

SEL-587-0, -1

**CURRENT DIFFERENTIAL RELAY
OVERCURRENT RELAY**

INSTRUCTION MANUAL

SCHWEITZER ENGINEERING LABORATORIES
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CAUTION: The relay contains devices sensitive to electrostatic discharge (ESD). When working on the relay with front or top cover removed, work surfaces and personnel must be properly grounded or equipment damage may result.



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



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 reenergize the relay with an IC reversed, do not place the relay in service using that IC, even if you correct the orientation.



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



DANGER: Removal of relay front panel exposes circuitry which may cause electrical shock that can result in injury or death.



DANGER: Contact with instrument terminals may cause electrical shock which can result in injury or death.



ATTENTION: Le relais contient des pièces sensibles aux décharges électrostatiques (DES). Quand on travaille sur le relais avec le panneau avant ou du dessus enlevé, les surfaces de travail et le personnel doivent être mis à la terre convenablement pour éviter les dommages à l'équipement.



ATTENTION: Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.



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.



AVERTISSEMENT: Cet équipement 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 non-autorisé à l'équipement pourrait être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès non-autorisé.



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: Le contact avec les bornes de l'instrument peut causer un choc électrique pouvant entraîner des blessures ou la mort.

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The English language manual is the only approved SEL manual.

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This product is covered by U.S. Patent Numbers: 5,208,545; 5,317,472; 5,479,315. U.S. Patent(s) Pending, and Foreign Patent(s) Granted and Pending.

This product is covered by the standard SEL 10-year warranty. For warranty details, visit www.seline.com or contact your customer service representative.

MANUAL CHANGE INFORMATION

The date code at the bottom of each page of this manual reflects the creation or revision date. Date codes are changed only on pages that have been revised and any following pages affected by the revisions (i.e., pagination). If significant revisions are made to a section, the date code on all pages of the section will be changed to reflect the revision date.

Each time revisions are made, both the main table of contents and the affected individual section table of contents are regenerated and the date code is changed to reflect the revision date.

Changes in this manual to date are summarized below (most recent revisions listed at top).

Revision Date	Summary of Revisions
	<p>The <i>Manual Change Information</i> section has been created to begin a record of revisions to this manual. All changes will be recorded in this Summary of Revisions table.</p>
20010606	<p>Made a typographical change in <i>Section 3: Relay Elements</i>.</p> <p>Made typographical changes and corrected <i>Figure 4.2: Close Logic Diagram</i> in <i>Section 4: Tripping, Closing, and Targeting Logic</i>.</p> <p>Corrected table cross reference and updated serial port <i>Settings Sheets</i> in <i>Section 5: Setting the Relay</i>.</p> <p>Added references to Modbus[®] protocol and information about strong passwords in <i>Section 6: Operator Interface</i>.</p> <p>Made typographical changes in <i>Section 7: Event Reports</i>.</p> <p>Improved description of Harmonic Blocking Function Test in <i>Section 8: Testing and Troubleshooting</i>.</p> <p>Updated <i>Appendix A: Firmware Revisions</i> to include the release of firmware R600 and R650 (add Modbus protocol) and the release of firmware R502 and R552.</p> <p>Included “CHANNEL” string in <i>CMETER PH Command</i> in <i>Appendix E: Compressed ASCII Commands</i>.</p> <p>Added <i>Appendix I: Modbus[®] RTU Communications Protocol</i>.</p>
20001110	<p>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.</p> <p><i>Section 1: Introduction and Specifications</i> corrected power supply, processing, metering, and differential specifications; added tightening torque and terminal connections specifications.</p> <p><i>Section 2: Installation</i> 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.</p>

Revision Date	Summary of Revisions
20001110 (continued)	<p>Settings Sheets clarified that the sheets apply to both the SEL-587-0 Relay and the SEL-587-1 Relay.</p> <p>Section 6: Operator Interface 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 (page 6-7) and time (page 6-14), and made typographical corrections to SEL-587 Relay Command Summary.</p> <p>Section 7: Events Reports explained the HIS command, the processing rate of the relay, quarter-cycle and eighth-cycle event reports, and the various options available with the EVE command.</p> <p>Section 8: Testing and Troubleshooting clarified Differential Element Pickup Test: 87U, 87R.</p> <p>Appendix B: Firmware (EPROM) Upgrade Instructions made typographical correction.</p>
20000616	<p>Section 3: Relay Elements, corrected Figure 3.7 on page 3-5.</p> <p>Section 6: Operator Interface, added descriptions of DATE and TIME commands.</p> <p>Appendix A: Firmware Versions, made formatting change.</p> <p>Appendix B: Firmware (EPROM) Upgrade Instructions, updated instructions.</p> <p>Appendix D: Configuration, Fast Meter, and Fast Operate Commands, made corrections.</p> <p>Appendix E: Compressed ASCII Commands, inserted event description that had been inadvertently omitted.</p>
20000505	<p>Section 1: Introduction and Specifications, updated specifications subsection.</p> <p>Section 3: Relay Elements, reorganized section for consistency and to add 87U drawing, SEL-587-0 Differential Element (87BL1) Blocking Logic drawing, overcurrent logic drawings, and setting descriptions.</p> <p>Section 4: Tripping, Closing, and Targeting Logic, fixed the Close Logic Diagram text, added Output Contact Functions subsection, modified Relay Targets subsection for target logic enhancements.</p> <p>Section 5: Setting the Relay, removed Current Transformer subsection and extra MER setting from Settings Sheet.</p> <p>Section 8: Testing and Troubleshooting, added clarifying information in Harmonic Blocking Function Test: PCT2, PCT4, and PCT5 Setting.</p> <p>Appendix A: Firmware Versions, updated.</p> <p>Appendix H: SEL-587 Relay Commissioning Test Worksheet, corrected typographical error.</p>

Revision Date	Summary of Revisions
991215	Added SEL-587-1, reorganized manual, and reissued complete manual.
991115	<p>Section 1: General Specifications, made minor corrections throughout section.</p> <p>Section 2: Mounting and Connections, 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.</p> <p>Section 4: Relay Application and Section 6: Operator Interface reissued due to cross-reference changes.</p> <p>Section 8: Testing, added Relay Self-Tests section.</p> <p>Inserted new Appendix B: Firmware Upgrade Instructions, relettered appendices following Appendix B.</p>
990715	Section 4: Settings Sheets . Updated format; combined 1 Amp and 5 Amp settings sheets. Tabs added to manual.
990521	Section 2: Mounting and Connections , Page 2-4. Corrected output labels on Figure 2.6.
990423	Reissued Main Table of Contents.
990322	Section 1: General Specifications , Pages 1-5 and 1-6. Corrected printer symbol error: replaced 0 (zero) with degree sign.
981019	<p>Reissued complete manual. Updates and corrections in formatting.</p> <p>Section 2: Mounting and Connections, Updated Drill Plans and rear-panel drawings, added information regarding part numbers.</p> <p>Section 4: Relay Application, Operating Current PU (O87P) - Clarification.</p>
980626	<p>Section 1, General Specifications, Page 5 - Removed note to show availability of 250 V “Level-Sensitive” inputs. Changed 250 Vdc dropout from 200 to 150 Vdc.</p> <p>Section 2, Two Rear-Panel Options, Page 4 - Added “10 A for L/R = 20 ms at 250 Vdc.”</p> <p>Section 2, Circuit Board Jumpers and Battery, Page 7 - Removed note to show availability of 250 V “Level-Sensitive” inputs.</p>

