verify the Calibration settings by issuing the **SHO C** command.

Step 23. If the settings do not match the settings recorded in *Step 4*, re-issue the settings with the **SET C** command.

Step 24. Issue the Status (**STA**) command to verify that all relay self-test parameters are within tolerance and the relay is enabled.

Step 25. Apply current signals to the relay.

Step 26. Issue the **MET** command.

Step 27. Verify that the current and voltage signals are correct.

Step 28. Issue the Trigger (**TRI**) and Event (**EVE**) commands.

Step 29. Verify that the current and voltage signals are correct in the event report.

The relay is now ready for your commissioning procedure.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
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Appendix C

SEL Distributed Port Switch Protocol

Overview

SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. It is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement.

Settings

Use the front-panel **SET** pushbutton or the serial port **SET P *n*** (*n* = 1, F) command to activate the LMD protocol. Change the port PROTOCOL setting from the default SEL to LMD to reveal the following settings:

Setting	Description
PREFIX:	One character to precede the address. This should be a character that does not occur in the course of other communications with the relay. Valid choices are one of the following: "@" "#" "$" "%" "&." The default is "@."
ADDRESS:	Two character ASCII address. The range is "01" to "99." The default is "01."
SETTLE TIME:	Time in seconds that transmission is delayed after the request to send (RTS line) asserts. This delay accommodates transmitters with a slow rise time.

Operation

NOTE: You can use the front-panel **SET** pushbutton to change the port settings to return to SEL protocol.

1. The relay ignores all input from this port until it detects the prefix character and the two-byte address.
2. Upon receipt of the prefix and address, the relay enables echo and message transmission.
3. Wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is warming up.
4. Until the relay connection terminates, you can use the standard commands that are available when PROTOCOL is set to SEL.

5. The **QUIT** command terminates the connection. If no data are sent to the relay before the port time-out period, it automatically terminates the connection.
6. Enter the sequence **<Ctrl+X> QUIT <CR>** before entering the prefix character, if all relays in the multidrop network do not have the same prefix setting.

Appendix D
Configuration, Fast Meter, and Fast Operate Commands

Overview

SEL relays have two separate data streams that share the same serial port. The human data communications with the relay consist of ASCII character commands and reports that are intelligible to humans using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) 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. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

SEL Application Guide *AG95-10, Configuration and Fast Meter Messages*, is a comprehensive description of the SEL binary messages. Below is a description of the messages provided in the SEL-587.

Message Lists

Table D.1 Binary Message List (Sheet 1 of 2)

Request to Relay (hex)	Response from Relay
A5C0	Relay Definition Block
A5C1	Fast Meter Configuration Block
A5D1	Fast Meter Data Block
A5C2	Demand Fast Meter Configuration Messages
A5D2	Demand Fast Meter Data Message
A5C3	Peak Demand Fast Meter Configuration Messages
A5D3	Peak Demand Fast Meter Message
A5CE	Fast Operate Configuration Block
A5E0	Fast Operate Remote Bit Control
A5E3	Fast Operate Breaker Control
A5B2	Oldest Unacknowledged Event Report Packet
A5B5	Acknowledge Event Report Most Recently Sent

Table D.1 Binary Message List (Sheet 2 of 2)

Request to Relay (hex)	Response from Relay
A5B9	Status Flag Byte and Clear Status Bits Command
A560	Most Recent Event Report
A561–A56A	Older Event Reports

Table D.2 ASCII Configuration List

Request to Relay (ASCII)	Response From Relay
ID	ASCII Firmware ID String and Terminal ID String
ENA	ASCII Names of Short Event Packet Data
DNA	ASCII Names of Relay Word bits
BNA	ASCII Names of status bits

Message Definitions

A5C0 Relay Definition Block

Table D.3 A5C0 Relay Definition Block (Sheet 1 of 2)

Data	Description
A5C0	Command
4A	Length
03	Support three protocols, SEL, LMD, and MOD
03	Support three Fast Meter messages (SEL-587-0 support two protects: SEL + LMD)
06	Six status flag commands
A5C1	Fast Meter configuration command
A5D1	Fast Meter command
A5C2	Demand Fast Meter configuration command
A5D2	Demand Fast Meter command
A5C3	Peak Demand Fast Meter configuration command
A5D3	Peak Demand Fast Meter command
0001	Event triggered flag bit
A5B200000000	Oldest unacknowledged short event report (hex)
0002	Self-test warning bit
5354410D0000	Check status (ASCII characters, <CR>, binary zeros) (STA <CR>)
0003	Self-test failure bit
5354410D0000	Check status (ASCII characters, <CR>, binary zeros) (STA <CR>)
0004	Settings change bit
A5C1000000	Reconfigure Fast Meter on settings change (hex)
0004	Setting change bit
53484F0D0000	Check settings (ASCII characters, <CR>, binary zeros) (SHO <CR>)
0004	Setting change bit
53484F204C0D	Check logic settings (ASCII characters, <CR>) (SHO L <CR>)
0100	SEL protocol, Fast Operate

Table D.3 A5C0 Relay Definition Block (Sheet 2 of 2)

Data	Description
0101	LMD protocol, Fast Operate
0002	MOD protocol
00	Reserved for future use
checksum	Checksum (1 byte)

A5C1 Fast Meter Configuration Block

Table D.4 A5C1 Fast Meter Configuration Block (Sheet 1 of 2)

Data	Description
A5C1	Fast Meter command
48	Length
01	One status flag byte
00	Scale factors in Fast Meter message
02	Two scale factors
04	Four analog input channels
04	Four samples per channel
11	Seventeen digital banks
01	One calculation block
000C	Analog channel offset
002C	Time stamp offset
0034	Digital offset
494100000000	Analog channel name (IA)
00	Analog channel type (integer)
01	Scale factor type (float)
0004	Scale factor offset in A5D1 message
494200000000	Analog channel name (IB)
00	Analog channel type (integer)
01	Scale factor type (float)
0004	Scale factor offset in A5D1 message
494300000000	Analog channel name (IC)
00	Analog channel type (integer)
01	Scale factor type (float)
0004	Scale factor offset in A5D1 message
494E00000000	Analog channel name (IN)
00	Analog channel type (integer)
01	Scale factor type (float)
0008	Scale factor offset in A5D1 message
1-byte	Line configuration: 00 - ABC, 01 - ACB; based on PHROT relay setting
03	Calculation type (currents only)
FFFF	Skew correction offset (none)
FFFF	Rs scale factor offset (none)
FFFF	Xs scale factor offset (none)

Table D.4 A5C1 Fast Meter Configuration Block (Sheet 2 of 2)

Data	Description
00	IA channel index
01	IB channel index
02	IC channel index
FF	VA channel index (none)
FF	VB channel index (none)
FF	VC channel index (none)
00	Reserved
checksum	1-byte checksum of all preceding bytes

Table D.5 A5C1 Fast Meter Configuration Block (Sheet 1 of 2)

Data	Description
A5C1	Fast Meter command
6A	Length
01	One status flag byte
00	Scale factors in Fast Meter message
02	Two scale factors
06	Six analog input channels
04	Four samples per channel
0D	Thirteen digital banks
02	Two calculation blocks
000C	Analog channel offset
003C	Time stamp offset
0044	Digital offset
494157310000	Analog channel name (IAW1)
00	Analog channel type (Integer)
01	Scale factor type (Float)
0004	First scale factor offset in Fast Meter message
494257310000	Analog channel name (IBW1)
00	
01	
0004	
494357310000	Analog channel name (ICW1)
00	
01	
0004	
494157320000	Analog channel name (IAW2)
00	
01	
0008	Second scale factor offset in Fast Meter message
494257320000	Analog channel name (IBW2)
00	

Table D.5 A5C1 Fast Meter Configuration Block (Sheet 2 of 2)

Data	Description
01	
0008	
494357320000	Analog channel name (ICW2)
00	
01	
0008	
Connection Information	Based on CTCON and PHROT settings (1 byte)
03	Currents only
FFFF	No skew adjustment
FFFF	
FFFF	No compensation
00	Channel index IAW1
01	IBW1
02	ICW1
FF	
FF	
FF	
Connection Information	Based on CTCON and PHROT settings (1 byte)
03	Currents only
FFFF	No skew adjustment
FFFF	
FFFF	No compensation
03	Channel index IAW2
04	IBW2
05	ICW2
FF	
FF	
FF	
00	Reserved for future use
checksum	Checksum (1 byte)

A5D1 Fast Meter Data Block

Table D.6 A5D1 Fast Meter Data Block (Sheet 1 of 2)

Data	Description
2 bytes	Command codes A5D1 (hex), outside the range of normal ASCII printable characters.
1 byte	Message length, 53 (hex)
1 byte	One status byte
4 bytes	Winding one scale factor (4-byte IEEE FPS)
4 bytes	Winding two scale factor (4-byte IEEE FPS)

Table D.6 A5D1 Fast Meter Data Block (Sheet 2 of 2)

Data	Description
48 bytes	The first and third half-cycles of two cycles of data saved by the relay. The data are presented in quarter-cycle sets of integer data in the following order: IAW1, IBW1, ICW1, IAW2, IBW2, ICW2.
8 bytes	Time stamp
13 bytes	13 digital banks, TAR0–TAR12
1 byte	Reserved for future use
1 byte	Checksum calculated by addition of all the above bytes
83 bytes	Total message length

A5C2 Demand Fast Meter Configuration Messages

Table D.7 A5C2 Demand Fast Meter Configuration Messages (Sheet 1 of 2)

Data	Description
A5C2	Demand Fast Meter command
76	Length
00	Zero status flag bytes
00	Scale factors in Fast Meter message
00	Zero scale factors
0A	Ten analog input channels
01	One sample per channel
00	Zero digital banks
00	Zero calculation blocks
0004	Analog channel offset
FFFF	No time stamp
FFFF	No digital data
494157310000	Analog channel name (IAW1)
02	Analog channel type (Double precision float)
FF	Scale factor type (No scale factor)
0000	Scale factor offset in Fast Meter message
494257310000	Analog channel name (IBW1)
02	
FF	
0000	
494357310000	Analog channel name (ICW1)
02	
FF	
0000	
334932573100	Analog channel name (3I2W1)
02	
FF	
0000	
495257310000	Analog channel name (IRW1)
02	

Table D.7 A5C2 Demand Fast Meter Configuration Messages (Sheet 2 of 2)

Data	Description
FF	
0000	
494157320000	Analog channel name (IAW2)
02	
FF	
0000	
494257320000	Analog channel name (IBW2)
02	
FF	
0000	
494357320000	Analog channel name (ICW2)
02	
FF	
0000	
334932573200	Analog channel name (3I2W2)
02	
FF	
0000	
495257320000	Analog channel name (IRW2)
02	
FF	
0000	
00	Reserved for future use
checksum	Checksum (1 byte)

A5D2 Demand Fast Meter Message

Table D.8 A5D2 Demand Fast Meter Message

Data	Description
2 bytes	Command codes A5D2 (hex), outside the range of normal ASCII printable characters
1 byte	Message length, 56 (hex)
1 byte	Reserved for future use
80 bytes	Demand meter values as calculated and saved by the relay. The data are presented in double precision floating point format in the following order: IAW1, IBW1, ICW1, 3I2W1, IRW1, IAW2, IBW2, ICW2, 3I2W2, IRW2.
1 byte	Reserved for future use
1 byte	Checksum calculated by addition of all the above bytes
86 bytes	Total message length

A5C3 Peak Demand Fast Meter Configuration Messages

Table D.9 A5C3 Peak Demand Fast Meter Configuration Message (Sheet 1 of 2)

Data	Description
A5C3	Peak demand Fast Meter command
76 (HEX)	Length
00	Zero status flag bytes
00	Scale factors in Fast Meter message
0A	Ten scale factors
0A	Ten analog input channels
01	One sample per channel
00	Zero digital banks
00	Zero calculation blocks
0004	Analog channel offset
FFFF	No message time stamp
FFFF	No digital data
494157310000	Analog channel name (IAW1)
02	Analog channel type (double precision float)
03	Scale factor type (time stamp)
0054	Scale factor offset in Fast Meter message
494257310000	Analog channel name (IBW1)
02	
03	
005C	
494357310000	Analog channel name (ICW1)
02	
03	
0064	
334932573100	Analog channel name (3I2W1)
02	
03	
006C	
495257310000	Analog channel name (IRW1)
02	
03	
0074	
494157320000	Analog channel name (IAW2)
02	
03	
007C	
494257320000	Analog channel name (IBW2)
02	
03	
0084	

Table D.9 A5C3 Peak Demand Fast Meter Configuration Message (Sheet 2 of 2)

Data	Description
494357320000	Analog channel name (ICW2)
02	
03	
008C	
334932573200	Analog channel name (3I2W2)
02	
03	
0094	
495257320000	Analog channel name (IRW2)
02	
03	
009C	
00	Reserved for future use
checksum	Checksum (1 byte)

A5D3 Peak Demand Fast Meter Message

Table D.10 A5D3 Peak Demand Fast Meter Message

Data	Description
2 bytes	Command codes A5D3 (hex), outside the range of normal ASCII printable characters
1 byte	Message length, A6 (hex)
1 byte	Reserved for future use
80 bytes	Peak demand meter values as calculated, time tagged, and saved by the relay. The data are presented in double precision floating point format in the following order: IAW1, IBW1, ICW1, 3I2W1, IRW1, IAW2, IBW2, ICW2, 3I2W2, IRW2.
80 bytes	Peak demand meter value time tags as saved by the relay. The data are presented in 8-byte time stamp format, (byte each for month, day, last 2 digits of year, hour, min, sec, msec (word)), in the following order: IAW1, IBW1, ICW1, 3I2W1, IRW1, IAW2, IBW2, ICW2, 3I2W2, IRW2.
1 byte	Reserved for future use
1 byte	Checksum calculated by addition of all the above bytes
166 bytes	Total message length

A5CE Fast Operate Configuration Block

Table D.11 A5CE Fast Operate Configuration Block (Sheet 1 of 2)

Data	Description
A5CE	Command
1A	Length
02	Support two circuit breakers
0004	Support four remote bit
01	Flags: Remote bit supported
00	Reserved for future use
31	Operate code, open breaker 1

Table D.11 A5CE Fast Operate Configuration Block (Sheet 2 of 2)

Data	Description
11	Operate code, close breaker 1
32	Operate code, open breaker 2
12	Operate code, close breaker 2
00	Operate code, clear remote bit RB1
20	Operate code, set remote bit RB1
40	Operate code, pulse remote bit RB1
01	Operate code, clear remote bit RB2
21	Operate code, set remote bit RB2
41	Operate code, pulse remote bit RB2
02	Operate code, clear remote bit RB3
22	Operate code, set remote bit RB3
42	Operate code, pulse remote bit RB3
03	Operate code, clear remote bit RB4
23	Operate code, set remote bit RB4
43	Operate code, pulse remote bit RB4
00	Reserved
checksum	Checksum (1 byte)

A5E0 Fast Operate Remote Bit Control

The external device sends the following message to perform a remote bit operation.

Table D.12 A5E0 Fast Operate Remote Bit Control

Data	Description
A5E0	Command
06	Message length
1-byte	Operate code:
	00–03 clear remote bit RB1–RB4
	20–23 set remote bit RB1–RB4
	40–43 pulse remote bit for RB1–RB4
1-byte	Operate validation: 4 • Operate code + 1
checksum	1-byte checksum of preceding bytes

The relay performs the specified remote bit operation if the following conditions are true:

- The Operate code is valid
- The Operate validation = 4 • Operate code + 1
- The message checksum is valid
- The FAST_OP port setting is set to Y
- The relay is enabled

Remote bit set and clear operations are latched by the relay. Remote bit pulse operations assert the remote bit for one processing interval (1/8 cycle).

A5E3 Fast Operate Breaker Control

The external device sends the following message to perform a fast breaker open/close.

Table D.13 A5E3 Fast Operate Breaker Control

Data	Description
A5E3	Command
06	Message length
1-byte	Operate code: 31—OPEN breaker 1 32—OPEN breaker 2 11—CLOSE breaker 1 12—CLOSE breaker 2
1-byte	Operate Validation: 4 • Operate code + 1
checksum	1-byte checksum of preceding bytes

The relay performs the specified breaker operation if the following conditions are true:

- Conditions 1–5 defined in the A5E0 message are true
- The **BREAKER** jumper is in place on the SEL-587 main board
- The TDURD setting is non-zero

A5B2 Oldest Unacknowledged Event Report Packet

Table D.14 A5B2 Oldest Unacknowledged Event Report Packet

Data	Description
2 bytes	Command codes A5B2 (hex), outside the range of normal ASCII printable characters
1 byte	Message length, 42 (hex)
1 byte	Active group at time of event report trigger, 0 for SEL-587
8 bytes	Time; byte each for month, day, last two digits of year, hour, min, sec, msec (word)
8 bytes	EVENT as defined below: TRP*n* — *n* = 1, 2, 3, 12, 13, 23, 123 1 = TRP1 tripping element 2 = TRP2 tripping element 3 = TRP3 tripping element MER — Element assertion in the MER equation assertion PULSE — **PULSE** command execution TRIG — **TRIGGER** command execution
4 byte	Duration as defined in EVE, in floating point format
40 bytes	Current magnitudes for the event trigger point in floating point format in the following order: IAW1, IBW1, ICW1, 3I2W1, IRW1, IAW2, IBW2, ICW2, 3I2W2, IRW2
1 byte	Reserved for future use
1 byte	Checksum calculated by addition of all the above bytes
66 bytes	Total message length

A5B5 Acknowledge Event Report Most Recently Sent

Typically, an external device sends A5B5 to acknowledge the A5B2 message.

A5B9 Status Flag Byte and Clear Status Bits Command

The status byte for the SEL-587 includes the following.

Bit	Usage	
0	Turn On	Set when the relay turns on, cleared by status acknowledge message.
1	Event Trigger	Set if triggering event report, cleared by acknowledging all events.
2	Self-Test Warning	Set if self-test warning, clear if all diagnostics pass.
3	Self-Test Failure	Set if self-test failure, clear if all diagnostics pass.
4	Setting Changes	Set if settings changed, cleared by the status acknowledge message.

A560 Most Recent Event Report

Send A560 for the most recent event.

A561–A56A Older Event Reports

Send A561 for the previous event report up to the oldest possible event report or A56A, whichever is less.