Revision Date	Summary of Revisions
970725	<p>Section 1, General Specifications, Pages 3-7 - Extensively reformatted for clarification.</p> <p>Section 1, General Specifications, Pages 6-7 - Reformatted the existing type tests and standards for clarification and added the following to Type Tests and Standards:</p> <ul style="list-style-type: none"> 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 <p>Section 1, General Specifications, Pages 4-5 - Added 24-volt power supply ratings to Output Contacts, Optoisolated Input Ratings, and Power Supply Ratings.</p> <p>Section 3, Differential Element Settings, Table 3.1, Page 4 - Added/clarified constraints for settings 087P, U87P, and TH5.</p> <p>Section 4, Pages 5-9, Added/clarified constraints for settings 087P, U87P, and TH5.</p> <p>Section 4, Overcurrent Element Measurands, Page 9 - Deleted incorrect instruction.</p>
970611	<p>EC Declaration of Conformity - Addition as addendum.</p> <p>Section 1: General Specifications, Page 1-3 through 1-6, - general corrections, clarification and consistency edits.</p>
970528	<p>Section 1, Page 3, General Specifications - corrected CT 1 second rating in AC Input Currents.</p> <p>Appendix A - Corrected event type indication to include TRP1 when TRP1 asserts during an event, but does not trigger the event.</p>
970414	<p>Instruction Manual Change Record - Removed from Instruction Manual - Replaced with this Manual Change Information document.</p> <p>Section 2, Page 8 - Passcode and Breaker Control Command Jumpers - Clarification.</p> <p>Section 8, Page 12 - Troubleshooting Procedure - Revise steps to adjust LCD contract.</p>

SEL-587 INSTRUCTION MANUAL

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SECTION 1: INTRODUCTION AND SPECIFICATIONS

INTRODUCTION

The SEL-587 Relay is available as either an SEL-587-0 or SEL-587-1 Relay. 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 Relay 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 Differential Relay 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 99-07 Bus Protection Using a Four-Winding Low-Impedance Percentage Differential Relay* from the SEL web site (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 using the front panel.

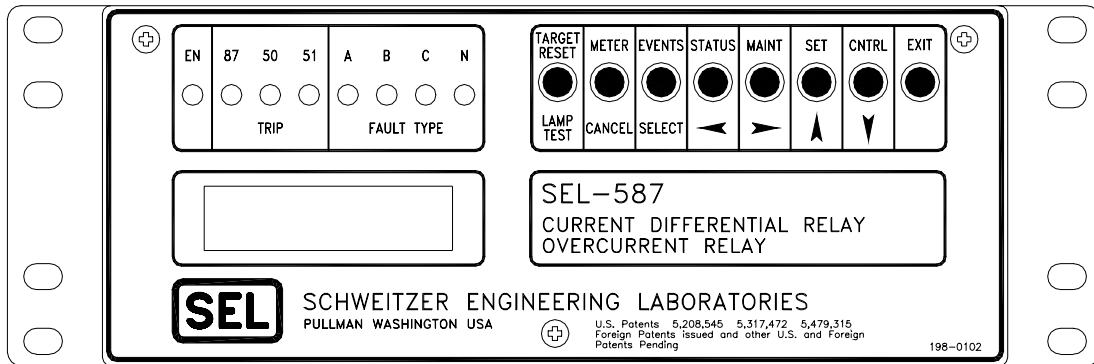
Section 7: Event Reports for a description of event report generation, summary event reports, long event reports, and their interpretation.

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

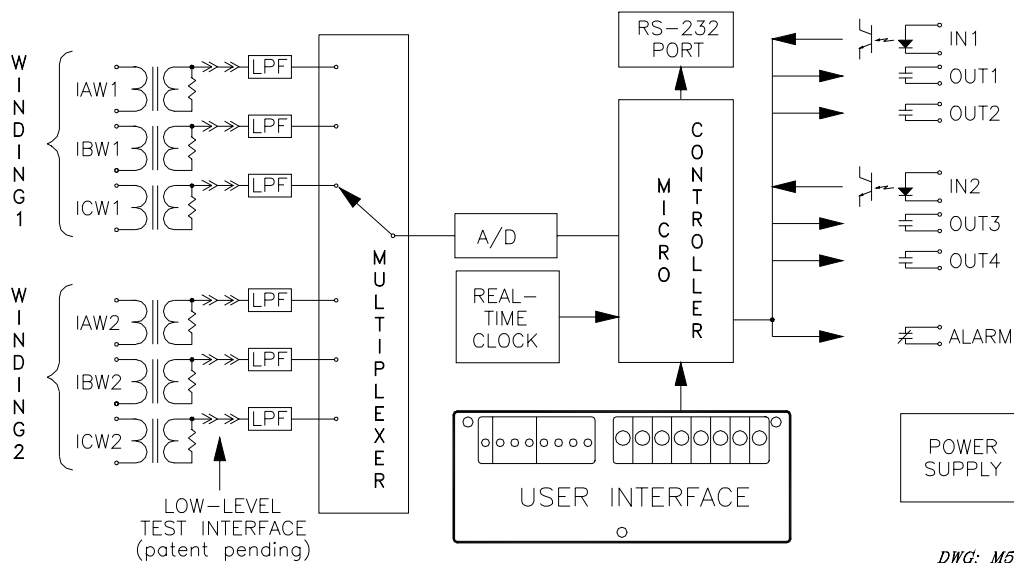
Figure 1.1 shows the front panel of both the SEL-587-0 and SEL-587-1 Relays.



DWG. 11096

Figure 1.1: SEL-587 Relay Front Panel

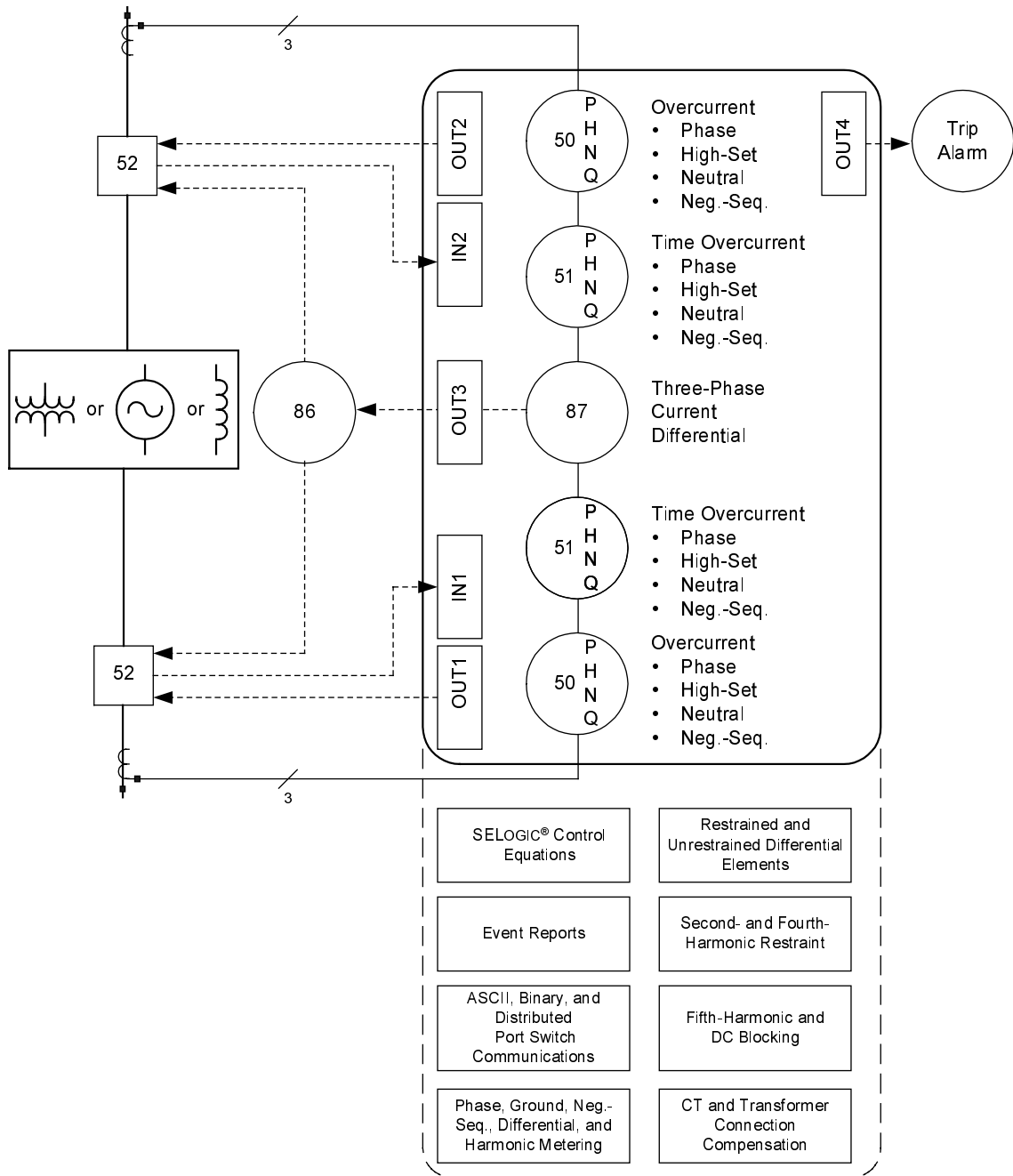
The block diagram in Figure 1.2 shows the relay hardware arrangement. A single microprocessor, data acquisition system, and power supply perform the functions required to provide current differential and overcurrent protection.



DWG: M5871001

Figure 1.2: SEL-587 Relay Hardware Block Diagram

SEL-587 RELAY FUNCTIONS



DWG: M5871035

Figure 1.3: SEL-587 Relay Protection Functions

Current Differential Protection

The SEL-587 Relay 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 Relay 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.

Programmable Output Contacts

The SEL-587 Relay 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 1.3, 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.

MODEL VARIATIONS

SEL-587-0 Relay

The SEL-587-0 Relay 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 Relay for new designs because of the additional features it provides.

SEL-587-1 Relay

Differences between the SEL-587-0 Relay and the SEL-587-1 Relay are explained below.

- The SEL-587-0 Relay trip logic can be set in one of two configurations while the SEL-587-1 Relay can be set in one of three configurations. Each relay's trip logic 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 Relay 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 Relay 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 Relay, the SEL-587-1 Relay 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, one EIA-232 port, 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.

RELAY SPECIFICATIONS

General

Tightening Torque: Terminal Block:
Minimum: 7 in-lb (0.8 Nm)
Maximum: 12 in-lb (1.4 Nm)
Connectorized:
Minimum: 4.4 in-lb (0.5 Nm)
Maximum: 8.8 in-lb (1.0 Nm)

Terminal Connections: Terminals or stranded copper wire. Ring terminals are recommended. Minimum temperature rating of 90°C.

AC Current Inputs: 5 A Nominal: 15 A continuous, 250 A for 1 second, 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 second, 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 Vdc or Vac
Range:	85–350 Vdc or 85–264 Vac
Interruption:	100 ms @ 250 Vdc
Ripple:	100%
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 255-11: 1979*.

Output Contacts: Conventional Terminal Blocks Option (Standard Outputs; see Figure 2.6):

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

Breaking Capacity (10,000 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; see Figure 2.7):

Make: 30 A
Carry: 6 A
MOV: 330 Vdc, 40 J
Pickup time: <5 ms
Dropout time: <8 ms, typical
Breaking Capacity (10,000 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 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

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 255-0-20: 1974*.

Optoisolated Inputs:

Conventional Terminal Blocks Option; see Figure 2.6:

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

Plug-In Connectors Option; see Figure 2.7:

24 Vdc: Pickup 15–30 Vdc
48 Vdc: Pickup 38.4–60 Vdc; Dropout 28.8 Vdc
125 Vdc: Pickup 105–150 Vdc; Dropout 75 Vdc
250 Vdc: Pickup 200–300 Vdc; Dropout 150 Vdc

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

Routine Dielectric Strength:

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:

EIA-232 or EIA-485
Baud rate: 300–38400 baud

Time-Code Input:

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

Dimensions:

See Figures 2.1 and 2.3.

Operating Temp.:

–40° to +85°C (–40° to +185°F).