ID Message

In response to the **ID** command, the relay sends the firmware ID, Relay TID setting, and the Modbus device code as described below.

```
<STX>
"FID=FID string","yyyy"
"CID=XXXX","yyyy"
"DEVID=TID setting","yyyy"
"DEVCODE=28","yyyy"
"PARTNO=058710025000","yyyy"
"CONFIG=111000","yyyy"
```

where:

yyyy = the 4-byte ASCII hex representation of the checksum for the message

FID = the FID string

CID = the checksum of the ROM code

DEVID = the terminal ID as set by the TID setting

DEVCODE = the Modbus® device code (28)

PARTNO = the part number

CONFIG = The first digit from the left is a 1 when NFREQ = 60 Hz and a 2 when NFREQ = 50 Hz. The second digit from the left is a 1 when PHROT = ABC and a 2 when PHROT = ACB. The third digit from the left is a 1 when the nominal current is 5 A and is a 2 when the nominal current is 1 A. The remaining three digits are always 0 for the SEL-587.

ENA Message

In response to the **ENA** command, the relay sends short event report data names.

```
<STX>"GROUP","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0CC7"<CR>
"EVENT","DUR","IAW1","IBW1,"ICW1","3I2W1","IRW1","IAW2","IBW2,
"ICW2","3I2W2","IRW2","12D6"<CR>
<ETX>
```

DNA Message

In response to the **DNA** command, the relay sends names of the Relay Word bits transmitted in the A5D1 message.

```
<STX> "EN", "87", "50", "51", "A", "B", "C", "N", "0661"
"51P1P", "51Q1P", "51N1P", "51P1T", "51Q1T", "51N1T", "*", "RB1", "0BC3"
"50P1P", "50Q1P", "50N1P", "50P1T", "50Q1T", "50N1T", "50P1H", "50N1H", "0D28"
"51P2P", "51Q2P", "51N2P", "51P2T", "51Q2T", "51N2T", "*", "RB2", "0BCA"
"50P2P", "50Q2P", "50N2P", "50P2T", "50Q2T", "50N2T", "50P2H", "50N2H", "0D30"
"87U1", "87U2", "87U3", "87U", "87R1", "87R2", "87R3", "87R", "0AC0"
"2HB1", "2HB2", "2HB3", "5HB1", "5HB2", "5HB3", "87BL", "RB3", "0AE1"
"TH5P", "TH5T", "PDEM", "NDEM", "QDEM", "TRP1", "TRP2", "TRP3", "0CAF"
"OC1", "OC2", "CC1", "CC2", "IN1", "IN2", "52A1", "52A2", "09BA"
"MTU3", "MTU2", "MTU1", "MER", "YT", "Y", "XT", "X", "09E6"
"51P1R", "51Q1R", "51N1R", "51P2R", "51Q2R", "51N2R", "*", "RB4", "0BC9"
"*", "*", "*", "ALARM", "OUT1", "OUT2", "OUT3", "OUT4", "0A15"
"*", "*", "*", "*", "*", "*", "*", "*", "04D0" <ETX>
```

The last field in each line is the four-byte ASCII representation of the checksum for the line. "*" indicates an unused bit location.

BNA Message

In response to the **BNA** command, the relay sends names of the bits transmitted in the status byte in the A5D1 message.

```
<STX>"*","*","*","STSET","STFAIL","STWARN","STEVE","STPWR","0C5A"<CR>
<ETX>
```

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Appendix E
Compressed ASCII Commands

Introduction

The SEL-587 provides Compressed ASCII versions of some of the relay ASCII commands. The Compressed ASCII commands allow an external device to obtain data from the relay, in a format which directly imports into spreadsheet or database programs, and which can be validated with a checksum.

The SEL-587 provides the following Compressed ASCII commands:

Table E.1 Compressed ASCII Commands

Command	Description
CASCII	Configuration message
CMETER	Meter message
CMETER D	Demand meter message
CMETER P	Peak demand meter message
CMETER DIF	Differential meter message
CMETER PH	Peak harmonic meter message
CSTATUS	Status message
CHISTORY	History message
CTARGET	Target message
CEVENT	Event message

CASCII Command—General Format

The Compressed ASCII configuration message provides data for an external computer to extract data from other Compressed ASCII commands. To obtain the configuration message for the Compressed ASCII commands available in an SEL relay, type:

CAS <CR>

The relay sends:

```
<STX> "CAS",n,"yyyy" <CR>
"COMMAND 1",ll,"yyyy" <CR>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy" <CR>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy" <CR>
"COMMAND 2",ll,"yyyy" <CR>
"#h","ddd","ddd",......,"ddd","yyyy" <CR>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy" <CR>
.
.
.
.
.
"COMMAND n",ll,"yyyy" <CR>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy" <CR>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy" <CR><ETX>
```

where:

n	is the number of Compressed ASCII command descriptions to follow.
COMMAND	is the ASCII name for the Compressed ASCII command as sent by the requesting device. The naming convention for the Compressed ASCII commands is a C preceding the typical command. For example, **CSTATUS** (abbreviated to **CST**) is the compressed **STATUS** command.
ll	is the minimum access level at which the command is available.
#H	identifies a header line to precede one or more data lines; # is the number of subsequent ASCII names. For example, 21H identifies a header line with 21 ASCII labels.
#h	identifies a header line to precede one or more data lines; # is the number of subsequent format fields. For example, 8h identifies a header line with 8 format fields.
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; # is the maximum number of subsequent data lines.
ddd	identifies a format field containing one of the following type designators: I = Integer data F = Floating point data mS = String of maximum m characters (e.g., 10S for a 10-character string
yyyy	is the 4-byte hex ASCII representation of the checksum.

A Compressed ASCII command may require multiple header and data configuration lines.

If a Compressed ASCII request is made for data that are not available, (e.g., the history buffer is empty or invalid event request), the relay responds with the following message:

```
<STX>"No Data Available","0668"<CR><ETX>
```

CASCII Command

Display the Compressed ASCII configuration message in Compressed ASCII format by sending:

CAS <CR>

The relay sends:

```
<STX>"CAS",9,"01AC"<CR>
"CME",1,"01A2"<CR>
"17H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IAW1","IBW1","ICW1",
"IAW2","IBW2","ICW2","3I2W1","IRW1","3I2W2","IRW2","1B73"<CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I","0D2E"<CR>
"CME D",1,"0206"<CR>
"17H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IAW1","IBW1","ICW1",
"IAW2", "IBW2","ICW2","3I2W1","IRW1","3I2W2","IRW2","1B73"<CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I","0D2E"<CR>
"CME P",1,"0212"<CR>
"07H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BE9"<CR>
"1D","I","I","I","I","I","I","I","05F4"<CR>
"09H","CHANNEL","MAG","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0F99"<CR>
"10D","8S","I","I","I","I","I","I","I","I","07D8"<CR>
"CME DIF",1,"0295"<CR>
"19H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IOP1","IOP2","IOP3",
"IRT1","IRT2","IRT3","I1F2","I2F2","I3F2","I1F5","I2F5","I3F5","1D98"<CR>
"1D","I","I","I","I","I","I","I","F","F","F","F","F","F","F","F","F","F","F","F",
     "0E7C"<CR>
"CME PH",1,"025A"<CR>
"07H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BE9"<CR>
"1D","I","I","I","I","I","I","I","05F4"<CR>
"09H","CURRENT","MAG","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0FC3"<CR>
"06D","8S","F","I","I","I","I","I","I","I","07DA"<CR>
"CST",1,"01B7"<CR>
"26H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IAW1","IBW1","ICW1",
"IAW2","IBW2","ICW2","MOF","+5V_PS","+5V_REG","-5V_REG","+10V_PS",
"-10V_PS","VBAT","TEMP","RAM","ROM","CR_RAM","EEPROM","FLASH","2E36"<CR>
"1D","I","I","I","I","I","I","I","6S","6S","6S","6S","6S","6S","6S","6S","6S","6S",
     "6S","6S","6S","6S","6S","6S",",6S","6S","6S","189B"<CR>
"CHI",1,"01A1"<CR>
"10H","REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","EVENT",
"TARGETS","12F8"<CR>
"20D","I","I","I","I","I","I","I","I","6S","18S","0903"<CR>
"CTA",1,"01A5"<CR>
"08h","6S","6S","6S","6S","6S","6S","6S","6S","0908"<CR>
"1D","I","I","I","I","I","I","I","I","06AD"<CR>
"CEV",1,"01AB"<CR>
"07H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BE9"<CR>
"1D","I","I","I","I","I","I","I","05F4"<CR>
"11H","IRW1","IAW1","IBW1","ICW1","IRW2","IAW2","IBW2","ICW2","MID",
"RLY_BITS","OUT_IN","13F6"<CR>
"60D","F","F","F","F","F","F","F","F","1S","18S","5S","09E2"<CR>
"07H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BE9"<CR>
"1D","I","I","I","I","I","I","I","05F4"<CR>
"11H","IOP1","IOP2","IOP3","IRT1","IRT2","IRT3","IF2","IF5","MID","RLY_BITS",
"OUT_IN","1370"<CR>
"60D","F","F","F","F","F","F","F","F","1S","27S","5S","09E2"<CR>
"CEV L",1,"0217"<CR>
"07H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BE9"<CR>
"1D","I","I","I","I","I","I","I","05F4"<CR>
"11H","IRW1","IAW1","IBW1","ICW1","IRW2","IAW2","IBW2","ICW2","MID",
"RLY_BITS","OUT_IN","13F6"<CR>
"240D","F","F","F","F","F","F","F","F","1S","18S","5S","0A12"<CR>
"07H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BE9"<CR>
"1D","I","I","I","I","I","I","I","05F4"<CR>
"11H","IOP1","IOP2","IOP3","IRT1","IRT2","IRT3","IF2","IF5","MID","RLY_BITS",
"OUT_IN","1370"<CR>
"240D","F","F","F","F","F","F","F","F","1S","27S","5S","0A12"<CR>
<ETX>
```

where:

#H represents a header line to precede one or more data lines with # number of subsequent ASCII names

#h represents a header line to precede one or more data lines with # number of subsequent format fields

#D identifies a data format line; # is the maximum number of subsequent data lines.

Format fields are of the following types
- I = Integer data
- F = Floating point data
- mS = String of maximum m characters

A Compressed ASCII command may require multiple header and data configuration lines.

If a Compressed ASCII request is made for data that are not available, (e.g., the history buffer is empty or invalid event request), the relay responds with the following message:

```
<STX>"No Data Available","0668" <CR><ETX>
```

CMETER Command

Display meter data in Compressed ASCII format by sending:

CME <CR>

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IAW1","IBW1",
"ICW1","IAW2","IBW2","ICW2","3I2W1","IRW1","3I2W2","IRW2","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
xxxx,"yyyy" <CR><ETX>
```

where:

xxxx = the data values corresponding to the first line labels
yyyy = the 4-byte hex ASCII representation of the checksum

CMETER D Command

Display demand meter data in Compressed ASCII format by sending:

CME D <CR>

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IAW1","IBW1",
"ICW1","IAW2","IBW2","ICW2","3I2W1","IRW1","3I2W2","IRW2","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
xxxx,xxxx,xxxx,"yyyy" <CR><ETX>
```

where:

xxxx = the data values corresponding to the first line labels
yyyy = the 4-byte hex ASCII representation of the checksum of the message through the comma preceding the checksum

CMETER P Command

Display peak demand meter data in Compressed ASCII format by sending:

CME P <CR>

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy" <CR>
"CHANNEL","MAG","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC",
"yyyy" <CR>
"xxxx",xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy" <CR><ETX>
```

(the fourth line is then repeated for each current)

where:

xxxx = the data values corresponding to the first line labels

yyyy = the 4-byte hex ASCII representation of the checksum of the message through the comma preceding the checksum

CMETER DIF Command

Display differential meter data in Compressed ASCII format by sending:

CME DIF <CR>

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IOP1","IOP2",
"IOP3","IRT1","IRT2","IRT3","I1F2","I2F2","I3F2","I1F5","I2F5","I3F5","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
xxxx,xxxx,xxxx,"yyyy" <CR><ETX>
```

where:

xxxx = the data values corresponding to the first line labels

yyyy = the 4-byte hex ASCII representation of the checksum of the message through the comma preceding the checksum

CMETER PH Command

Display peak harmonic meter data in Compressed ASCII format by sending:

CME PH <CR>

The relay sends:

```
<STX>"MONTH","DAY","YEAR"
"HOUR","MIN","SEC","MSEC","yyyy" <CR>
"xxxx",xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy" <CR><ETX>
"CHANNEL","MAG","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR>
"xxxx",xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy" <CR><ETX>
```

(the fourth line is then repeated for each current) where:

xxxx = the data values corresponding to the first line labels

yyyy = the 4-byte hex ASCII representation of the checksum of the message through the comma preceding the checksum

CSTATUS Command

Display status data in Compressed ASCII format by sending:

CST <CR>

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IAW1","IBW1","ICW1",
"IAW2","IBW2","ICW2","MOF","+5V_PS","+5V_REG","-5V_REG","+10V_PS","-10V_PS",
"VBAT","TEMP","RAM","ROM","CR_RAM","EEPROM","FLASH","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx",
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx",
"xxxx","xxxx","yyyy" <CR><ETX>
```

where:

xxxx = the data values corresponding to the first line labels

yyyy = the 4-byte hex ASCII representation of the checksum

CHISTORY Command

Display history data in Compressed ASCII format by sending:

CHI <CR>

The relay sends:

```
<STX>"REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC",
"EVENT","TARGETS","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"xxxx","xxxx","yyyy" <CR><ETX>
```

(the second line is then repeated for each record)

where:

xxxx = the data values corresponding to the first line labels

yyyy = the 4-byte hex ASCII representation of the checksum

CTARGET Command

Display target data in Compressed ASCII format by sending:

CTA *n* <CR>

where *n* is one of the target numbers accepted by the **TAR** command. If *n* is omitted, 1 is used.

The relay sends:

```
<STX>"llll","llll","llll","llll","llll","llll","llll","llll","yyyy" <CR>
x,x,x,x,x,x,x,x,"yyyy" <CR><ETX>
```

where:

1111 = the labels for the given target
x = 0 or 1 corresponding to the first line labels
yyyy = the 4-byte hex ASCII representation of the checksum

CEVENT Command

Display event report in Compressed ASCII format by sending:

CEV *n* <CR>

where *n* is the number of the event report, as used in the **EVE** command.

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy" <CR>
"IRW1","IAW1","IBW1","ICW1","IRW2","IAW2","IBW2,"ICW2","MID","RLY_BITS",
"OUT_IN"," yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"z","xxxx","xxxx","yyyy" <CR>
<ETX>
```

(the fourth line is then repeated for each data line in record one)

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy" <CR>
"IOP1","IOP2","IOP3","IRT1","IRT2","IRT3","IF2,"IF5","MID","RLY_BITS",
"OUT_IN","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"z","xxxx","xxxx","yyyy" <CR>
<ETX>
```

(the fourth line is then repeated for each data line in record two)

where:

xxxx = the data values corresponding to the first and third line labels
yyyy = the 4-byte hex ASCII representation of the checksum
z = > for mid-fault record and empty for all others
MID = the mid-fault record indication
RLY_BITS = the relay element data

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Appendix F
Transformer/CT Winding Connection Diagrams

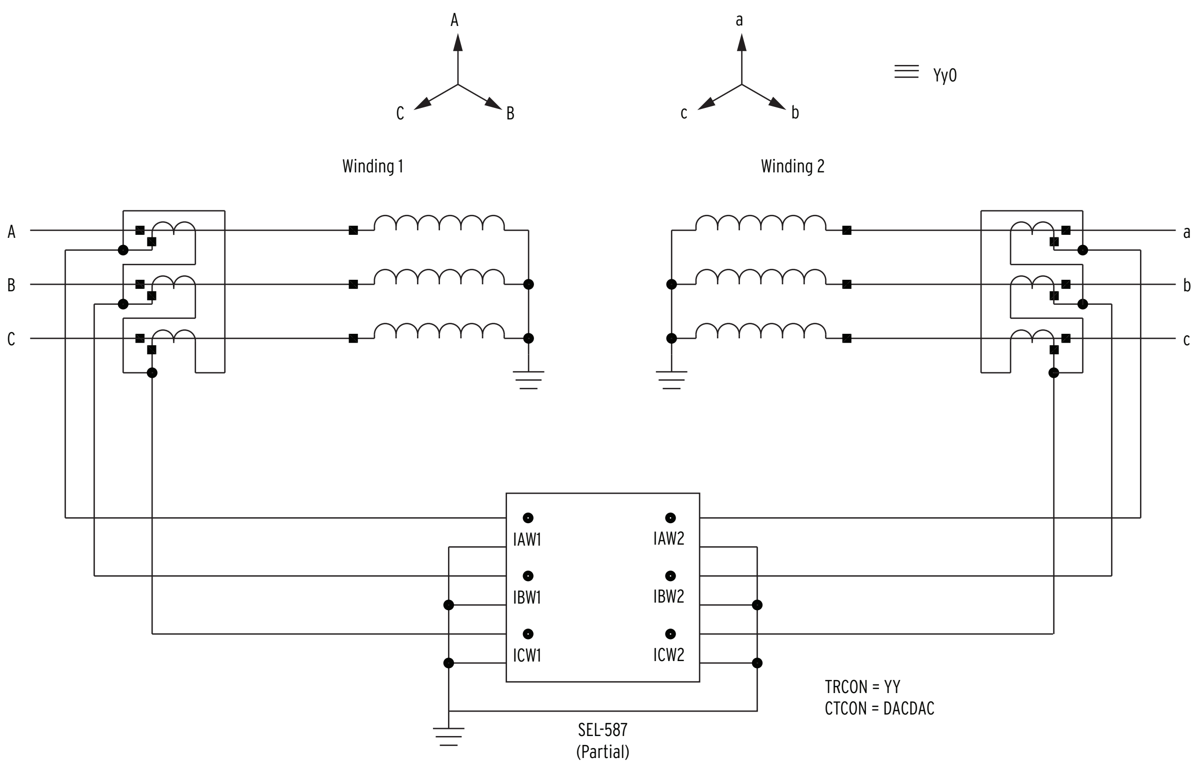

Figure F.1 Wye-Wye Power Transformer With Delta-Delta CT Connections

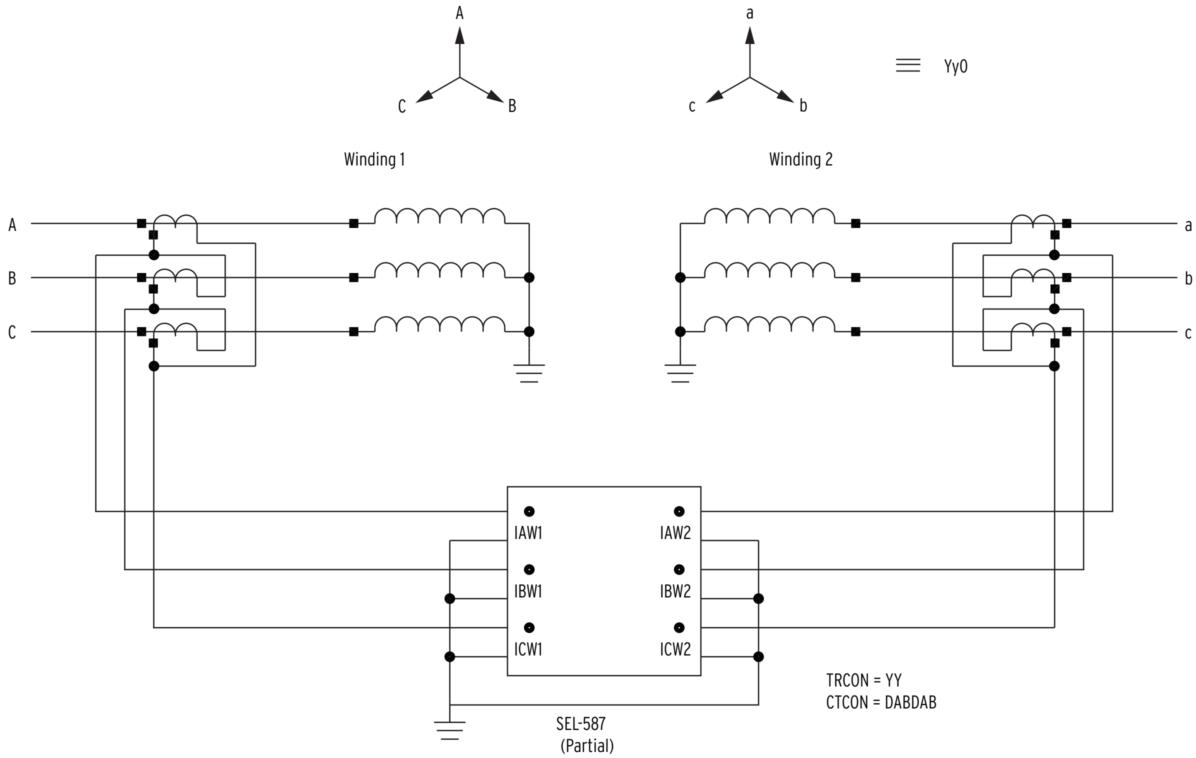

Figure F.2 Wye-Wye Power Transformer With Delta-Delta CT Connections

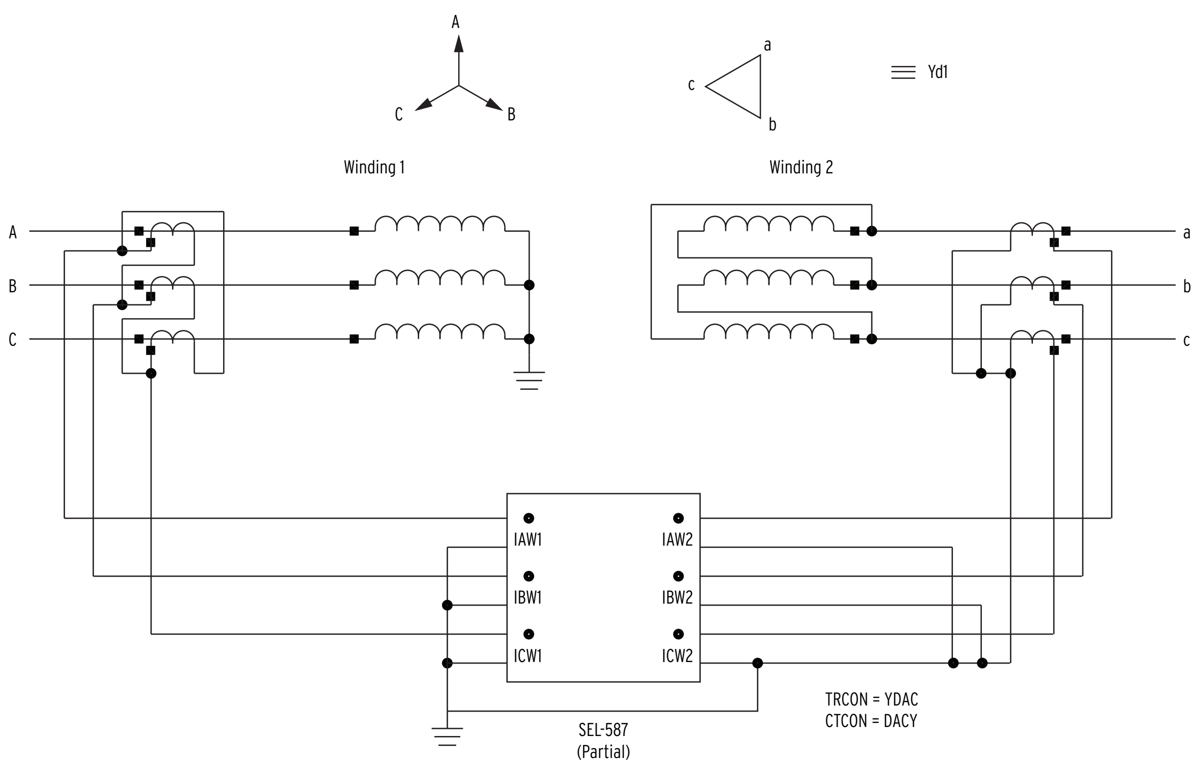

Figure F.3 Wye-Delta Power Transformer With Delta-Wye CT Connections

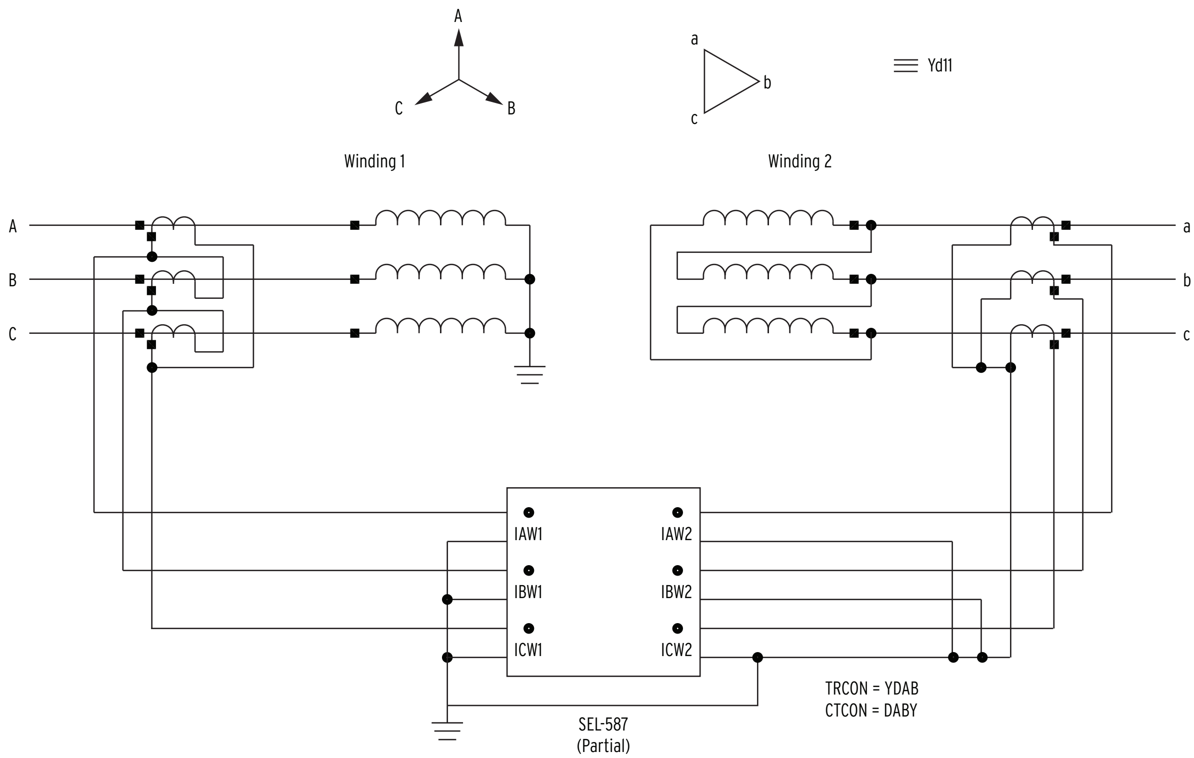

Figure F.4 Wye-Delta Power Transformer With Delta-Wye CT Connections

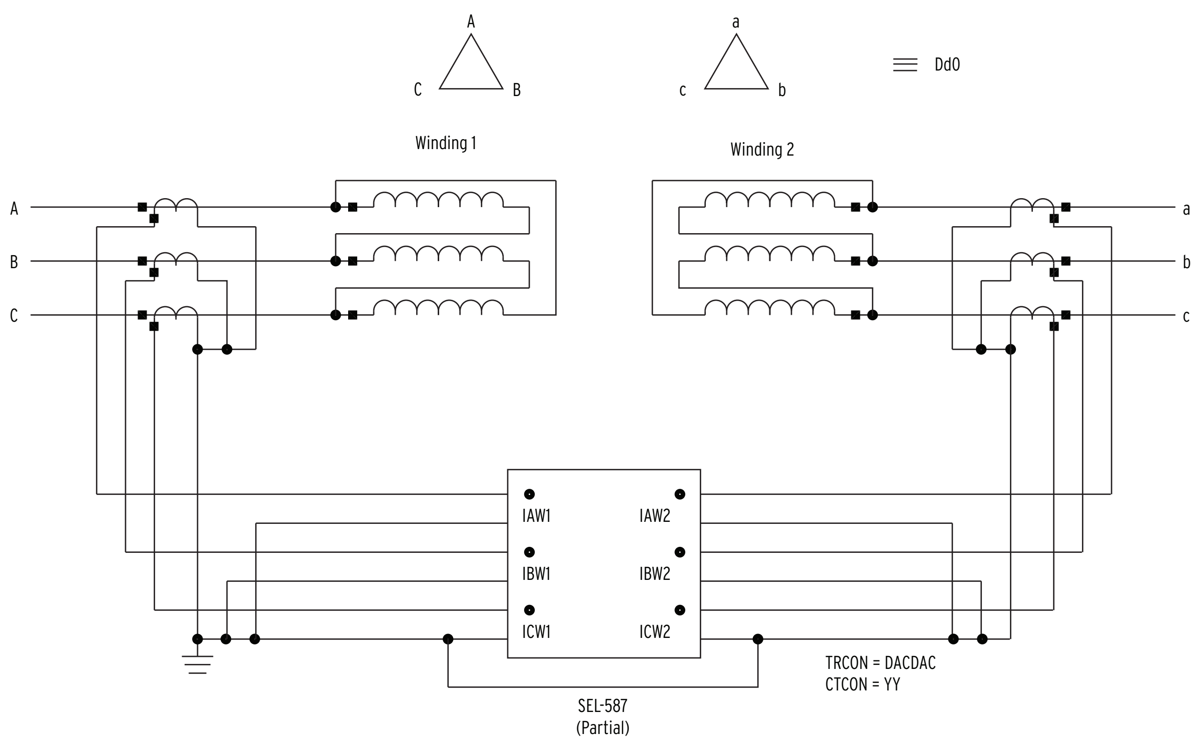

Figure F.5 Delta-Delta Power Transformer With Wye-Wye CT Connections

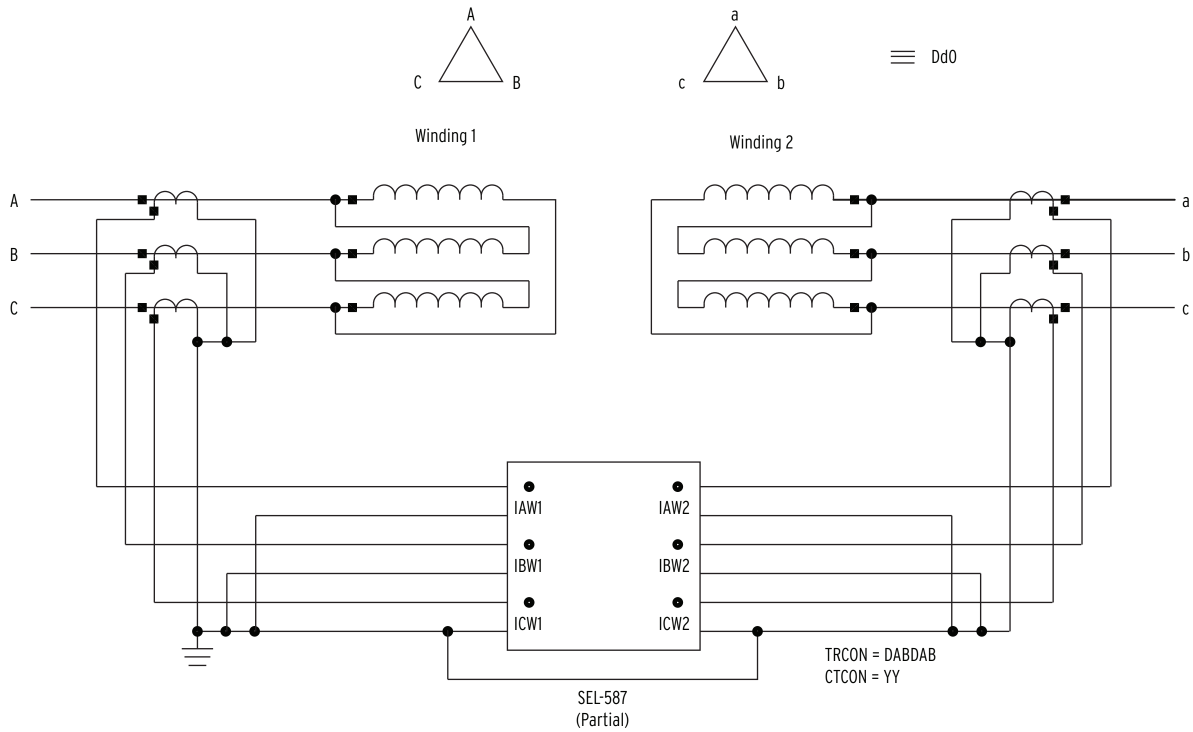

Figure F.6 Delta-Delta Power Transformer With Wye-Wye CT Connections

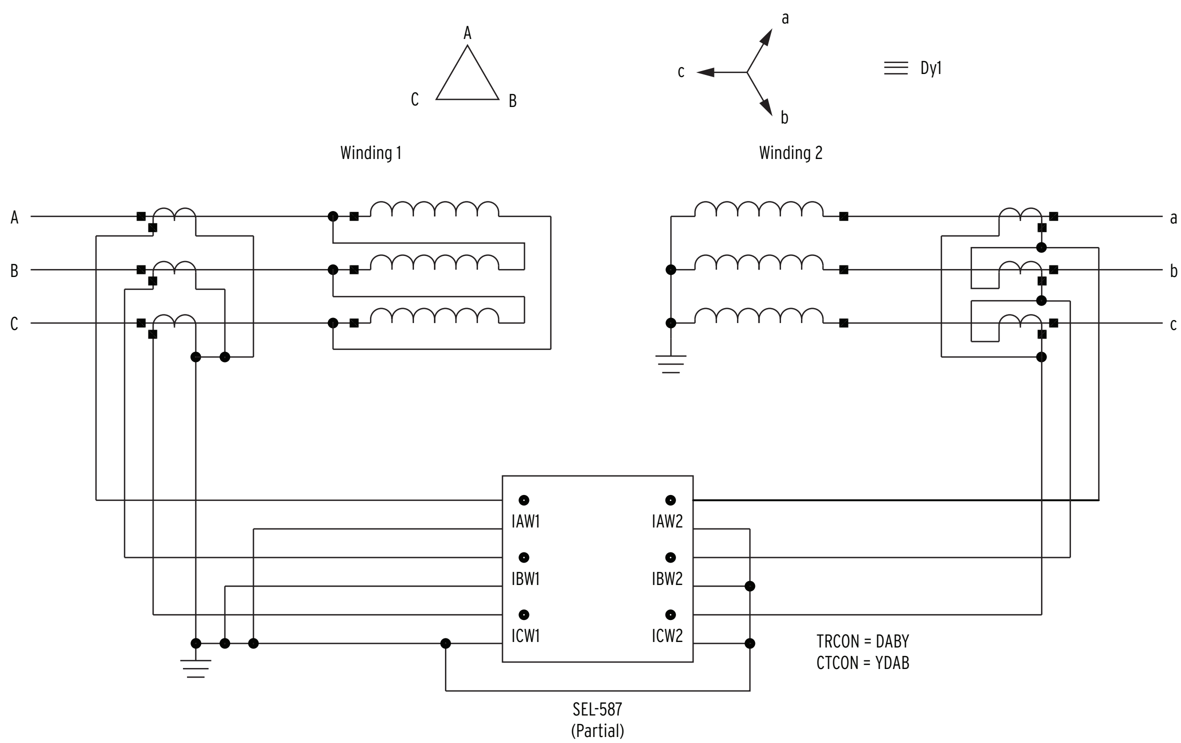

Figure F.7 Delta-Wye Power Transformer With Wye-Delta CT Connections

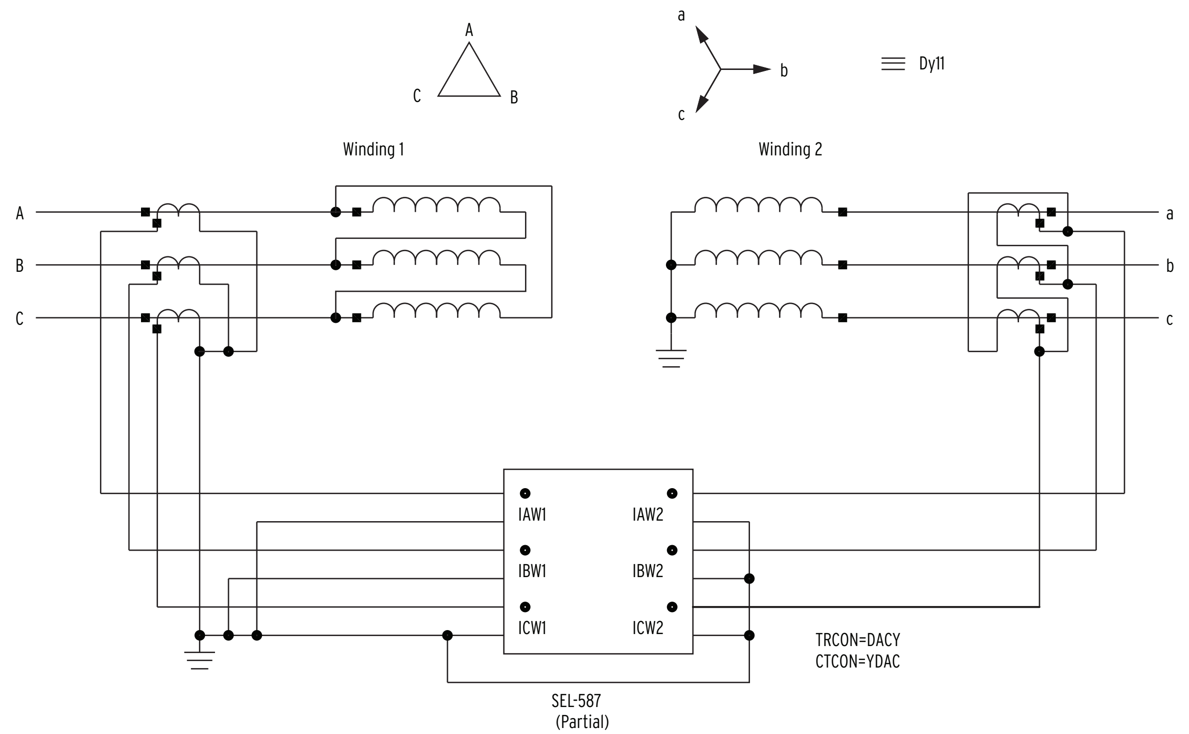

Figure F.8 Delta-Wye Power Transformer With Wye-Delta CT Connections

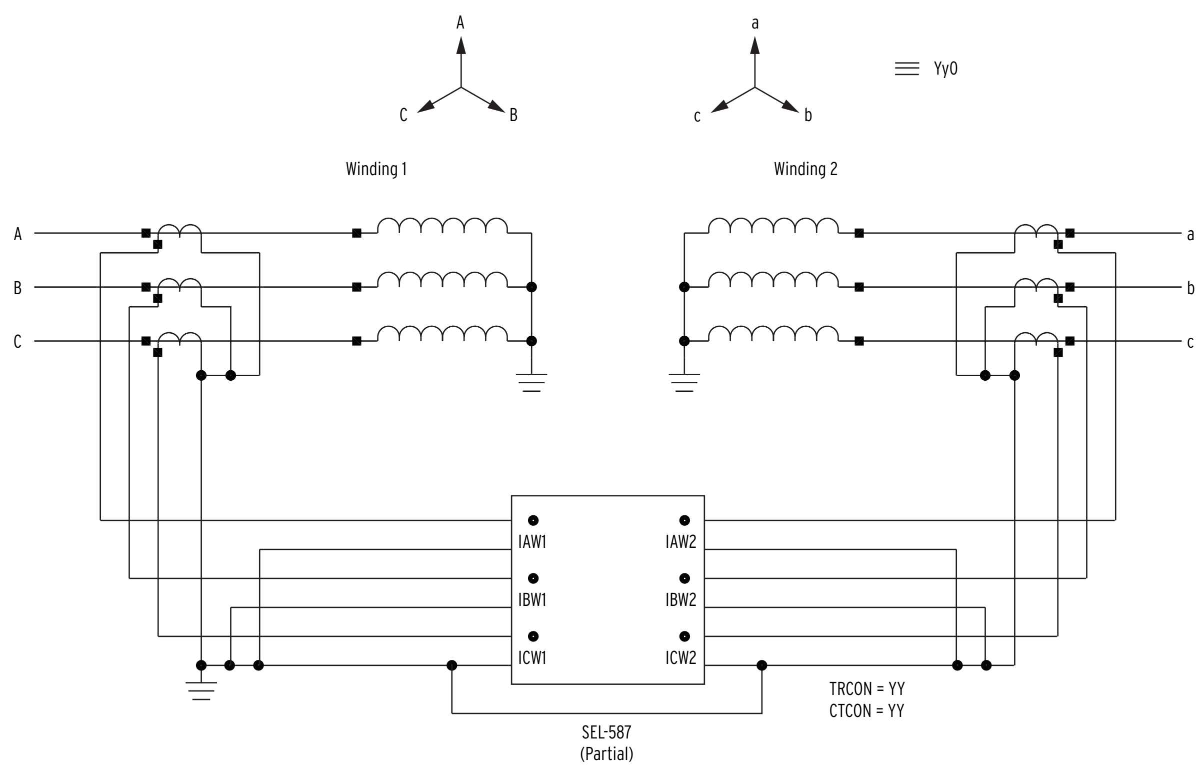

Figure F.9 Wye-Wye Power Transformer With Wye-Wye CT Connections

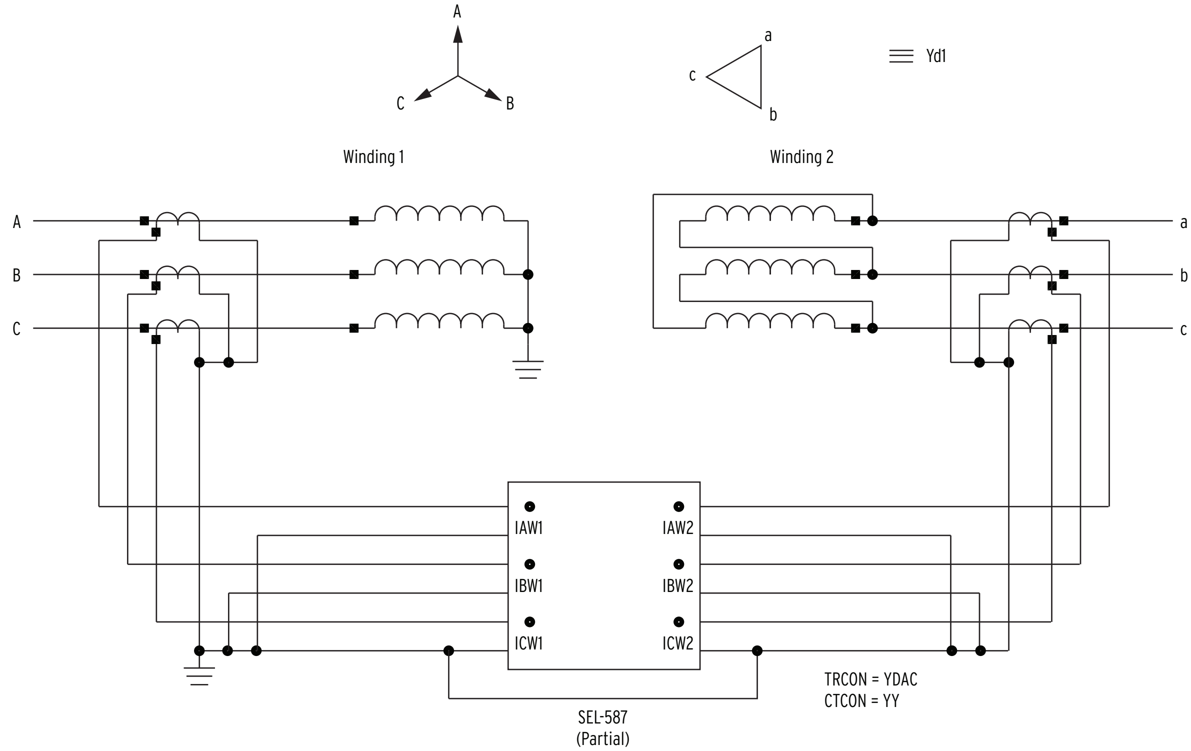

Figure F.10 Wye-Delta Power Transformer With Wye-Wye CT Connections

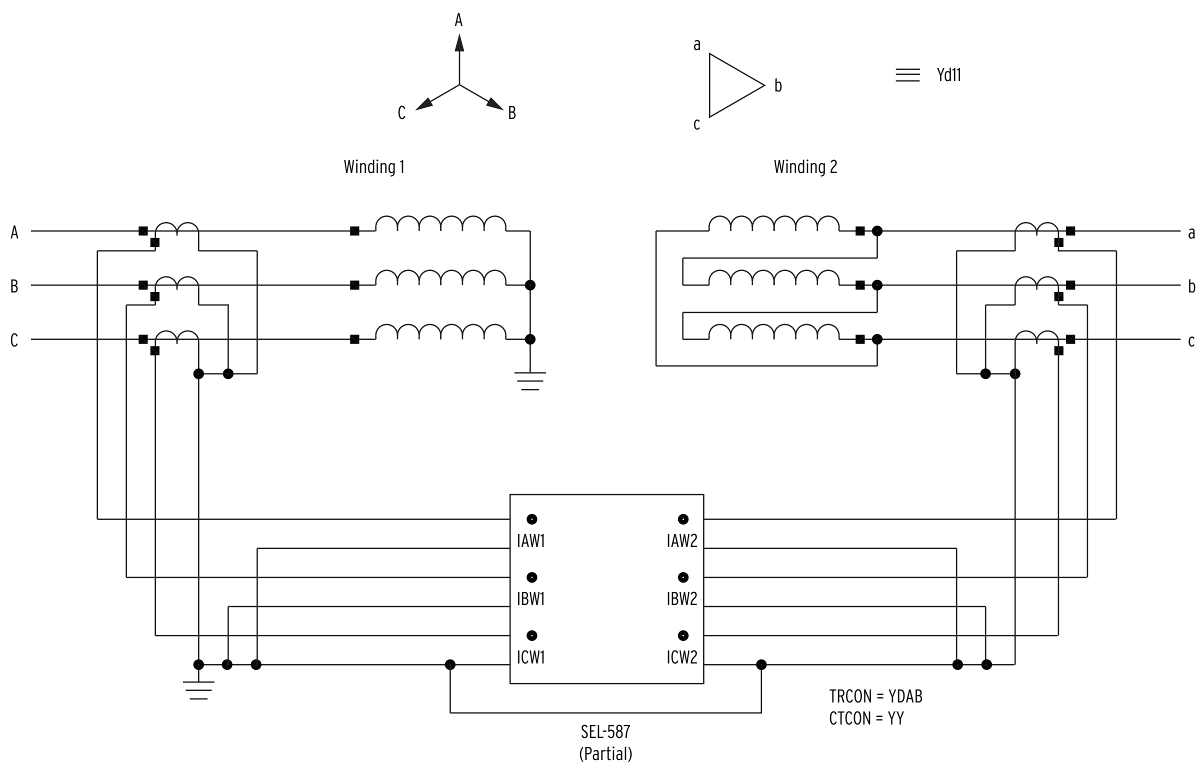

Figure F.11 Wye-Delta Power Transformer With Wye-Wye CT Connections

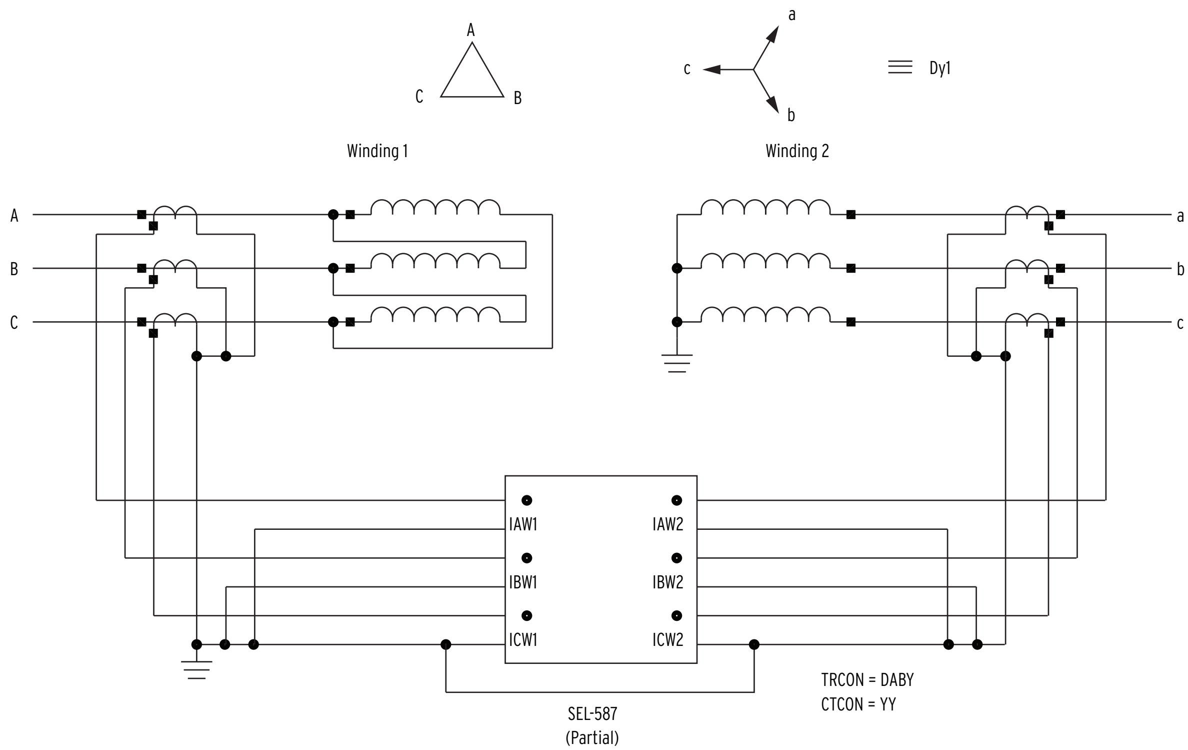

Figure F.12 Delta-Wye Power Transformer With Wye-Wye CT Connections

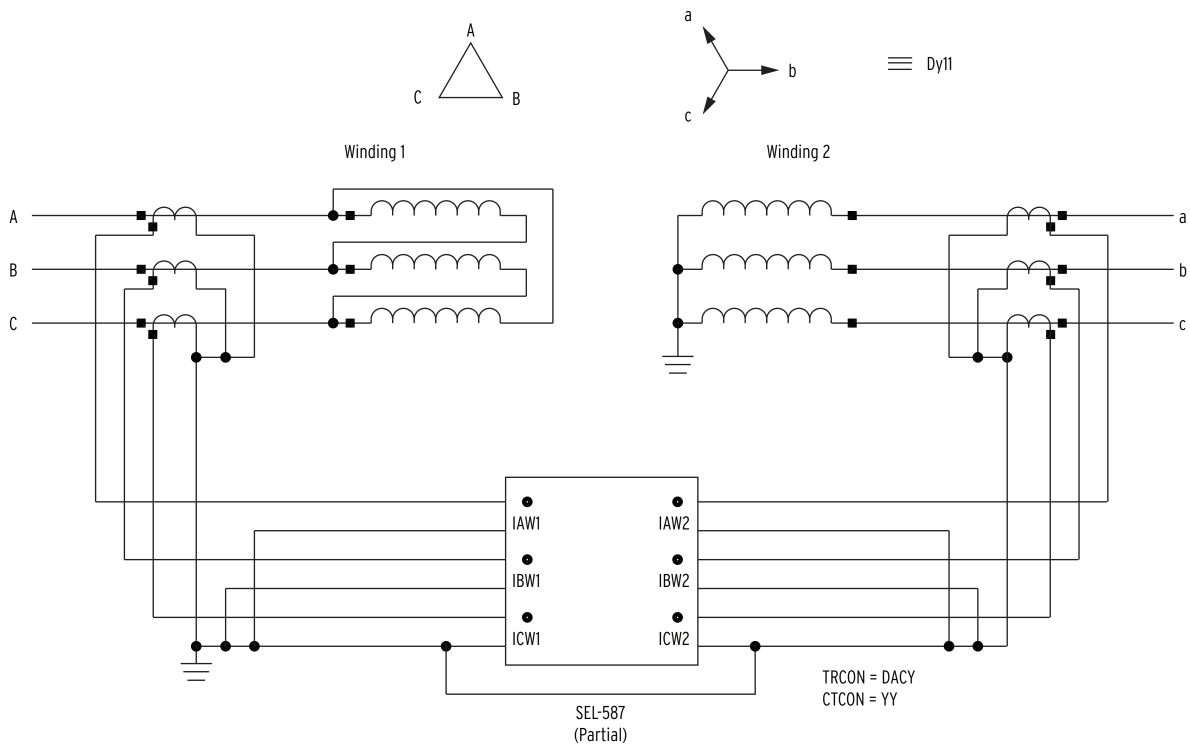

Figure F.13 Delta-Wye Power Transformer With Wye-Wye CT Connections

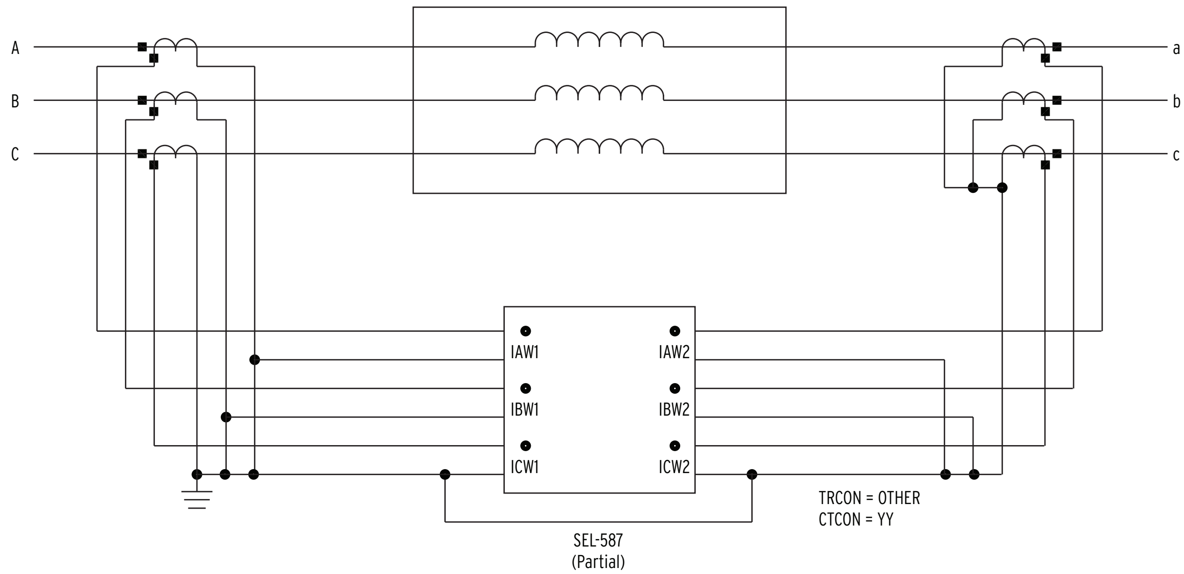

Figure F.14 Protected Machine With No Internal Phase Shift Resulting From Connections

Appendix G

Manual Calculation of Relay TAP Settings

Introduction

The SEL-587 internally calculates TAP1 and TAP settings to ensure minimal CT ratio mismatch. You need to verify that the TAP settings:

1. Yield a value between 0.1 • I_N and 32 • I_N
2. Produce a ratio $\dfrac{TAP_{MAX}}{TAP_{MIN}} \le 4.5$

For example, consider this delta-wye transformer application. The transformer and system data are shown in *Table G.1*.

Table G.1 Example Power System and Transformer Data

MVA Rating:	62 MVA
High-Side L-L Voltage (VWDG1):	230 kV (wye-grounded)
Low-Side L-L Voltage (VWDG2):	13.8 kV (delta)
230 kV CT 1-way lead burden (RHSlead):	3.69 ohm
230 kV CT burden, C200:	0.31 ohm
230 kV CT connection:	Y
13.8 kV CT 1-way lead burden (RLSlead):	0.2 ohm
13.8 kV CT burden, C200:	0.31 ohm
13.8 kV CT connection:	Y
Maximum Symmetrical Internal Faults (230 kV):	I (3-ph) = 40000 A
Maximum Symmetrical Internal Faults (13.8 kV):	I (3-ph) = 16000 A