Relay Weight:

5 lbs, 12 oz (2.6 kg)

Relay Shipping Weight:

9 lbs (4kg)

Type Tests:	*Generic Emissions, Heavy Industrial:	EN 50081-2: 1994, Class A
	*Generic Immunity, Heavy Industrial:	EN 50082-2: 1995, Class A
	*Radiated and Conducted Emissions:	EN 55011: 1991, Class A
	*Conducted Radio Frequency:	EN 61000-4-6: 1996, ENV 50141: 1996, 10 Vrms
	Radiated Radio Frequency (900 MHz with modulation):	ENV 50204: 1996, 10 V/m
	Cold:	IEC 68-2-1: 1990, Test Ad, 16 hours at -40°C
	Dry Heat:	IEC 68-2-2: 1974, Test Bd, 16 hours at +85°C
	Damp Heat, Steady State:	IEC 68-2-3: 1969, 96 hours at 40°C, 93% relative humidity
	Damp Heat, Cyclic:	IEC 68-2-30: 1980, Test Db, 55°C, 6 cycles, 95% humidity
	Dielectric Strength:	IEC 255-5: 1977 IEEE C37.90: 1989, 2500 Vac on analog, contact inputs, and contact outputs; 3100 Vdc on power supply; 2200 Vdc on EIA-485 communications port
	Impulse:	IEC 255-5: 1977, 0.5 J, 5000 V
	Vibration:	IEC 255-21-1: 1988, Class 2
	Shock and Bump:	IEC 255-21-2: 1988, Class 2
	Seismic:	IEC 255-21-3: 1993, Class 2 (Conventional Terminal Block only)
	1 MHz Burst Disturbance:	IEC 255-22-1: 1988, Class 3 (2500 V common and differential mode)
	Electrostatic Discharge:	IEC 255-22-2: 1996, Level 4
	Radiated Radio Frequency:	IEC 255-22-3: 1989, 10 V/m
	Fast Transient Disturbance:	IEEE C37.90.2: 1995 IEC 255-22-4: 1992, Level 4 (4 kV @ 2.5 kHz on power supply; 2 kV @ 5 kHz on input/output, signal, data, and control lines)
	Object Penetration:	IEC 529: 1989, IP 3X
	Surge Withstand Capability:	IEEE C37.90.1: 1989, 3000 V oscillatory, 5000 V transient

Note: * = terminal block version only

Certifications: ISO: Relay is designed and manufactured using ISO-9001 certified quality program.
UL508 (Conventional Terminal Block 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: $\pm 2\% \pm 0.10 \text{ A}$
1 A Model: $\pm 2\% \pm 0.02 \text{ A}$
Demand Currents:
5 A Model: $\pm 2\% \pm 0.10 \text{ A}$
1 A Model: $\pm 2\% \pm 0.02 \text{ A}$

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: $\pm 5\% \pm 0.10 \text{ A}$
1 A Model: $\pm 5\% \pm 0.02 \text{ A}$
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: $\pm 5\% \pm 0.10 \text{ A}$
1 A Model: $\pm 5\% \pm 0.02 \text{ A}$
Time Delay Accuracy: $\pm 0.1\% \pm 0.25 \text{ cycle}$

Instantaneous/Definite-Time Overcurrent Elements (Winding)

Pickup Range (A secondary)
5A Model: 0.5–80.0 A
1 A Model: 0.1–16.0 A
Pickup Accuracy (A secondary)
5A Model: $\pm 5\% \pm 0.10 \text{ A}$
1 A Model: $\pm 5\% \pm 0.02 \text{ A}$
Pickup Time
(Typ/Max): 0.75/1.20 cycles
Time Delay Range: 0–16,000 cycles
Time Delay Accuracy: $\pm 0.1\% \pm 0.25 \text{ cycle}$

Time Overcurrent Elements (Winding and Combined Current)

Pickup Range (A secondary)
5A Model: 0.50–16.00 A
1 A Model: 0.10–3.20 A

Pickup Accuracy (A secondary)

5A Model: $\pm 5\% \pm 0.10 \text{ A}$

1 A Model: $\pm 5\% \pm 0.02 \text{ A}$

Pickup Time

(Typ/Max): 0.75/1.20 cycles

Curve 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

US Curves: 0.50–15.00, .01 step

IEC Curves: 0.05–1.00, .01 step

Timing Accuracy:

$\pm 4\% \pm 1.5$ 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 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

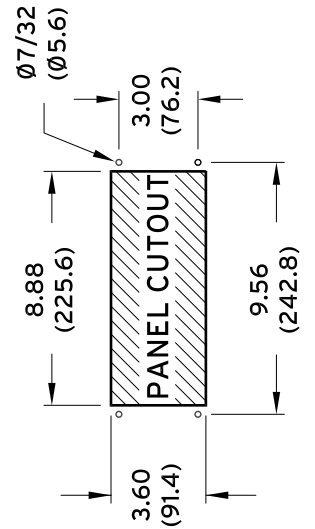
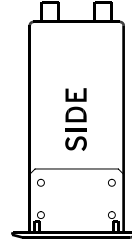
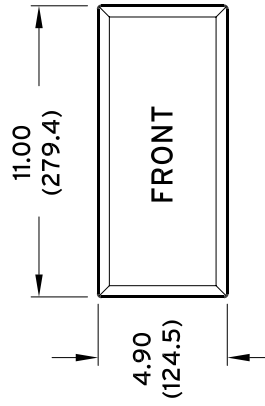
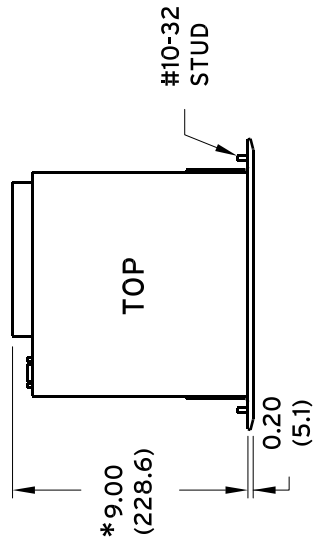
Rack Mount

We offer the SEL-587 Relay in a rack-mount version that bolts easily into a standard 19-inch rack with a mounting bracket or another SEL-500 series relay. See Figure 2.3 and Figure 2.4. From the front of the relay, insert four bolts (two on each side) through the holes on the relay mounting flange and/or mounting bracket, and use nuts to secure the relay to the rack. See Figure 2.1 and Figure 2.2.

Panel Mount

We also offer the SEL-587 Relay in a panel-mount version for a clean look. Panel-mount relays have sculpted front panel molding that covers all installation holes. 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 with the drilled holes in your panel, and use nuts to secure the relay to the panel.