Maximum Symmetrical External Fault (230 kV):	I (3-ph) = 1000 A

Since the fault currents are high enough to produce CT saturation for internal faults, a CT simulation was used to validate the operation of the unrestrained differential element on the high internal fault current. We select the following CT ratios:

CTR1 = 160 to 1

CTR2 = 600 to 1

Current TAPs (TAP1, TAP2) are calculated as follows:

$$TAP1 = \frac{MVA \bullet 1000 \bullet C1}{\sqrt{3} \bullet VWDG1 \bullet CTR1}$$

$$TAP2 = \frac{MVA \bullet 1000 \bullet C2}{\sqrt{3} \bullet VWDG2 \bullet CTR2}$$

where C1 and C2 are defined by the transformer and CT connections shown in *Table 4.1*.

$$\mathrm{TAP1} = \frac{62 \bullet 1000 \bullet 1}{\sqrt{3} \bullet 230 \bullet 160} = 0.97$$

$$\mathrm{TAP2} = \frac{62 \bullet 1000 \bullet 1}{\sqrt{3} \bullet 13.8 \bullet 600} = 4.32$$

These TAP settings fall within the acceptable relay setting range.

1. The TAP settings are within the range 0.5–160 A secondary.
2. The ratio, TAP_{MAX}/TAP_{MIN} = 4.32/0.97 = 4.45, which is less than the 4.5 maximum allowed by the relay.

The relay will calculate these TAP settings automatically if you enter the MVA, VWDG1, and VWDG2 settings. If you set MVA = OFF, you can enter the TAP settings directly. VWDG1 and VWDG2 settings are not used when MVA = OFF.

Appendix H

SEL-587 Relay Commissioning Test Worksheet

Transformer and Relay Data

Relay ID (RID): ______________________

Terminal ID (TID): ______________________

MVA (Size): ____________ Metered Load Data

VWDG1 (Winding 1, kV): ____________ MW = ________

VWDG2 (Winding 2, kV): ____________ MVAR = ________

TRCON (xfmr conn): ____________ MVA (Calc): ________ $\text{MVA} = \sqrt{\text{MW}^2 + \text{MVAR}^2}$

CTCON (CT conn): ____________

$$\text{AMPS\_PRI} = \frac{\text{MVA} \bullet 1000}{\sqrt{3} \bullet \text{kV}}$$

CTR1 (Winding 1 CT ratio): ____________ XMFR Amperes (Calc)

CTR2 (Winding 2 CT ratio): ____________ Winding 1 amperes, primary: ________

TAP1 (Winding 1 tap): ____________ Winding 2 amperes, primary: ________

TAP2 (Winding 2 tap): ____________

O87P (Rest. pickup): ____________ RELAY Amperes (expected)

$$\text{AMPS\_RELAY} = \frac{\text{AMPS\_PRI}}{\text{CTR}}(\text{wye CTs})$$

$$\text{AMPS\_RELAY} = \frac{\text{AMPS\_PRI} \bullet \sqrt{3}}{\text{CTR}}(\text{delta CTs})$$

SLP1 (Slope 1 %): ____________ Winding 1 amperes, sec: ________

SLP2 (Slope 2 %): ____________ Winding 2 amperes, sec: ________

IRS1 (Rest SLP1 limit): ____________

U87P (Unrest. pickup): ____________

Field Test Measurements					
Use **METER DIF** command (or front panel):					
IOP1 = ______	IOP2 = ______	IOP3 = ______	IRT1 = ______	IRT2 = ______	IRT3 = ______
Mismatch := $\frac{IOP}{IRT}$	MM1 = ______	MM2 = ______	MM3 = ______	Mismatch < 0.10?	______
If Mismatch ratio is less than 0.10, then differential currents are acceptable.					
If Mismatch ratio is greater than 0.10, then differential currents are too high: check individual current magnitudes and phase angles.					

Obtain winding current values by using one of the following two methods:

➤ Use the Access Level 1 command **METER SEC**:

```
=>METER SEC <Enter>
```

➤ With older SEL-587 relays, the **METER SEC** command may not be available. In that case, use the Access Level C command **TEST METER**:

```
==>>TEST METER <Enter>
```

IAW1 =	______ A	______ deg	IBW1 =	______ A	______ deg	ICW1 =	______ A	______ deg
IAW2 =	______ A	______ deg	IBW2 =	______ A	______ deg	ICW2 =	______ A	______ deg

Checklist

1. Expected amperes match measured amperes
2. Phasor rotation is as expected.
3. Circle your transformer and CT connection:

If:

TRCON = DABY, CTCON = YDAB

TRCON = YDAB, CTCON = DABY

TRCON = DACY, CTCON = YDAC

TRCON = YDAC, CTCON = DACY

TRCON = YY, CTCON = DABDAB

TRCON = YY, CTCON = DACDAC

TRCON = DABDAB, CTCON = YY

TRCON = DACDAC, CTCON = YY

TRCON = YY, CTCON = YY

Then: Phase angles are 180º apart.

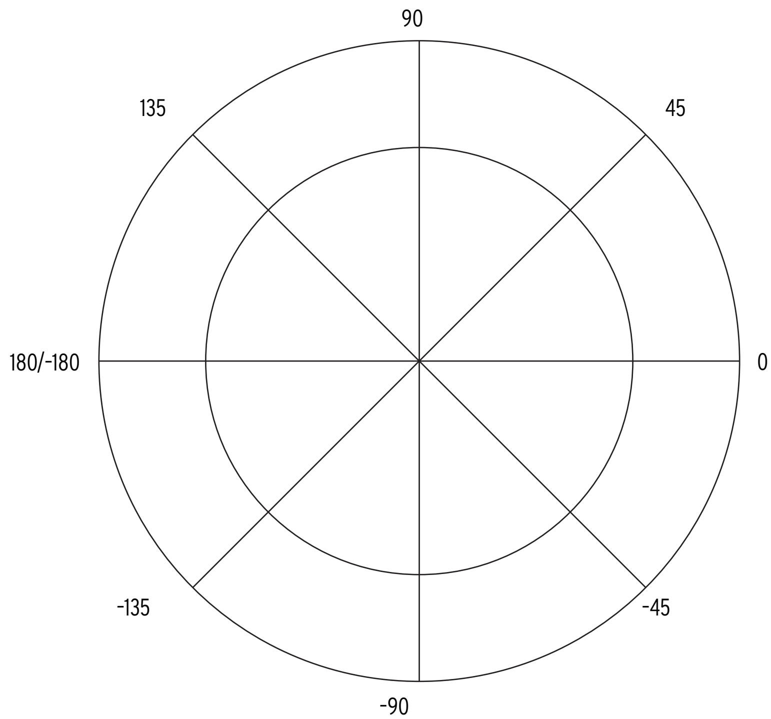

Figure H.1 Plot Phasors

If:

TRCON = DABY, CTCON = YY

TRCON = YDAC, CTCON = YY

Then: IW2 leads IW1 by 150º for PHROT = ABC.

Then: IW2 lags IW1 by 150º for PHROT = ACB.

If:

TRCON = DACY, CTCON = YY

TRCON = YDAB, CTCON = YY

Then: IW2 lags IW1 by 150º for PHROT = ABC.

Then: IW2 leads IW1 by 150º for PHROT = ACB.

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Appendix I
Modbus RTU Communications Protocol

Introduction

This appendix describes Modbus® RTU communications features supported by the SEL-587-1 at the rear-panel communications port. The port at the back of the panel can be either EIA-232 or EIA-485 depending upon the options selected by the user at the time of relay purchase.

Complete specifications for the Modbus protocol are available from the Modicon website at www.modicon.com.

Enable Modbus protocol by using the serial port settings. When Modbus protocol is enabled, the relay switches the port to Modbus protocol and deactivates the ASCII protocol.

Modbus RTU is a binary protocol that permits communication between a single client device and multiple server devices. The communication is half duplex; only one device transmits at a time. The client transmits a binary command that includes the address of the desired server device. All of the server devices receive the message, but only the server device with the matching address responds.

The SEL-587-1 Modbus communication allows a Modbus client device to:

- ➤ Acquire metering, monitoring, and event data from the relay.
- ➤ Control SEL-587-1 output contacts and remote bits.
- ➤ Read the SEL-587-1 self-test status and learn the present condition of all relay protection elements.

Modbus RTU Communications Protocol

Modbus Queries

Modbus RTU client devices initiate all exchanges by sending a query. The query consists of the fields shown in *Table I.1*.

Table I.1 Modbus Query Fields

Field	Number of Bytes
Server Device Address	1 byte
Function Code	1 byte
Data Region	0–251 bytes
Cyclical Redundancy Check (CRC)	2 bytes

The SEL-587-1 SLAVEID setting defines the server device address. Set this value to a unique number for each device on the Modbus network. For Modbus communication to operate properly, no two server devices can have the same address.

Function codes supported by the SEL-587-1 are described in *Table I.2*.

The cyclical redundancy check detects errors in the received data. If an error is detected, the relay discards the packet.

Modbus Responses

The server device sends a response message after it performs the action requested in the query. If the server cannot execute the command for any reason, it sends an error response. Otherwise, the server device response is formatted similarly to the query including the server address, function code, data (if applicable), and a cyclical redundancy check value.

Supported Modbus Function Codes

The SEL-587-1 supports the Modbus function codes shown in *Table I.2*.

Table I.2 SEL-587-1 Modbus Function Codes

Codes	Description
01h	Read Coil Status
02h	Read Input Status
03h	Read Holding Registers
04h	Read Input Registers
05h	Force Single Coil
06h	Preset Single Register
07h	Read Exception Status
08h	Loopback Diagnostic Command
10h	Preset Multiple Registers
64h	Scattered Register Read

Modbus Exception Responses

The SEL-587-1 sends an exception code under the conditions described in *Table I.3*.

Table I.3 SEL-587-1 Modbus Exception Codes

Exception Code	Error Type	Description
01	Illegal Function Code	The received function code is either undefined or unsupported.
02	Illegal Data Address	The received command contains an unsupported address in the data field.
03	Illegal Data Value	The received command contains a value that is out of range.
04	Device Error	The SEL-587-1 is in the wrong state for the requested function.
06	Busy	The SEL-587-1 is unable to process the command at this time due to a busy resource.

In the event that any of the errors listed in *Table I.3* occur, the relay assembles a response message that includes the exception code in the data field. The relay sets the most significant bit in the function code field to indicate to the client that the data field contains an error code, instead of the requested data.

Cyclical Redundancy Check

The SEL-587-1 calculates a 2-byte CRC value by using the device address, function code, and data fields. It appends this value to the end of every Modbus response. When the client device receives the response, it recalculates the CRC. If the calculated CRC matches the CRC sent by the SEL-587-1, the client device uses the data received. If there is not a match, the check fails and the message is ignored. The devices use a similar process when the client sends queries.

01h Read Coil Status Command

Use function code 01h to read the On/Off status of the selected bits (coils). You can read the status of up to 2000 bits per query. Note that the relay coil addresses start at 0 (e.g., Coil 1 is located at address zero). The coil status is packed one coil per bit of the data field. The Least Significant Bit (LSB) of the first data byte contains the starting coil address in the query. The other coils follow towards the high order end of this byte and from low order to high order in subsequent bytes.

Table I.4 01h Read Coil Status Commands

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (01h)
2 bytes	Address of the First Bit
2 bytes	Number of Bits to Read
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (01h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the relay calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the relay adds one more byte to maintain the balance of bits, padded by zeros to make an even byte.

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

Refer to *Table I.10* for coil number assignments.

02h Read Input Status Command

Use function code 02h to read the On/Off status of the selected bits (inputs). You can read the status of up to 2000 bits per query. Note that the input addresses start at 0 (e.g., Input 1 is located at address zero). The input status is packed one input per bit of the data field. The LSB of the first data byte contains the starting input address in the query. The other inputs follow towards the high order end of this byte, and from low order to high order in subsequent bytes.

Table I.5 02h Read Input Status Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (02h)
2 bytes	Address of the First Bit
2 bytes	Number of Bits to Read
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (02h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the relay calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the relay adds one more byte to maintain the balance of bits, padded by zeros to make an even byte.

Input numbers are defined in *Table I.6*.

Table I.6 SEL-587-1 Inputs

Description								Input Number
EN	87	50	51	A	B	C	N	8–1
*	IN1	IN2	ALARM	OUT1	OUT2	OUT3	OUT4	16–9
51P1P	51Q1P	51N1P	51P1T	51Q1T	51N1T	*	RB1	24–17
50P1P	50Q1P	50N1P	50P1T	50Q1T	50N1T	50P1H	50N1H	32–25
51P2P	51Q2P	51N2P	51P2T	51Q2T	51N2T	*	RB2	40–33
50P2P	50Q2P	50N2P	50P2T	50Q2T	50N2T	50P2H	50N2H	48–41
87U1	87U2	87U3	87U	87R1	87R2	87R3	87R	56–49
2HB1	2HB2	2HB3	5HB1	5HB2	5HB3	87BL	RB3	64–57
TH5P	TH5T	PDEM	NDEM	QDEM	TRP1	TRP2	TRP3	72–65
OC1	OC2	CC1	CC2	IN1	IN2	52A1	52A2	80–73
MTU3	MTU2	MTU1	MER	YT	Y	XT	X	88–81
51P1R	51Q1R	51N1R	51P2R	51Q2R	51N2R	*	RB4	96–89
*	*	*	ALARM	OUT1	OUT2	OUT3	OUT4	101–97

In each row, the input numbers are assigned from the right-most input to the left-most input (i.e., Input 1 is “N” and Input 8 is “EN”). Input addresses start at 0000 (i.e., Input 1 is located at Input Address 0000).

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

03h Read Holding Register Command

Use function code 03h to read directly from the Modbus Register map shown in *Table I.19*. You can read a maximum of 125 registers at once with this function code. Most clients use 4X references with this function code. If you are accustomed to 4X references with this function code, for five-digit addressing, add 40001 to the standard database address.

Table I.7 03h Read Holding Register Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (03h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (03h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

04h Read Input Registers Command

Use function code 04h to read from the Modbus Register map shown in *Table I.19*. You can read a maximum of 125 registers at once with this function code. Most clients use 3X references with this function code. If you are accustomed to 3X references with this function code, for five-digit addressing, add 30001 to the standard database address.

Table I.8 04h Read Holding Register Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (04h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (04h)
1 byte	Bytes of data (n)
n bytes	Data
2 bytes	CRC-16

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

05h Force Single Coil Command

Use function code 05h to set or clear a coil.

Table I.9 05h Force Single Coil Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (05h)
2 bytes	Coil Reference
1 byte	Operation Code (FF for bit set, 00 for bit clear)
1 byte	Placeholder (00)
2 bytes	CRC-16
The command response is identical to the command request.	

The coil numbers supported by the SEL-587-1 are listed in *Table I.10*. The physical coils (Coils 1–5) are self-resetting. Pulsing a set remote bit clears the remote bit.

Table I.10 SEL-587-1 Command Coils (Sheet 1 of 2)

Coil	Field
1	OUT1
2	OUT2
3	OUT3

Table I.10 SEL-587-1 Command Coils (Sheet 2 of 2)

Coil	Field
4	OUT4
5	ALARM
6	RB1
7	RB2
8	RB3
9	RB4
10	Pulse RB1
11	Pulse RB2
12	Pulse RB3
13	Pulse RB4

Coil addresses start at 0000 (i.e., Coil 1 is located at Coil address 0000). If the relay is disabled or the breaker jumper is not installed, it will respond with error code 4 (Device Error). In addition to error code 4, the relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Invalid bit (coil) number	Illegal Data Address (02h)	Invalid Address
Illegal bit state requested	Illegal Data Value (03h)	Illegal Function Code/Op Code
Format error	Illegal Data Value (03h)	Bad Packet Format

06h Preset Single Register Command

The SEL-587-1 uses this function to allow a Modbus client to write directly to a database register. Refer to the Modbus Register Map in *Table I.19* for a list of registers that can be written using this function code. If you are accustomed to 4X references with this function code, for six-digit addressing, add 400001 to the standard database addresses.

Table I.11 06h Preset Single Register Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (06h)
2 bytes	Register Address
2 bytes	Data
2 bytes	CRC-16
The command response is identical to the command request.	

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Illegal register address	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal register value	Illegal Data Value (03h)	Illegal Write
Format error	Illegal Data Value (03h)	Bad Packet Format

07h Read Exception Status Command

The SEL-587-1 uses this function to allow a Modbus client to read the present status of the relay and protected circuit.

Table I.12 07h Read Exception Status Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (07h)
0 bytes	No Data Fields Are Sent
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (07h)
1 byte	Status Byte
2 bytes	CRC-16
The status byte is sent least significant bit first, and consists of the following bits:	
Bit 0	OUT4 Status
Bit 1	OUT3 Status
Bit 2	OUT2 Status
Bit 3	OUT1 Status
Bit 4	Alarm Output status
Bit 5	Input 2 Status
Bit 6	Input 1 Status
Bit 7	Relay Status

If the status bit is set to 1, the following are true for the status indicated by the bit:

- Output and Alarm contacts are asserted.
- Relay inputs are asserted.
- Relay is disabled.

If the status bit is set to 0, the following are true for the status indicated by the bit:

- Output and Alarm contacts are deasserted.
- Relay inputs are deasserted.
- Relay is enabled.

The relay response to errors in the query is shown below:

Error	Error Code Returned	Communication Counter Increments
Format error	Illegal Data Value (03h)	Bad Packet Format

08h Loopback Diagnostic Command

The SEL-587-1 uses this function to allow a Modbus client to perform a diagnostic test on the Modbus communications channel and relay. When the subfunction field is 0000h, the relay returns a replica of the received message.

Table I.13 08h Loopback Diagnostic Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field (identical to data in client request)
2 bytes	CRC-16

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Illegal subfunction code	Illegal Data Value (03h)	Illegal Function Code/Op Code
Format error	Illegal Data Value (03h)	Bad Packet Format

10h Preset Multiple Registers Command

This function code works much like code 06h, except that it allows you to write multiple registers at once, up to 100 per operation. Refer to the Modbus Register Map in *Table I.19* for a list of registers that can be written using this function code. If you are accustomed to 4X references with the function code, for six-digit addressing, simply add 400001 to the standard database addresses.

Table I.14 10h Preset Multiple Registers Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers to Write
1 byte	Bytes of Data (n)
n bytes	Data
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers
2 bytes	CRC-16

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Illegal register to set	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal number of registers to set	Illegal Data Value (03h)	Illegal Register Illegal Write
Incorrect number of bytes in query data region	Illegal Data Value (03h)	Bad Packet Format Illegal Write
Invalid register data value	Illegal Data Value (03h)	Illegal Write

64h Scattered Register Read

The SEL-587-1 uses this function to allow a Modbus client to read noncontiguous registers in a single request. A maximum of 100 registers can be read in a single query.

Table I.15 64h Scattered Register Read Command

Bytes	Field
Requests from the client must have the following format:	
1 byte	Server Address
1 byte	Function Code (64h)
1 byte	Query Data Length
1 byte	Subfunction Code (04h)[a]
1 byte	Transmission Number
2 bytes	Address of First Register
2 bytes	Address of Second Register
•	•
•	•
•	•
2 bytes	Address of *n*th Register
2 bytes	CRC-16
A successful response from the server will have the following format:	
1 byte	Server Address
1 byte	Function Code (64h)
1 byte	Response Data Length
1 byte	Subfunction Code (04h)[a]
1 byte	Transmission Number
2 bytes	Data from First Register
2 bytes	Data from Second Register
•	•
•	•
•	•
2 bytes	Data from *n*th Register
2 bytes	CRC-16

[a] Only subfunction 04h is supported.

The relay responses to errors in the query are shown below:

Error	Error Code Returned	Communication Counter Increments
Incorrect/Illegal query data length	Illegal Data Value (03h)	Bad Packet Format
Invalid subfunction code	Illegal Data Value (03h)	Illegal Function Code/Op Code
Illegal register address	Illegal Data Address (02h)	Invalid Address

Controlling Output Contacts and Remote Bits by Using Modbus

The SEL-587-1 Modbus Register Map (*Table I.19*) includes three fields that allow a Modbus client to force the relay to perform a variety of operations. Use Modbus function codes 06h or 10h to write the appropriate command codes and parameters into the registers shown in *Table I.16*. If function code 06h is used to write to a command code that has parameters, the parameters must be written before the command code. After issuing a command, parameters 1 and 2 are cleared and must be rewritten prior to the next command.

Table I.16 SEL-587-1 Modbus Command Region

Address	Field
0130h	Command Code
0131h	Parameter 1
0132h	Parameter 2

Table I.17 defines the command codes, their function and associated parameters, and the Modbus function code used to initiate the related command code.

Table I.17 Modbus Command Codes (Sheet 1 of 2)

Command Code	Function	Parameter Definition	Modbus Function Code
01	Open Breaker 1	No parameter	06h, 10h
02	Open Breaker 2	No parameter	06h, 10h
03	Close Breaker 1	No parameter	06h, 10h
04	Close Breaker 2	No parameter	06h, 10h
05	Reset Targets	No parameter	06h, 10h
06	Trigger	No parameter	06h, 10h
07	Pulse OUT1	1–30 seconds duration (defaults to 1 second)	06h, 10h
08	Pulse OUT2	1–30 seconds duration (defaults to 1 second)	06h, 10h
09	Pulse OUT3	1–30 seconds duration (defaults to 1 second)	06h, 10h
10	Pulse OUT4	1–30 seconds duration (defaults to 1 second)	06h, 10h
11	Pulse Alarm	1–30 seconds duration (defaults to 1 second)	06h, 10h
12	Switch Protocol	0080h	06h, 10h

Table I.17 Modbus Command Codes (Sheet 2 of 2)

Command Code	Function	Parameter Definition	Modbus Function Code
13[a]	Reset Data Regions	0000 0000 0000 0001—Demand Metering	06h, 10h
		0000 0000 0000 0010—Peak Metering	
		0000 0000 0000 0100—Peak Harmonics	
		0000 0000 0000 1000—History Buffer (History and events)	
		0000 0000 0001 0000—Breaker Monitor 1	
		0000 0000 0010 0000—Breaker Monitor 2	
		0000 0000 0100 0000—Communication Counters	
14	Control Remote Bits	See *Note 1*	06h, 10h

[a] Parameter of Command Code 13 is masked to allow you to manipulate several data regions simultaneously.

Note 1

Command Code 14—Control Remote Bits:

This code controls the remote bits. This command code has two parameters.

Parameter 1 determines the bit operation.

Value	Operation
1	Set
2	Clear
3	Pulse (1/8 cycle)

Parameter 2 determines which bit to control. It is bit masked for future expansion, but only one bit can be controlled at a time. The highest numbered bit will be controlled if more than one bit occurs in the parameter.

Bit Pattern	Remote Bit
0000 0000 0000 0001	RB1
0000 0000 0000 0010	RB2
0000 0000 0000 0100	RB3
0000 0000 0000 1000	RB4

In addition to the error codes returned for function codes 06h or 10h, the following error codes are returned for command codes.

Error Codes

- ➤ If the relay is disabled or if the breaker jumper is not installed while the commands 1–4 and 7–11 are issued, the relay will return error code 04 (device error).
- ➤ If the relay is disabled while Reset Targets command (05) is issued, the relay will return error code 04h (device error).
- ➤ If the **TRIGGER** command (06) cannot be executed due to multiple events in progress, the relay will return error code 06h (device busy). If the relay is disabled while this command is issued, the relay will return 04h (device error).
- ➤ If the Switch Protocol command (12) or Reset command (13) cannot be executed if the relay is busy, it will return error code 06h (device busy).

Reading Event Data by Using Modbus

The Modbus Register Map (*Table I.19*) provides a feature that allows you to download complete event data via Modbus. The SEL-587-1 stores the 20 latest event summaries and 10 latest 15-cycle, full-length event reports. Refer to *Section 7: Event Reports* for more detailed description.

The event report will contain both analog and digital data. To download the event data by using Modbus, proceed as follows:

1. Write the event number you wish to download at address 0151h.
2. Write the channel number you wish to download at address 0152h. Refer to *Table I.18* for the channel number assignment.
3. Read the four-sample per cycle raw event data from the Modbus Map.

Note that reading event data via Modbus is significantly slower compared to the other data in the Modbus Register Map (*Table I.19*). Typical response time to read a single channel data via Modbus is about 300 ms at 9600 baud rate.

Table I.18 Assign Event Report Channel by Using Address 0152 (Sheet 1 of 2)

Set 0152	To Read Data From Channel
1	IR Winding 1
2	IA Winding 1
3	IB Winding 1
4	IC Winding 1
5	IR Winding 2
6	IA Winding 2
7	IB Winding 2
8	IC Winding 2
9	Relay Element Status Row 1[a]
10	Relay Element Status Row 2[a]
11	Relay Element Status Row 3[a]
12	Relay Element Status Row 4[a]
13	Relay Element Status Row 5[a]
14	Relay Element Status Row 6[a]
15	Relay Element Status Row 7[a]
16	Relay Element Status Row 8[a]

Table I.18 Assign Event Report Channel by Using Address 0152 (Sheet 2 of

Set 0152	To Read Data From Channel
17	Relay Element Status Row 9[a]
18	Relay Element Status Row 10[a]
19	Relay Element Status Row 11[a]

[a] Refer to Section 6: Operator Interface to obtain the contents of each relay element status row. Relay Element Status Row 0, which represents targets, is displayed at 019Bh in the Modbus Map.

If the user selects an event number for which there are no data available, 8000h will be returned.

Reading History Data by Using Modbus

The Modbus Register Map (*Table I.19*) provides a feature that allows you to download complete history of the last 20 events via Modbus. The history contains the date and time stamp, type of event that triggered the report, and the targets. Refer to Note 3 of the Modbus Map for a list of event types.

To download the history data by using Modbus, write the event number (1–20) to address 0141h. Then read the history of the specific event number you requested from the Modbus Map (*Table I.19*).

If the user selects a history number for which there are no data available, 8000h will be returned.

Table I.19 Modbus Map (Sheet 1 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
Relay ID						
0000–0016	FID[a]	ASCII String	–	–	–	–
0017–0019	Revision[a]	ASCII String	–	–	–	–
001A–0022	Relay ID[a]	ASCII String	–	–	–	–
0023–002B	Terminal ID[a]	ASCII String	–	–	–	–
002C	Reserved (see *Note 1*)					
002D	Device Tag #[b]	15044	–	–	–	–
002E	Feature Set ID[b]	0	–	–	–	–
002F	Reserved					
Relay Status						
0030	Channel IAW1 offset value[c]	mV	–5000	5000	1	1
0031	Channel IAW1 status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
0032	Channel IBW1 offset value[c]	mV	–5000	5000	1	1
0033	Channel IBW1 status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–

Table I.19 Modbus Map (Sheet 2 of 16)

Address (Hex)	Field	Units	Range Low	Range High	Range Step	Scale Factor
0034	Channel ICW1 offset value[c]	mV	–5000	5000	1	1
0035	Channel ICW1 status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
0036	Channel IAW2 offset value[c]	mV	–5000	5000	1	1
0037	Channel IAW2 status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
0038	Channel IBW2 offset value[c]	mV	–5000	5000	1	1
0039	Channel IBW2 status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
003A	Channel ICW2 offset value[c]	mV	–5000	5000	1	1
003B	Channel ICW2 status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
003C	(MOF) DC offset in A/D circuit when a grounded input is selected[c]	mV	-5000	5000	1	1
003D	MOF status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
003E	+5 V power supply voltage value[b]	V	0	600	1	0.01
003F	+5 V power supply status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
0040	+5_REG power supply value[b]	V	0	600	1	0.01
0041	+5_REG power supply status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
0042	–5_REG power supply value[c]	V	–600	0	1	0.01
0043	–5_REG power supply status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
0044	+10_ps power supply value[b]	V	0	1500	1	0.01
0045	+10_ps power supply status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–

Table I.19 Modbus Map (Sheet 3 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0046	–10_ps power supply value[c]	V	–1500	0	1	0.01
0047	–10_ps power supply status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
0048	VBAT power supply value[b]	V	0	500	1	0.01
0049	VBAT power supply status message[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
004A	TEMP in degrees Celsius[c]	°C	–100	100	1	1
004B	Temperature status[b] 0 = OK 1 = Warn 2 = Fail	–	–	–	–	–
004C	RAM status[b] 0 = OK, 2 = Fail	–	–	–	–	–
004D	ROM status[b] 0 = OK, 2 = Fail	–	–	–	–	–
004E	CR_RAM status[b] 0 = OK, 2 = Fail	–	–	–	–	–
004F	EEPROM status[b] 0 = OK, 2 = Fail	–	–	–	–	–
0050	FLASH status[b] 0 = OK, 2 = Fail	–	–	–	–	–
0051	Enable status[b] 0 = relay enabled, 2 = relay disabled	–	–	–	–	–
0052–005F	Reserved					
Instantaneous Meter						
0060	Instantaneous current A-phase[b] Winding 1	Amps	0	65535	1	1
0061	Instantaneous current A-phase[b] Angle Winding 1	Degrees	0	36000	1	0.01
0062	Instantaneous current B-phase[b] Winding 1	Amps	0	65535	1	1
0063	Instantaneous current B-phase[b] Angle Winding 1	Degrees	0	36000	1	0.01
0064	Instantaneous current C-phase[b] Winding 1	Amps	0	65535	1	1
0065	Instantaneous current C-phase[b] Angle Winding 1	Degrees	0	36000	1	0.01
0066	Instantaneous negative-sequence current $3I_2$[b] Winding 1	Amps	0	65535	1	1
0067	Instantaneous negative-sequence current Angle $3I_2$[b] Winding 1	Degrees	0	36000	1	0.01
0068	Instantaneous residual current I_R[b] Winding 1	Amps	0	65535	1	1
0069	Instantaneous residual current Angle I_R[b] Winding 1	Degrees	0	36000	1	0.01
006A	Instantaneous current A-phase[b] Winding 2	Amps	0	65535	1	1
006B	Instantaneous current A-phase[b] Angle Winding 2	Degrees	0	36000	1	0.01
006C	Instantaneous current B-phase[b] Winding 2	Amps	0	65535	1	1

Table I.19 Modbus Map (Sheet 4 of 16)

Address (Hex)	Field	Units	Range Low	Range High	Range Step	Scale Factor
006D	Instantaneous current B-phase[b] Angle Winding 2	Degrees	0	36000	1	0.01
006E	Instantaneous current C-phase[b] Winding 2	Amps	0	65535	1	1
006F	Instantaneous current C-phase[b] Angle Winding 2	Degrees	0	36000	1	0.01
0070	Instantaneous negative-sequence current $3I_2$[b] Winding 2	Amps	0	65535	1	1
0071	Instantaneous negative-sequence current Angle $3I_2$[b] Winding 2	Degrees	0	36000	1	0.01
0072	Instantaneous residual current I_R[b] Winding 2	Amps	0	65535	1	1
0073	Instantaneous residual current Angle I_R[b] Winding 2	Degrees	0	36000	1	0.01
Differential Currents						
0074	Operate current differential element 1	Amps	0	65535	1	0.1
0075	Operate current differential element 2	Amps	0	65535	1	0.1
0076	Operate current differential element 3	Amps	0	65535	1	0.1
0077	Restraint current differential element 1	Amps	0	65535	1	0.1
0078	Restraint current differential element 2	Amps	0	65535	1	0.1
0079	Restraint current differential element 3	Amps	0	65535	1	0.1
007A	2nd harmonic current differential element 1	Amps	0	65535	1	0.1
007B	2nd harmonic current differential element 2	Amps	0	65535	1	0.1
007C	2nd harmonic current differential element 3	Amps	0	65535	1	0.1
007D	5th harmonic current differential element 1	Amps	0	65535	1	0.1
007E	5th harmonic current differential element 2	Amps	0	65535	1	0.1
007F	5th harmonic current differential element 3	Amps	0	65535	1	0.1
Demand Meter						
0080	Demand current A-phase[b] Winding 1	Amps	0	65535	1	1
0081	Demand current B-phase[b] Winding 1	Amps	0	65535	1	1
0082	Demand current C-phase[b] Winding 1	Amps	0	65535	1	1
0083	Demand negative-sequence current $3I_2$[b] Winding 1	Amps	0	65535	1	1
0084	Demand residual current I_R[b] Winding 1	Amps	0	65535	1	1
0085	Demand current A-phase[b] Winding 2	Amps	0	65535	1	1
0086	Demand current B-phase[b] Winding 2	Amps	0	65535	1	1
0087	Demand current C-phase[b] Winding 2	Amps	0	65535	1	1
0088	Demand negative-sequence current $3I_2$[b] Winding 2	Amps	0	65535	1	1
0089	Demand residual current I_R[b] Winding 2	Amps	0	65535	1	1
Peak Demand Meter						
008A	Peak demand current A-phase[b] Winding 1	Amps	0	65535	1	1
008B	Peak demand current B-phase[b] Winding 1	Amps	0	65535	1	1
008C	Peak demand current C-phase[b] Winding 1	Amps	0	65535	1	1
008D	Peak demand negative-sequence current $3I_2$[b] Winding 1	Amps	0	65535	1	1

Table I.19 Modbus Map (Sheet 5 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
008E	Peak demand residual current I_R[b] Winding 1	Amps	0	65535	1	1
008F	Peak demand current A-phase[b] Winding 2	Amps	0	65535	1	1
0090	Peak demand current B-phase[b] Winding 2	Amps	0	65535	1	1
0091	Peak demand current C-phase[b] Winding 2	Amps	0	65535	1	1
0092	Peak demand negative-sequence current $3I_2$[b] Winding 2	Amps	0	65535	1	1
0093	Peak demand residual current I_R[b] Winding 2	Amps	0	65535	1	1
Peak Harmonic Meter						
0094	Peak 2nd harmonic current differential element 1	Amps	0	65535	1	0.1
0095	Peak 2nd Harmonic current differential element 2	Amps	0	65535	1	0.1
0096	Peak 2nd Harmonic current differential element 3	Amps	0	65535	1	0.1
0097	Peak 5th Harmonic current differential element 1	Amps	0	65535	1	0.1
0098	Peak 5th Harmonic current differential element 2	Amps	0	65535	1	0.1
0099	Peak 5th Harmonic current differential element 2	Amps	0	65535	1	0.1
Peak Demand Time Stamp (see Note 6)						
009A	Peak demand time A-phase Winding 1	ss	0	59	1	1
009B		mm	0	59	1	1
009C		hh	0	23	1	1
009D	Peak demand date A-phase Winding 1	dd	1	31	1	1
009E		mm	1	12	1	1
009F		yyyy	1992	2999	1	1
00A0	Peak demand time B-phase Winding 1	ss	0	59	1	1
00A1		mm	0	59	1	1
00A2		hh	0	23	1	1
00A3	Peak demand date B-phase Winding 1	dd	1	31	1	1
00A4		mm	1	12	1	1
00A5		yyyy	1992	2999	1	1
00A6	Peak demand time C-phase Winding 1	ss	0	59	1	1
00A7		mm	0	59	1	1
00A8		hh	0	23	1	1
00A9	Peak demand date C-phase Winding 1	dd	1	31	1	1
00AA		mm	1	12	1	1
00AB		yyyy	1992	2999	1	1
00AC	Peak demand time 3I2 Winding 1	ss	0	59	1	1
00AD		mm	0	59	1	1
00AE		hh	0	23	1	1
00AF	Peak demand date 3I2 Winding 1	dd	1	31	1	1
00B0		mm	1	12	1	1
00B1		yyyy	1992	2999	1	1

Table I.19 Modbus Map (Sheet 6 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
00B2	Peak demand time IR Winding 1	ss	0	59	1	1
00B3		mm	0	59	1	1
00B4		hh	0	23	1	1
00B5	Peak demand date IR Winding 1	dd	1	31	1	1
00B6		mm	1	12	1	1
00B7		yyyy	1992	2999	1	1
00B8	Peak demand time A-phase Winding 2	ss	0	59	1	1
00B9		mm	0	59	1	1
00BA		hh	0	23	1	1
00BB	Peak demand date A-phase Winding 2	dd	1	31	1	1
00BC		mm	1	12	1	1
00BD		yyyy	1992	2999	1	1
00BE	Peak demand time B-phase Winding 2	ss	0	59	1	1
00BF		mm	0	59	1	1
00C0		hh	0	23	1	1
00C1	Peak demand date B-phase Winding 2	dd	1	31	1	1
00C2		mm	1	12	1	1
00C3		yyyy	1992	2999	1	1
00C4	Peak demand time C-phase Winding 2	ss	0	59	1	1
00C5		mm	0	59	1	1
00C6		hh	0	23	1	1
00C7	Peak demand date C-phase Winding 2	dd	1	31	1	1
00C8		mm	1	12	1	1
00C9		yyyy	1992	2999	1	1
00CA	Peak demand time 3I2 Winding 2	ss	0	59	1	1
00CB		mm	0	59	1	1
00CC		hh	0	23	1	1
00CD	Peak demand date 3I2 Winding 2	dd	1	31	1	1
00CE		mm	1	12	1	1
00CF		yyyy	1992	2999	1	1
00D0	Peak demand time IR Winding 2	ss	0	59	1	1
00D1		mm	0	59	1	1
00D2		hh	0	23	1	1
00D3	Peak demand date IR Winding 2	dd	1	31	1	1
00D4		mm	1	12	1	1
00D5		yyyy	1992	2999	1	1
Peak Harmonic Current Time Stamp (see Note 6)						
00D6	Peak 2nd Harmonic time element 1	ss	0	59	1	1
00D7		mm	0	59	1	1
00D8		hh	0	23	1	1

Table I.19 Modbus Map (Sheet 7 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
00D9	Peak 2nd Harmonic date element 1	dd	1	31	1	1
00DA		mm	1	12	1	1
00DB		yyyy	1992	2999	1	1
00DC	Peak 2nd Harmonic time element 2	ss	0	59	1	1
00DD		mm	0	59	1	1
00DE		hh	0	23	1	1
00DF	Peak 2nd Harmonic date element 2	dd	1	31	1	1
00E0		mm	1	12	1	1
00E1		yyyy	1992	2999	1	1
00E2	Peak 2nd Harmonic time element 3	ss	0	59	1	1
00E3		mm	0	59	1	1
00E4		hh	0	23	1	1
00E5	Peak 2nd Harmonic date element 3	dd	1	31	1	1
00E6		mm	1	12	1	1
00E7		yyyy	1992	2999	1	1
00E8	Peak 5th Harmonic time element 1	ss	0	59	1	1
00E9		mm	0	59	1	1
00EA		hh	0	23	1	1
00EB	Peak 5th Harmonic date element 1	dd	1	31	1	1
00EC		mm	1	12	1	1
00ED		yyyy	1992	2999	1	1
00EE	Peak 5th Harmonic time element 2	ss	0	59	1	1
00EF		mm	0	59	1	1
00F0		hh	0	23	1	1
00F1	Peak 5th Harmonic date element 2	dd	1	31	1	1
00F2		mm	1	12	1	1
00F3		yyyy	1992	2999	1	1
00F4	Peak 5th Harmonic time element 3	ss	0	59	1	1
00F5		mm	0	59	1	1
00F6		hh	0	23	1	1
00F7	Peak 5th Harmonic date element 3	dd	1	31	1	1
00F8		mm	1	12	1	1
00F9		yyyy	1992	2999	1	1
00FA	Reserved					
00FB	Reserved					
00FC	Reserved					
00FD	Reserved					
00FE	Reserved					
00FF	Reserved					

Table I.19 Modbus Map (Sheet 8 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
Breaker Monitor Data						
0100	Internal Trip Counter Breaker 1					
0101	Internal Trip Current A Breaker 1	Amps	0	65535	1	1
0102	Internal Trip Current B Breaker 1	Amps	0	65535	1	1
0103	Internal Trip Current C Breaker 1	Amps	0	65535	1	1
0104	External Trip Counter Breaker 1					
0105	External Trip Current A Breaker 1	Amps	0	65535	1	1
0106	External Trip Current B Breaker 1	Amps	0	65535	1	1
0107	External Trip Current C Breaker 1	Amps	0	65535	1	1
0108	Internal Trip Counter Breaker 2					
0109	Internal Trip Current A Breaker 2	Amps	0	65535	1	1
010A	Internal Trip Current B Breaker 2	Amps	0	65535	1	1
010B	Internal Trip Current C Breaker 2	Amps	0	65535	1	1
010C	External Trip Counter Breaker 2					
010D	External Trip Current A Breaker 2	Amps	0	65535	1	1
010E	External Trip Current B Breaker 2	Amps	0	65535	1	1