PANEL MOUNT CHASSIS



RACK MOUNT CHASSIS

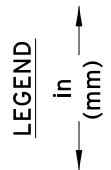
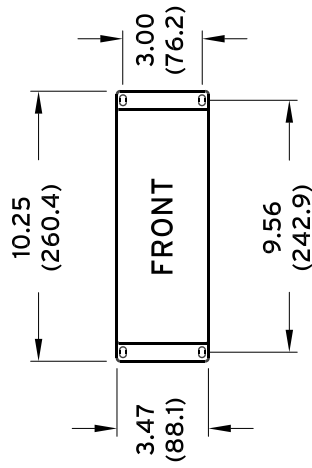
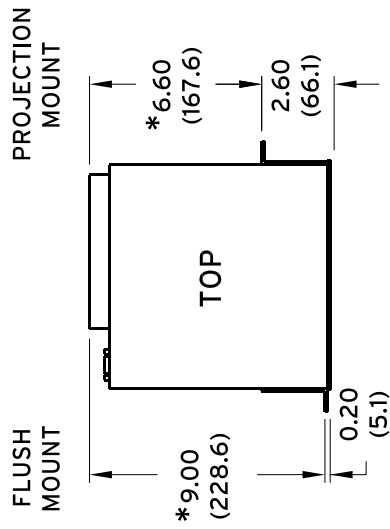
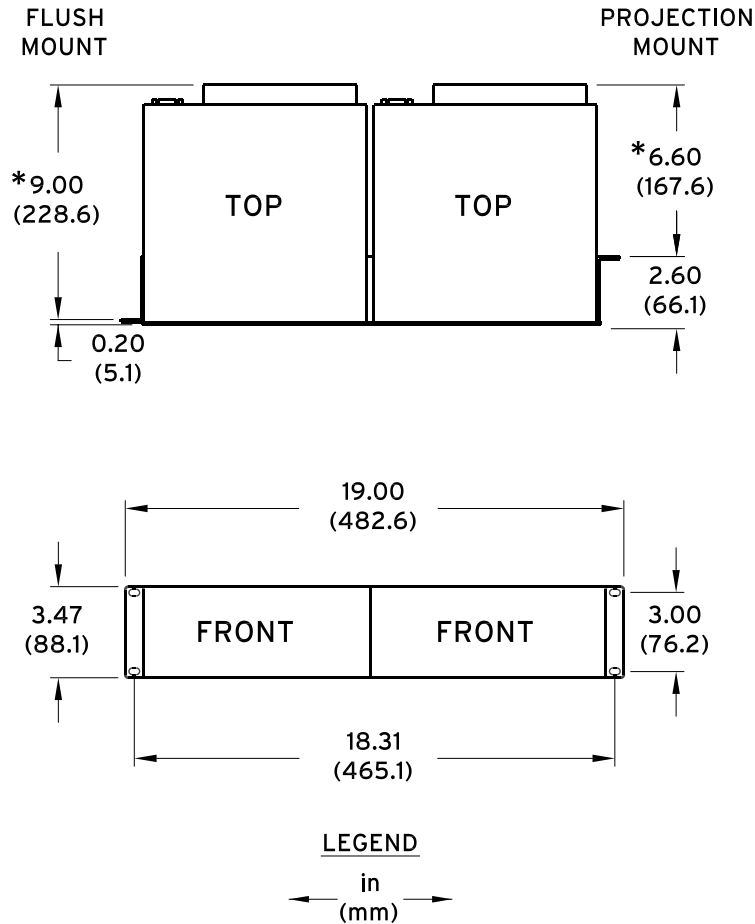


Figure 2.1: Relay Dimensions, Panel Cutout, and Drill Plan

* ADD 0.65 (16.5) FOR CONNECTORIZED RELAYS

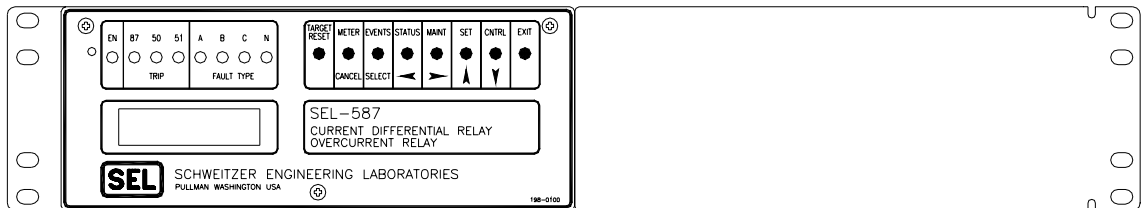
RACK MOUNT DUAL CHASSIS



* ADD 0.65 (16.5) FOR CONNECTORIZED RELAYS

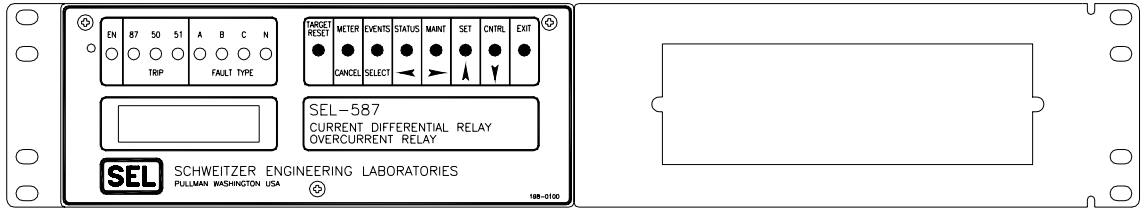
i1594b

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



DWG. 1119-111

Figure 2.3: Relay Fitted With Mounting Bracket (SEL P/N 9100) for Mounting in 19-Inch Rack



DWG. 1119-112

Figure 2.4: Relay Fitted With Mounting Bracket (SEL P/N 9102) for Mounting in 19-Inch Rack Including Cutout to Fit an FT-1 Test Switch

REAR-PANEL CONNECTIONS

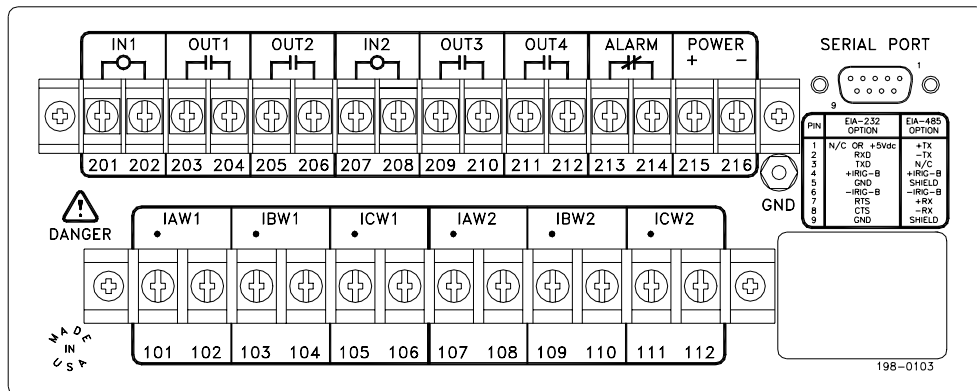
We provide two options for secure connection of wiring to the relay rear panel. One of these is the conventional terminal block, in which you use size #6-32 screws to secure rear-panel wiring. The other option uses plug-in (Connectorized) connections that offer robust connections while minimizing installation 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 using a Phillips or slotted screwdriver. You may request locking screws from the factory. Refer to Figure 2.5 to make all terminal block connections.