010F	External Trip Current C Breaker 2	Amps	0	65535	1	1
Relay Time and Date						
0110 (RW) (see *Note* 2)	Time[b]	ss	0	59	1	1
0111 (RW)	[b]	mm	0	59	1	1
0112 (RW)	[b]	hh	0	23	1	1
0113 (RW)	Date[b]	dd	1	31	1	1
0114 (RW)	[b]	mm	1	12	1	1
0115 (RW)	[b]	yyyy	1992	2999	1	1
0116–011F	Reserved					
Relay Word						
0120	Targets Bit 0 = 1 if any of bits 8–15 are set to 1 Bit 0 = 0 if all of bits 8–15 are set to 0 Bits 1–7 = 0 Bit 8 = N Bit 9 = C-phase Bit 10 = B-phase Bit 11 = A-phase Bit 12 = 51 Bit 13 = 50 Bit 14 = 87 Bit 15 = Enable					

Table I.19 Modbus Map (Sheet 9 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0121	Contact Status					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = OUT4					
	Bit 9 = OUT3					
	Bit 10 = OUT2					
	Bit 11 = OUT1					
	Bit 12 = Alarm					
	Bit 13 = IN2					
	Bit 14 = IN1					
	Bit 15 = 0					
0122	Row 1					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = RB1					
	Bit 9 = 0					
	Bit 10 = 51N1T					
	Bit 11 = 51Q1T					
	Bit 12 = 51P1T					
	Bit 13 = 51N1P					
	Bit 14 = 51Q1P					
	Bit 15 = 51P1P					
0123	Row 2					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = 50N1H					
	Bit 9 = 50P1H					
	Bit 10 = 50N1T					
	Bit 11 = 50Q1T					
	Bit 12 = 50P1T					
	Bit 13 = 50N1P					
	Bit 14 = 50Q1P					
	Bit 15 = 50P1P					
0124	Row 3					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					

Table I.19 Modbus Map (Sheet 10 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
	Bit 8 = RB2					
	Bit 9 = 0					
	Bit 10 = 51N2T					
	Bit 11 = 51Q2T					
	Bit 12 = 51P2T					
	Bit 13 = 51N2P					
	Bit 14 = 51Q2P					
	Bit 15 = 51P2P					
0125	Row 4					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = 50N2H					
	Bit 9 = 50P2H					
	Bit 10 = 50N2T					
	Bit 11 = 50Q2T					
	Bit 12 = 50P2T					
	Bit 13 = 50N2P					
	Bit 14 = 50Q2P					
	Bit 15 = 50P2P					
0126	Row 5					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = 87R					
	Bit 9 = 87R3					
	Bit 10 = 87R2					
	Bit 11 = 87R1					
	Bit 12 = 87U					
	Bit 13 = 87U3					
	Bit 14 = 87U2					
	Bit 15 = 87U1					
0127	Row 6					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = RB3					
	Bit 9 = 87BL					
	Bit 10 = 5HB3					
	Bit 11 = 5HB2					

Table I.19 Modbus Map (Sheet 11 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
	Bit 12 = 5HB1					
	Bit 13 = 2HB3					
	Bit 14 = 2HB2					
	Bit 15 = 2HB1					
0128	Row 7					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = TRP3					
	Bit 9 = TRP2					
	Bit 10 = TRP1					
	Bit 11 = QDEM					
	Bit 12 = NDEM					
	Bit 13 = PDEM					
	Bit 14 = TH5T					
	Bit 15 = TH5P					
0129	Row 8					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = 52A2					
	Bit 9 = 52A1					
	Bit 10 = IN2					
	Bit 11 = IN1					
	Bit 12 = CC2					
	Bit 13 = CC1					
	Bit 14 = OC2					
	Bit 15 = OC1					
012A	Row 9					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = X					
	Bit 9 = XT					
	Bit 10 = Y					
	Bit 11 = YT					
	Bit 12 = MER					
	Bit 13 = MTU1					
	Bit 14 = MTU2					
	Bit 15 = MTU3					

Table I.19 Modbus Map (Sheet 12 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
012B	Row 10					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = RB4					
	Bit 9 = 0					
	Bit 10 = 51N2R					
	Bit 11 = 51Q2R					
	Bit 12 = 51P2R					
	Bit 13 = 51N1R					
	Bit 14 = 51Q1R					
	Bit 15 = 51P1R					
012C	Row 11					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bits 1–7 = 0					
	Bit 8 = OUT4					
	Bit 9 = OUT3					
	Bit 10 = OUT2					
	Bit 11 = OUT1					
	Bit 12 = ALARM					
	Bit 13 = 0					
	Bit 14 = 0					
	Bit 15 = 0					
012D	Row 12					
	Bits 0–15 = 0					
012E	Reserved					
012F	Reserved					
Commands (see Note 5)						
0130 (W)	Command Code		1	14		
0131 (W)	Parameter 1					
0132 (W)	Parameter 2					
0133–013F	Reserved					
History Records						
0140	Number of History Records[b]		1	20	1	1
0141 (RW)	History Selection[b]		1	20	1	1
0142	Event Time[b]	millisec	0	999	1	1
0143	[b]	ss	0	59	1	1
0144	[b]	mm	0	59	1	1
0145	[b]	hh	0	23	1	1

Table I.19 Modbus Map (Sheet 13 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0146	Event Date[b]	dd	1	31	1	1
0147	[b]	mm	1	12	1	1
0148	[b]	yyyy	1992	2999	1	1
0149	Event Type[a]	ASCII string				
014A		see *Note 3*				
014B						
014C						
014D	Event Code Type	see *Note 3*				
014E	Targets					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8–15 are set to 0					
	Bit 1–7 = 0					
	Bit 8 = N					
	Bit 9 = C-phase					
	Bit 10 = B-phase					
	Bit 11 = A-phase					
	Bit 12 = 51					
	Bit 13 = 50					
	Bit 14 = 87					
	Bit 15 = Enable					
014F	Reserved					
Event Reporting (see Note 4)						
0150	Number event records[b]	–	1	10	1	1
0151	Event selection[b]	–	1	10	1	1
0152	Channel selection[b]	–	1	19	1	1
0153	1/4 cycle[c]		–32767	32767	1	1
0154	1/2 cycle[c]		–32767	32767	1	1
0155	3/4 cycle[c]		–32767	32767	1	1
0156	1 cycle[c]		–32767	32767	1	1
0157	1 1/4 cycle[c]		–32767	32767	1	1
0158	1 1/2 cycle[c]		–32767	32767	1	1
0159	1 3/4 cycle[c]		–32767	32767	1	1
015A	2 cycle[c]		–32767	32767	1	1
015B	2 1/4 cycle[c]		–32767	32767	1	1
015C	2 1/2 cycle[c]		–32767	32767	1	1
015D	2 3/4 cycle[c]		–32767	32767	1	1
015E	3 cycle[c]		–32767	32767	1	1
015F	3 1/4 cycle[c]		–32767	32767	1	1
0160	3 1/2 cycle[c]		–32767	32767	1	1
0161	3 3/4 cycle[c]		–32767	32767	1	1

Table I.19 Modbus Map (Sheet 14 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0162	4 cycle[c]		–32767	32767	1	1
0163	4 1/4 cycle[c]		–32767	32767	1	1
0164	4 1/2 cycle[c]		–32767	32767	1	1
0165	4 3/4 cycle[c]		–32767	32767	1	1
0166	5 cycle[c]		–32767	32767	1	1
0167	5 1/4 cycle[c]		–32767	32767	1	1
0168	5 1/2 cycle[c]		–32767	32767	1	1
0169	5 3/4 cycle[c]		–32767	32767	1	1
016A	6 cycle[c]		–32767	32767	1	1
016B	6 1/4 cycle[c]		–32767	32767	1	1
016C	6 1/2 cycle[c]		–32767	32767	1	1
016D	6 3/4 cycle[c]		–32767	32767	1	1
016E	7 cycle[c]		–32767	32767	1	1
016F	7 1/4 cycle[c]		–32767	32767	1	1
0170	7 1/2 cycle[c]		–32767	32767	1	1
0171	7 3/4 cycle[c]		–32767	32767	1	1
0172	8 cycle[c]		–32767	32767	1	1
0173	8 1/4 cycle[c]		–32767	32767	1	1
0174	8 1/2 cycle[c]		–32767	32767	1	1
0175	8 3/4 cycle[c]		–32767	32767	1	1
0176	9 cycle[c]		–32767	32767	1	1
0177	9 1/4 cycle[c]		–32767	32767	1	1
0178	9 1/2 cycle[c]		–32767	32767	1	1
0179	9 3/4 cycle[c]		–32767	32767	1	1
017A	10 cycle[c]		–32767	32767	1	1
017B	10 1/4 cycle[c]		–32767	32767	1	1
017C	10 1/2 cycle[c]		–32767	32767	1	1
017D	10 3/4 cycle[c]		–32767	32767	1	1
017E	11 cycle[c]		–32767	32767	1	1
017F	11 1/4 cycle[c]		–32767	32767	1	1
0180	11 1/2 cycle[c]		–32767	32767	1	1
0181	11 3/4 cycle[c]		–32767	32767	1	1
0182	12 cycle[c]		–32767	32767	1	1
0183	12 1/4 cycle[c]		–32767	32767	1	1
0184	12 1/2 cycle[c]		–32767	32767	1	1
0185	12 3/4 cycle[c]		–32767	32767	1	1
0186	13 cycle[c]		–32767	32767	1	1
0187	13 1/4 cycle[c]		–32767	32767	1	1
0188	13 1/2 cycle[c]		–32767	32767	1	1
0189	13 3/4 cycle[c]		–32767	32767	1	1

Table I.19 Modbus Map (Sheet 15 of 16)

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
018A	14 cycle[c]		–32767	32767	1	1
018B	14 1/4 cycle[c]		–32767	32767	1	1
018C	14 1/2 cycle[c]		–32767	32767	1	1
018D	14 3/4 cycle[c]		–32767	32767	1	1
018E	15 cycle[c]		–32767	32767	1	1
Event Summary Data						
018F	Event type[a]	ASCII string				
0190		see *Note 3*				
0191						
0192						
0193	Event type code	see *Note 3*				
0194	Event time[b]	millisec	0	999	1	1
0195	[b]	ss	0	59	1	1
0196	[b]	mm	0	59	1	1
0197	[b]	hh	0	23	1	1
0198	Event date[b]	dd	1	31	1	1
0199	[b]	mm	1	12	1	1
019A	[b]	yyyy	1992	2999	1	1
019B	Targets					
	Bit 0 = 1 if any of bits 8–15 are set to 1					
	Bit 0 = 0 if all of bits 8-15 are set to 0					
	Bit 1–7 = 0					
	Bit 8 = N					
	Bit 9 = C-phase					
	Bit 10 = B-phase					
	Bit 11 = A-phase					
	Bit 12 = 51					
	Bit 13 = 50					
	Bit 14 = 87					
	Bit 15 = Enable					
019C	Event duration	Cycles	1	16	1	1
019D	Event current A-phase Winding 1	Amps	0	65535	1	
019E	Event current B-phase Winding 1	Amps	0	65535	1	
019F	Event current C-phase Winding 1	Amps	0	65535	1	
01A0	Event negative-sequence current Winding 1	Amps	0	65535	1	
01A1	Event residual current Winding 1	Amps	0	65535	1	
01A2	Event current A-phase Winding 2	Amps	0	65535	1	
01A3	Event current B-phase Winding 2	Amps	0	65535	1	
01A4	Event current C-phase Winding 2	Amps	0	65535	1	
01A5	Event negative-sequence current Winding 2	Amps	0	65535	1	

Table I.19 Modbus Map (Sheet 16 of 16)

Address (Hex)	Field	Units	Range Low	Range High	Range Step	Scale Factor
01A6	Event residual current Winding 2	Amps	0	65535	1	
01A7–01AF	Reserved					
Maximum Current Limit						
01B0	Phase current[d]	Amps	–32767	32767	1	1
01B1	Phase current[e]	Exponent	–4	4	1	1
01B2	Neutral current[d]	Amps	–32767	32767	1	1
01B3	Neutral current[e]	Exponent	–4	4	1	1
01B4–01BF	Reserved					
Communication Counter						
01C0	Number of messages received[b]	–	0	65535	1	1
01C1	Number of messages sent to other devices[b]	–	0	65535	1	1
01C2	Invalid address[b]	–	0	65535	1	1
01C3	Bad CRC[b]	–	0	65535	1	1
01C4	UART error[b]	–	0	65535	1	1
01C5	Illegal function code/Op code[b]	–	0	65535	1	1
01C6	Illegal register[b]	–	0	65535	1	1
01C7	Illegal write[b]	–	0	65535	1	1
01C8	Bad packet format[b]	–	0	65535	1	1
01C9	Bad packet length[b]	–	0	65535	1	1
01CA	Reserved					
01CB	Reserved					
|	Reserved					
|	Reserved					
1FFB	Device tag #[b]	15044	–	–	–	–
1FFC	Feature set ID[b]	0				
1FFD	Reserved					
|	Reserved					
FFFF	Reserved					

[a] Two 8-bit ASCII characters per register.
[b] 16-bit unsigned value.
[c] 16-bit signed value.
[d] Two 16-bit registers needed to accomplish the Signed Integer Dynamic Fixed Point data format. Final value read = ($R1 \cdot 10^{R2}$).
[e] R1 is the content of register 01B0h (01B2h). R2, which is stored in 01B1h (01B3h), determines the decimal point position for the final value.

Note 1

Reserved addresses return 8000h.

Note 2

Registers (RW) are read-write registers. Registers (W) are write-only registers. All other registers are read-only.

Note 3

Event Types

ASCII String	Code
TRP1	93
TRP2	94
TRP3	95
MER	70
PULSE	92
TRIG	15

Note 4

The Modbus map (*Table I.19*) provides a feature that allows you to download complete event data via Modbus. See *Table I.18* for data descriptions.

Note 5

Refer to *Table I.17* for a list of command codes.

Note 6

Peak values must be read before reading the corresponding Time Stamp. Failure to do so will result in the returned values for Time Stamp being 8000h.

General Comments

All registers are 16 bits with bit locations ranging from 0 to 15.

Relay words, targets, and contact status are mapped in bit positions 8–15 in the register. The 0 bit position of this register is set equal to 1 if any of the 1–15 positions are set to 1.

Appendix J
PC Software

Overview

NOTE: PC software is updated more frequently than relay firmware. As a result, the descriptions in this section may differ slightly from the software. Select **Help** in the PC software for information.

SEL provides many PC software solutions (applications) that support SEL devices. These software solutions are listed in *Table J.1*.

Visit selinc.com to obtain the latest versions of the software listed in *Table J.1*.

Table J.1 SEL Software Solutions

Product Name	Description
SEL Compass®	This application provides an interface for web-based notification of product updates and automatic software updating.
ACSELERATOR QuickSet® SEL-5030 Software	QuickSet is a powerful setting, event analysis, and measurement tool that aids in applying and using the relay. See the *ACSELERATOR QuickSet SEL-5030 Software Instruction Manual* for information about the various QuickSet applications.[a]
ACSELERATOR Architect® SEL-5032 Software	Use this application to design and commission SEL IEDs in IEC 61850 substations, create and map GOOSE messages, utilize predefined reports, create and edit data sets, and read in SCD, ICD, and CID files.
ACSELERATOR TEAM® SEL-5045 Software	The TEAM system provides custom data collection and movement of a wide variety of device information. The system provides tools for device communication, automatic collection of data, and creation of reports, warnings, and alarms. See *ACSELERATOR Team SEL-5045 Software Instruction Manual* for information about the various TEAM applications.
SEL-5601-2SYNCHROWAVE® Event Software	Converts SEL Compressed ASCII and COMTRADE event report files to oscillography.
Cable Selector SEL-5801 Software	Selects the proper SEL cables for your application.

[a] The SEL-587 does not support the freeform logic described in the QuickSet instruction manual.

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Appendix K
Cybersecurity Features

Introduction and Security Environment

Product Function

The SEL-587 is a protective relay that has two serial communications ports. The serial ports allow you to access three password-protected access levels for the device that provide different capabilities. The communications protocols available on the SEL-587 allow the device to periodically communicate information like relay status or metering quantities to other devices such as a SCADA client. The available communications protocols also allow for local engineering access via a terminal connection.

Security Requirements

The SEL-587 is designed to be applied in secure environments like substation control houses, switchyards, or similar control facilities. Only permit authorized personnel physical or remote access to the relay. Depending on relay configuration, the SEL-587 has one or two serial ports for local or remote access. Restrict communications to the SEL-587 to trusted network segments that are isolated from the internet.

Version Information

Obtaining Version Information

To determine the firmware version, view the status report by using the serial port **STATUS** command or the front-panel **STATUS** pushbutton. The status report displays the Firmware Identification (FID) number.

For firmware versions prior to date code 20010406, the status report displays the following FID number:

FID=SEL-587**-1-Rxxx-Vxb-Dxxxxxx**

For firmware versions with the date code of 20010406, or later, the status report displays the following FID number:

FID=SEL-587**-1-Rxxx-Vxb-Z001001-Dxxxxxxxx** (SEL-587-1)

FID=SEL-587**-0-Rxxx-Vxb-Z001001-Dxxxxxxxx** (SEL-587-0)

The firmware revisions number is after the R, and the date code is after the D. The single x after the V is a 1 for a 1 A relay and 5 for a 5 A relay.

Firmware series R101–R1*xx* and R401–R4*xx* are stored in through-hole EPROM. Firmware series R500–R7*xx* are stored in SMT (surface-mount technology) EPROM. Firmware series R8*xx* are stored in FLASH.

Appendix A: Firmware and Manual Versions includes the release notes for every firmware version. More firmware version information, including identification of the current version and identification of compatible SELBOOT versions, is available at selinc.com/products/firmware/.

Integrity Indicators

The **ID** command displays the firmware checksum identifier (CID). Use the Firmware Tools page on the SEL website to verify the CID values for the SEL-587.

Commissioning and Decommissioning

Commissioning

All serial ports of the SEL-587 are enabled by default and cannot be disabled.

Secure Operation Recommendations

The SEL-587 provides a physical ALARM output contact that you can use to monitor relay diagnostic failures or access to the relay. If a diagnostic self-test results in the relay disabling protection, the ALARM output contact asserts and provides an external indication of the relay failure. When you log in at Access Level 2 or C, the ALARM output contact pulses for 1 second. If access is denied, the ALARM contact pulses for 1 second.

Good operating practice is to always monitor the physical state of the ALARM output contact.

Decommissioning

It is often desirable to erase settings and data from a relay when it is removed from service. You can completely erase all the settings and data from the SEL-587 by using the following procedure:

Step 1. Log in at Access Level 2, and use the **CAL** command to log in to Access Level C.

Step 2. Execute the **R_S** command.

Step 3. Allow the relay to restart.

Once this procedure is complete, all settings, passwords, and other data are erased; and you can return the relay to inventory, redeploy it, or dispose of it.

Returning Protective Relays for Service

When returning protective relays to SEL for service, preserve the data stored in the relay because it is needed to diagnose many problems.

One option is to leave data in the relay but specify special handling to protect the data. The online return merchandise authorization (RMA) form contains an option for special BES Cyber Asset handling. Ensure that the RMA number generated during the return process appears on the exterior of the shipping container. The shipping method you choose should provide tracking information and delivery confirmation.