DWG:M5870025

Figure 2.5: Relay Rear Panel (Conventional Terminal Blocks Option)

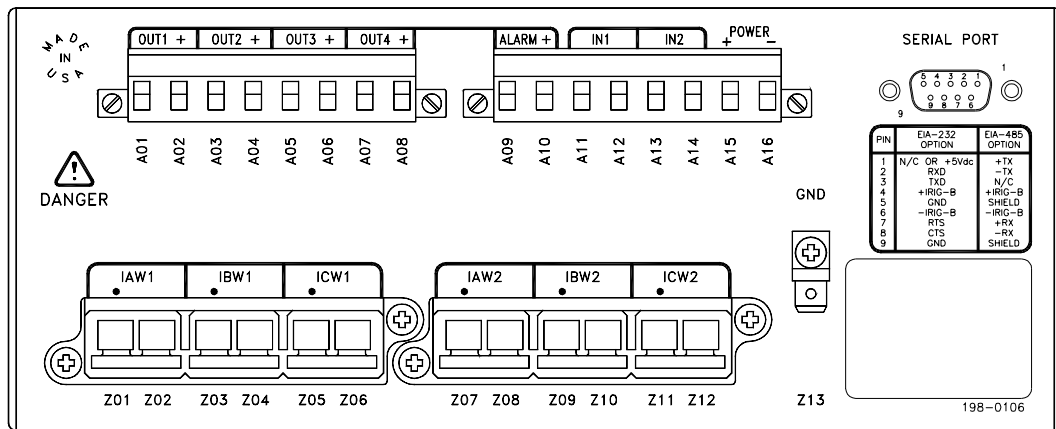
Output contacts OUT1–OUT4 and ALARM are not polarity dependent.

Optoisolator inputs IN1 and IN2 are not polarity dependent.

All screws are size #6-32.

Connectorized

To use the Connectorized version of the SEL-587 Relay, ask your SEL sales or customer service representative for the appropriate model option table and order wiring harness kit WA03870W_xX_xA, where x designates wire sizes and length. You can find the model option table on the SEL web site at <http://www.selinc.com>. Refer to Figure 2.6 to make all Connectorized connections.



DWD: 11380

Figure 2.6: Relay Rear Panel (Plug-In Connectors Option)

Important: Improvements in Connectorized SEL-587 Relays (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 Relay 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 2.6 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 *General Specifications* in *Section 1: Introduction and Specifications* 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.
- Accepts wire size AWG 16 to 10 (special tool required to attach wire to connector).
- Can be ordered prewired.

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

SEL-587 RELAY AC/DC CONNECTION DIAGRAMS

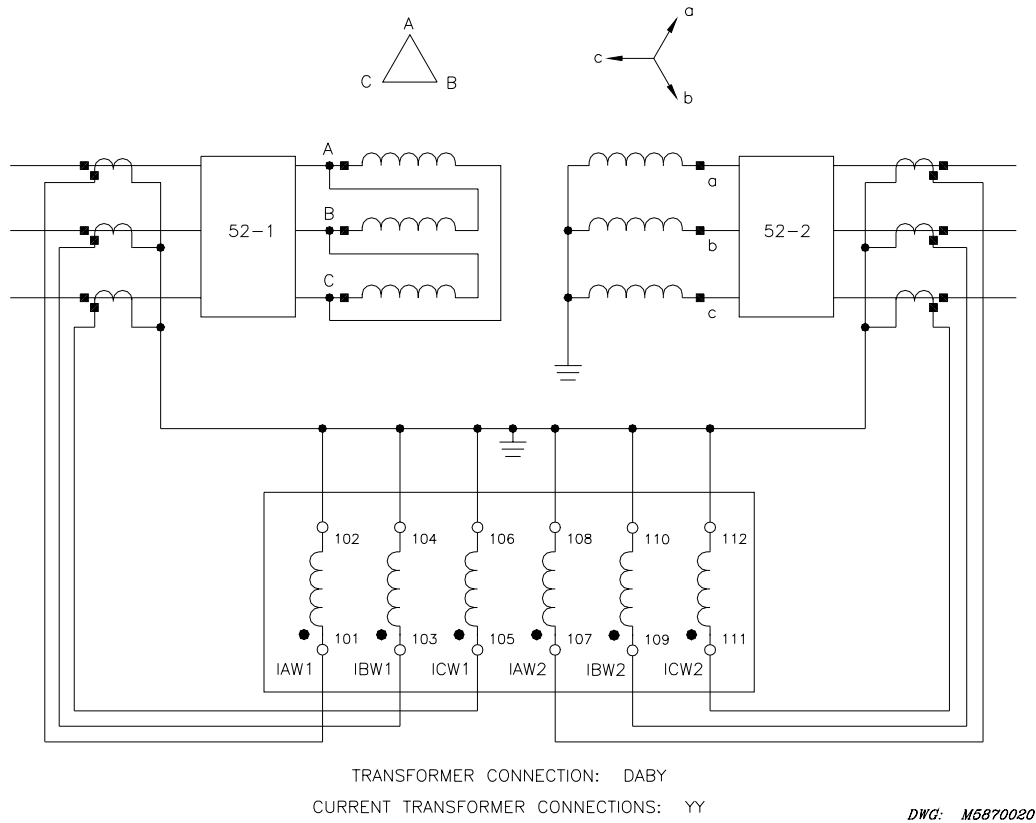


Figure 2.7: Example AC Connections - See Appendix F for Other Configurations

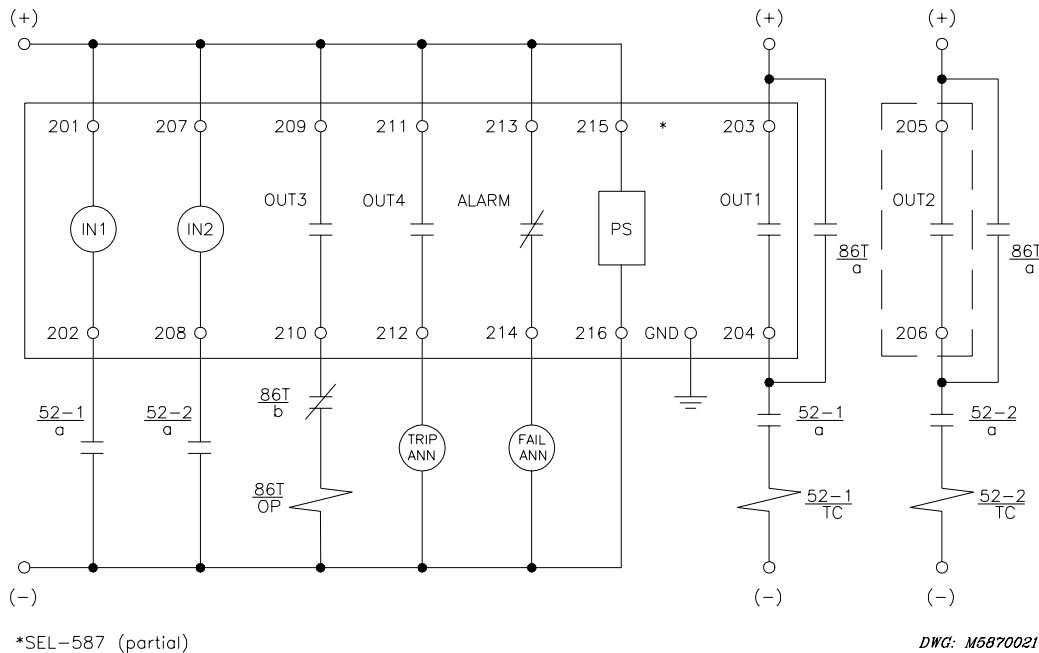


Figure 2.8: Example DC Connections

CIRCUIT BOARD JUMPERS AND BATTERY

Control Voltage Jumpers (Conventional Terminal Blocks Option Only)

Relays equipped with Conventional Terminal Blocks have field-changeable jumpers that select the control voltage for two digital inputs. The jumpers are factory configured to the control voltage specified at time of ordering. The jumpers may be changed as outlined below.

Note: Relays equipped with plug-in connectors have fixed “level-sensitive” inputs that are factory configured to the control voltage specified at time of ordering. These relays are not field changeable.

Refer to *General Specifications* in *Section 1: Introduction and Specifications* for details on operating voltage and current levels.

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

1. Deenergize the relay.
2. Remove the three front-panel screws and the relay front panel.



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

3. Disconnect the analog signal ribbon cable and the 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.
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 2.9.
5. Install or remove jumpers according to Table 2.1 to select the desired control voltage level.
6. Slide the drawout assembly into the relay chassis. Reconnect the analog signal ribbon cable and the power supply cable. Replace the relay front panel and reenergize the relay.

Table 2.1: Control Input Voltage Selection Jumper Positions

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

Output Contact Jumpers (Conventional Terminal Blocks Option Only)

Refer to Figure 2.9. 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 deenergized 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 deenergized and open when the output contact coil is energized. These jumpers are soldered in place.

In Figure 2.9, 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.

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.

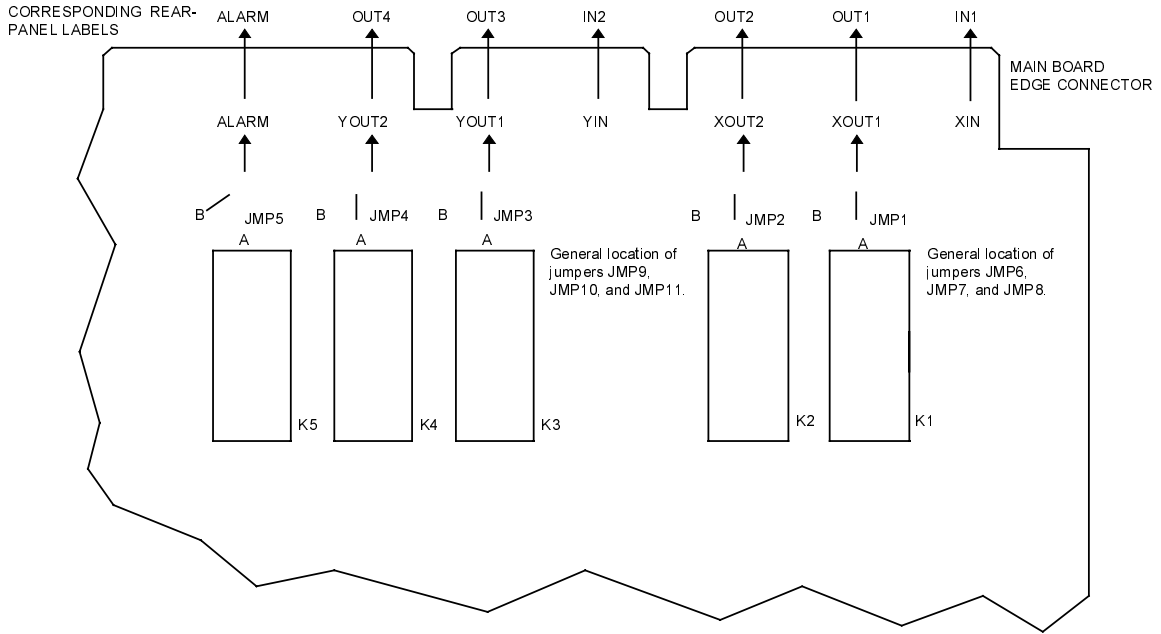


Figure 2.9: Input and Output Jumper Locations (Conventional Terminal Blocks Option Only)

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 is toward the rear of the main board, near the rear-panel EIA-232 serial communications port. This jumper connects or disconnects +5 Vdc to pin 1 on the EIA-232 serial communications port. In a standard relay shipment, jumper JMP12 would be removed (out of place) so that the +5 Vdc is not connected to pin 1 on the EIA-232 serial communications port. See Figure 2.11.

Output Contact OUT4 Control Jumper

Refer to Figure 2.10 and Table 2.2. 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.

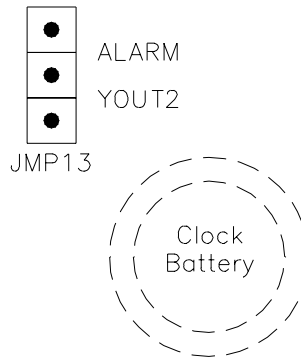


Figure 2.10: Output Contact OUT4 Control Jumper Location

Table 2.2: Required Position of Jumper JMP13 for Desired Output Contact OUT4 Operation

Position	Output Contact OUT4 Operation
<ul style="list-style-type: none"> • ALARM • YOUT2 	Regular output contact OUT4 (operated by Relay Word bit OUT4). Jumper JMP13 comes in this position in a standard relay shipment.
<ul style="list-style-type: none"> • ALARM • YOUT2 • 	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.

If jumper JMP13 is in position ALARM and both output contacts OUT4 and ALARM are the same output contact type (“a” or “b”), they 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”), they will be in opposite states (one is closed and one is open).

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

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.



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

To change the battery, take the following steps:

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



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

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.
4. Locate the battery on the right-hand side of the relay main board.
5. Remove the battery from beneath the clip and install a new one. The positive side (+) of the battery faces up.
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 reenergize the relay.
7. Set the relay date and time (see *Section 6: Operator Interface*).

PORT CONNECTOR AND COMMUNICATIONS CABLES

Figure 2.11 is a drawing of the 9-pin port connector.

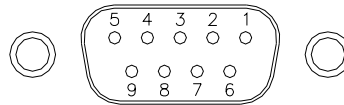


Figure 2.11: Female Chassis Connector, as Viewed From Outside Panel

Table 2.3 identifies pinouts for each pin of a 9-pin EIA-232 or 9-pin RS-485 port connector, while Table 2.4 defines the function of each serial communications port pin.