If your processes do not permit the relay to be shipped with the settings intact, the other option is to export settings and data from the relay, and then erase the data from the relay as described in Decommissioning. You can send the data to SEL separately from the relay by coordinating with an SEL application engineer or customer service representative to use SEL's secure file transfer service (securefile.selinc.com). Include the RMA number for the associated product in the file name.

Prior to return shipping of your BES Cyber Asset, SEL follows NIST Special Publication 800-88 Revision 1 guidelines to ensure secure handling and destruction of all customer data before returning the unit. The returned unit will also be packaged by using tamper-evident tape or a similar device. The shipping service will provide tracking information and delivery confirmation.

External Interfaces

Ports and Services

The SEL-587 models have one or two serial ports, as described in the following paragraphs. All physical ports of the relay are enabled by default and cannot be disabled. No SEL-587 models have an Ethernet interface.

- The SEL-587 models with firmware revision R704 and earlier have one rear serial port. The serial port can be either EIA-232 or EIA-485 depending on the ordered option.
- The SEL-587 models with firmware revision R800 and later have one front-panel serial port and one rear serial port. The rear serial port can be either EIA-232 or EIA-485 depending on the ordered option. The front-panel serial port is always EIA-232.

The SEL-587 provides the following software communications protocols.

Protocol	Description
SEL ASCII Protocol	Designed for manual and automatic communications.
SEL Distributed Port Switch Protocol (see *Appendix C: SEL Distributed Port Switch Protocol*)	Permits multiple SEL relays to share a common communications channel.
SEL Fast Meter Protocol (see *Appendix D: Configuration, Fast Meter, and Fast Operate Commands*)	Supports binary messages to transfer metering and control messages.
SEL Compressed ASCII Protocol (see *Appendix E: Compressed ASCII Commands*)	Provides compressed versions of some of the relay ASCII commands.
Modbus RTU Communications Protocol (see *Appendix I: Modbus RTU Communications Protocol*)	Permits multiple IEDs to share a common communications channel.

Firmware Upgrade Interface

The SEL-587 firmware upgrade interface includes a firmware loader program called SELBOOT. To upgrade firmware, use the SELBOOT program to download an SEL-supplied firmware file from a PC to the relay through one of the serial ports. Refer to *Appendix B: Firmware Upgrade Instructions* for more information.

Access Controls

Privilege Levels

The SEL-587 has four access levels. Three access levels require separate passwords that allow administrators to restrict access to users authorized for the capabilities those levels provide.

Centrally Managed Accounts

The SEL-587 does not support centrally managed accounts.

Local Accounts (or Access Levels)

The SEL-587 supports the following four access levels. These access levels cannot be edited.

- **Access Level 0**: The lowest access level that provides limited read-only functions for unauthenticated users.
- **Access Level 1**: Allows you to look at more information such as settings and metering but still read-only.

- **Access Level 2**: Allows you to change relay settings.
- **Access Level C**: Restricted access level for specific maintenance functions, some of which should be used only under the direction of SEL.

Passwords

The SEL-587 ships with default passwords in place for each access level that you should change at installation. *Table K.1* lists the factory-default passwords for Access Levels 1, 2, and C.

Table K.1 Access Levels and Passwords

Access Level	Factory-Default Password
1	587
2	587
C[a]	332

[a] Use Access Level C only under the direction of SEL.

Change the default passwords at installation. Failure to set non-default passwords for all access levels may allow unauthorized access. SEL is not responsible for any damage resulting from unauthorized access.

For firmware revisions R105/R405 or later, passwords may include as many as six characters. Valid characters consist of A–Z, a–z, 0–9, "-", and ".". Upper- and lowercase letters are treated as different characters.

For firmware revisions R103/R402 or earlier, passwords may include three numbers. Valid numbers consist of 0–9. Valid passcodes are numbers ranging from 000 to 999.

If the passwords are lost or you want to operate the relay without password protection, put the main board password jumper (**JMP22**) in place (password jumper = ON). Refer to *Circuit Board Jumpers and Battery on page 2.11* for password jumper information.

X.509 Certificates

The SEL-587 does not support X.509 certificates.

Physical Access Controls

The SEL-587 has no physical access controls. However, you can monitor physical ingress by wiring a door sensor to one of the SEL-587 contact inputs. This input can then be mapped for SCADA monitoring or added to the MER equation so that you can monitor when physical access to the relay occurs. You also can wire an electronic latch to an SEL-587 contact output and then map this output for SCADA control.

Logging Features

Security Events

When you log in to the SEL-587 at Access Level 2, the ALARM Relay Word bit asserts to logical 1 for 1 second and the ALARM output contact coil is de-energized for 1 second.

The ALARM Relay Word bit can be mapped for SCADA monitoring. The ALARM output contact can be physically monitored to provide a notification of when Access Level 2 is reached.

Internal Log Storage

The SEL-587 does not provide security logs to notify users of the storage capacity of the relay or indications that the storage capacity is full. The SEL-587 self-manages its memory storage capacity for each of the event recording features by overwriting older entries first when storage is full.

The relay generates (triggers) standard 15-cycle event reports by using fixed and programmable conditions. These reports show information for 15 continuous cycles. The relay stores event summaries for the 20 latest events and full-length reports for the 10 latest events in nonvolatile memory. If more reports are triggered, the latest event report overwrites the oldest event report.

Syslog

The SEL-587 does not support Syslog functionality.

Alarm Contact

When the relay is operational, the ALARM output contact coil is energized. The alarm logic and circuitry keep the ALARM output contact coil energized. Depending on the ALARM output contact type (a or b) the ALARM output contact closes or opens. An a type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A b type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

To verify the mechanical integrity of the ALARM output contact, execute the serial port command **PULSE ALARM**. Executing this command de-energizes the ALARM output contact coil for 1 second.

The ALARM Relay Word bit deasserts to logical 0 when the relay is operational. When the **PULSE ALARM** command is executed, the ALARM Relay Word bit asserts to logical 1 for 1 second. Also, when you enter Access Level 2, the ALARM Relay Word bit asserts to logical 1 for 1 second (and the ALARM output contact coil is de-energized for 1 second).

The SEL-587 operates the ALARM output contact if three consecutive incorrect password attempts are made at any access level.

Backup and Restore

The SEL-587 supports the backup and restoration of settings. The Read and Send functions are available in the ACSELERATOR QuickSet SEL-5030 Software. Connect the SEL-587 to a PC that has the latest version of QuickSet installed. Once communications are established, read the settings from the SEL-587 and save them as a .rdb file. You can open settings files with the .rdb extension and send them back to SEL-587 relays with the same part number and firmware configuration.

Malware Protection Features

The SEL-587 is an embedded product that includes the following features to protect against malware:

- **Use of an embedded environment that allows neither installation nor execution of new programs.** SEL embedded devices cannot load or run new programs. These devices also run memory integrity checks to ensure that the running program has not been altered.
- **Verification of software stored in permanent memory.** When the device starts, it performs a detailed checksum of the contents of permanent memory and verifies the checksum value to verify integrity.
- **Firmware hashes.** SEL provides firmware hashes as a tool to verify the integrity of SEL-587 firmware files prior to installation. Visit selinc.com/products/firmware to perform firmware file hash verification.

For questions or concerns about the malware protection features of a specific firmware revision, contact SEL.

Product Updates

The most recent instruction manual release is available on selinc.com for download. *Appendix A: Firmware and Manual Versions* contains the latest product updates.

The *Appendix A: Firmware and Manual Versions* entries for firmware versions released after March 1, 2022, adds the [Cybersecurity] tag to each firmware change that is related to a security vulnerability, and [Cybersecurity Enhancement] to other cybersecurity improvements.

Obtain information regarding security vulnerabilities at selinc.com/security_vulnerabilities/.

Obtaining Updates

Contact your local SEL customer service representative for firmware updates for the SEL-587.

Update Verification

A terminal **ID** command gives users a firmware CID for the firmware installed in a running relay. Additionally, SEL provides firmware hashes as a tool to verify the integrity of firmware files. Visit selinc.com/products/firmware to verify firmware CID and hash values.

Contact SEL

For further questions or concerns about SEL product security, contact SEL.

Email: security@selinc.com

Phone: +1 (509) 332-1890

SEL-587-0, -1 Relay Command Summary

Command	Description
Access Level 0 Commands The only thing that can be done at Access Level 0 is to go to Access Level 1. The screen prompt is =	
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
Access Level 1 Commands The Access Level 1 commands primarily allow the user to look at information (e.g., settings, metering, etc.), not change it. The screen prompt is =>	
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
BRE	View breaker monitor trip counter and trip current data for a specified breaker
CEV	Causes the relay to generate a compressed event report
DAT	Show date presently in the relay
DAT *m/d/y*	Enter date in this manner if Date Format setting DATE_F = MDY
DAT *y/m/d*	Enter date in this manner if Date Format setting DATE_F = YMD
EVE *n*	Show standard 15-cycle event report number *n*, with 1/4-cycle resolution (*n* = 1 through 20, with *n* = 1 most recent)
EVE L *n*	Show standard 15-cycle event report number *n*, with 1/16-cycle resolution (*n* = 1 through 20, with *n* = 1 most recent)
EVE L C *n*	Causes the relay to add digital data at the end of the EVENT L *n* report
EVE R *n*	Causes the relay to display an unfiltered event report with 1/16-cycle sampling
EVE R C *n*	Causes the relay to add digital data at the end of the EVENT R *n* report
HIS *n*	Show brief summary of the *n* latest standard 15-cycle event reports
HIS C	Clear the brief summary and corresponding standard 15-cycle event reports
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input
MET *n*	Display instantaneous metering data. Enter *n* to scroll metering *n* times on screen.
MET D *n*	Display demand data. Enter *n* to scroll metering *n* times on screen. Select **MET RD *n*** to reset.
MET DIF *n*	Display differential element quantities. Enter *n* to scroll metering *n* times on screen.
MET P *n*	Display peak demand data. Enter *n* to scroll metering *n* times on screen. Select **MET RP *n*** to reset.
MET PH *n*	Display peak harmonic (PH) current values. Enter *n* to scroll metering n times on screen. Select **MET RPH** to reset.
MET SEC *n*	Display secondary magnitude and angle for phase, negative-sequence, and residual currents. Enter *n* to scroll metering *n* times on screen.
QUI	Quit to Access Level 0. Returns front-panel LEDs to the default targets (corresponding to command **TAR 0**).
SHO	Display relay settings (overcurrent, reclosing, timers, etc.)
SHO L	Show SELOGIC® control equation settings
SHO P *n*	Show port settings (*n* = 1, F)
STA	Display self-test status. **STA C** resets self-test warnings/failures.
TAR # *n*	Display Relay Word row # status (# = 0 through 11) on remapped front-panel LED targets. Enter number *n* to scroll Relay Word row # status *n* times on screen.
TAR R	Return front-panel LED targets to regular operation and reset the **FAULT TYPE** front-panel targets

Command	Description
TIM	Show or set time (24 hour time). Show time presently in the relay by entering just **TIM**. Example time 22:47:36 is entered with command **TIM 22:47:36**.
TRI	Trigger an event report
Access Level 2 Commands The Access Level 2 commands primarily allow the user to change settings or operate relay parameters and output contacts. All Access Level 1 commands can also be executed from Access Level 2. The screen prompt is =>>	
BRE *n* R	Reset breaker *n* (*n* = 1, 2) monitor trip counters and trip current data
CLO *n*	Assert the close (CC*n*) Relay Word bit, where *n* = 1, 2. If CC*n* is assigned to an output contact (e.g., OUT2 = CC1), then the output contact will assert if command **CLO *n*** is executed and the circuit breaker is open.
CON *n*	Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1 through 4). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following: **SRB *n*** set Remote Bit *n* (assert RB*n*) **CRB *n*** clear Remote Bit *n* (deassert RB*n*) **PRB *n*** pulse Remote Bit *n* (assert RB*n* for one processing interval [1/8 cycle])
OPE *n*	Valid only if TDURD > 0. Assert the open (OC*n*) Relay Word bit, where *n* = 1, 2. If OC*n* is assigned to an MTU*n* Relay Word bit and the associated TRP*n* Relay Word bit is assigned to an output contact (e.g., OUT1 = TRP1), then the output contact will assert if command **OPE *n*** is executed.
PAS	Show existing Access Level 1 and Access Level 2 passwords
PAS 1	View Access Level 1 password
PAS 2	View Access Level 2 password
PAS 1 *xxxxxx*	Change Access Level 1 password to *xxxxxx*
PAS 2 *xxxxxx*	Change Access Level 2 password to *xxxxxx*
PUL *n m*	Pulse output contact *n* (*n* = 1, 2, 3, 4, and ALARM). Enter number *m* to pulse for *m* seconds (*m* = 1 to 30 [seconds]), otherwise pulse time is 1 second.
RES *n*	Reset time-overcurrent elements for Winding *n* (*n* = 1, 2)
SET *n*	View or change relay settings (overcurrent, reclosing, timers, etc.)
SET L *n*	View or change SELOGIC control equation settings
SET P *n*	View or change port settings (*n* = 1, F)

SEL-587-0, -1 Relay Command Summary

Command	Description
Access Level 0 Commands The only thing that can be done at Access Level 0 is to go to Access Level 1. The screen prompt is =	
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
Access Level 1 Commands The Access Level 1 commands primarily allow the user to look at information (e.g., settings, metering, etc.), not change it. The screen prompt is =>	
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
BRE	View breaker monitor trip counter and trip current data for a specified breaker
CEV	Causes the relay to generate a compressed event report
DAT	Show date presently in the relay
DAT *m/d/y*	Enter date in this manner if Date Format setting DATE_F = MDY
DAT *y/m/d*	Enter date in this manner if Date Format setting DATE_F = YMD
EVE *n*	Show standard 15-cycle event report number *n*, with 1/4-cycle resolution (*n* = 1 through 20, with *n* = 1 most recent)
EVE L *n*	Show standard 15-cycle event report number *n*, with 1/16-cycle resolution (*n* = 1 through 20, with *n* = 1 most recent)
EVE L C *n*	Causes the relay to add digital data at the end of the EVENT L *n* report
EVE R *n*	Causes the relay to display an unfiltered event report with 1/16-cycle sampling
EVE R C *n*	Causes the relay to add digital data at the end of the EVENT R *n* report
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HIS C	Clear the brief summary and corresponding standard 15-cycle event reports
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SET L *n*	View or change SELOGIC control equation settings
SET P *n*	View or change port settings (*n* = 1, F)