Table 2.3: Pinouts for EIA-232 and RS-485 Ports

Pin	EIA-232 Option	EIA-485 (4-wire) Option
1	N/C or +5 Vdc (main board jumper JMP12)	+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

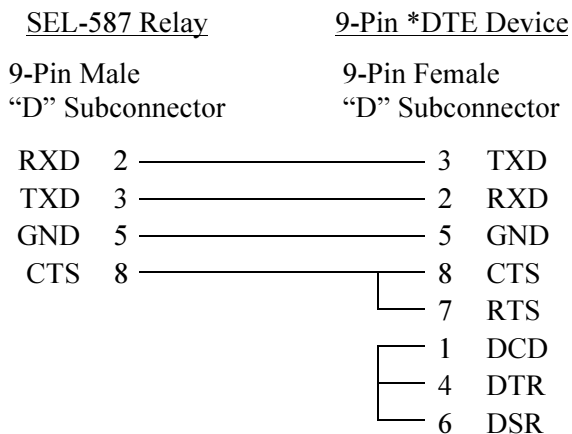
Table 2.4: Serial Communications Port Pin Function Definitions

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

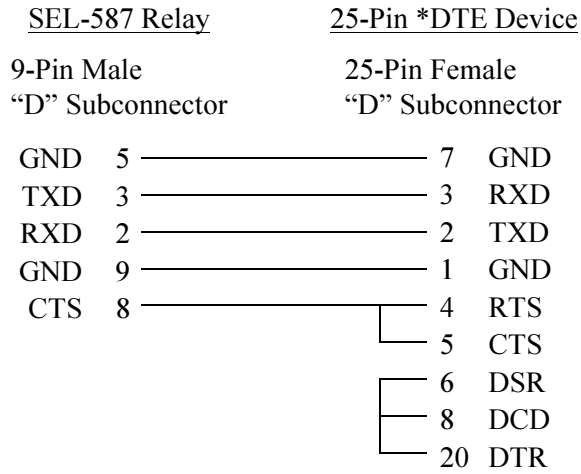
The following cable diagrams show several types of EIA-232 serial communications cables. Obtain these and other cables from SEL. Contact the factory for more information.

SEL-587 to Computer

Cable C234A

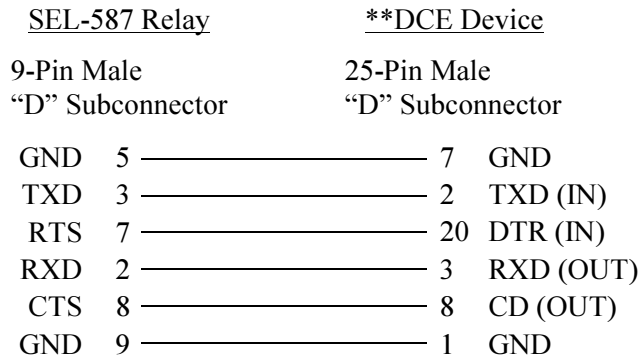


Cable C227A



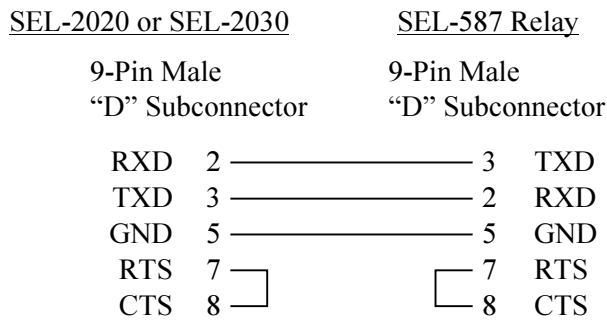
SEL-587 Relay to Modem

Cable C222



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

Cable C272A
Data Only



Cable 273A

SEL-2020 or 2030

SEL-587

9-Pin Male
“D” Subconnector

9-Pin Male
“D” Subconnector



- * DTE = Data Terminal Equipment (Computer, Terminal, Printer, etc.)
- ** DCE = Data Communications Equipment (Modem, etc.)

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 Relay are available at our website: www.selinc.com. You may find the following application guides useful:

Table 3.1: Application Guides Related to the SEL-587 Relay

Application Guide Number	Application Guide Title	Date Code
AG95-18	Protecting Three Single-Phase Transformers Connected Delta-Wye with CTs inside the Delta – SEL587 Relay	950522
AG96-09	Protecting $\pm 30^\circ$ and $\pm 150^\circ$ 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
AG97-20	Protecting Dy11 Transformer with a Zig-Zag Grounding Bank with the SEL-587	970904
AG2000-01	Determining the Correct TRCON Setting in the SEL-587 Relay When Applied to Delta-Wye Power Transformers	20000209

DIFFERENTIAL PROTECTION

Differential Protection Overview

Apply the SEL-587 Relay 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 Relay 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 Relay consists of three current differential elements. Each differential element provides percentage differential protection with independent second- and fifth-harmonic blocking. You may select independent or common harmonic blocking.

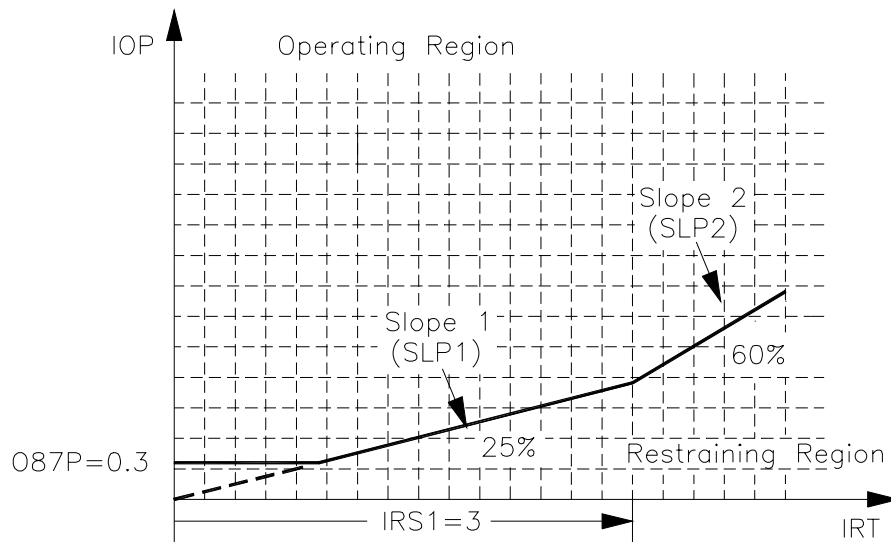
The SEL-587-1 Relay also consists of three current differential elements. Each differential element provides percentage differential protection with independent even-harmonic restraint and fifth-harmonic and dc blocking. The user may select even-harmonic blocking instead of even-harmonic restraint. You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

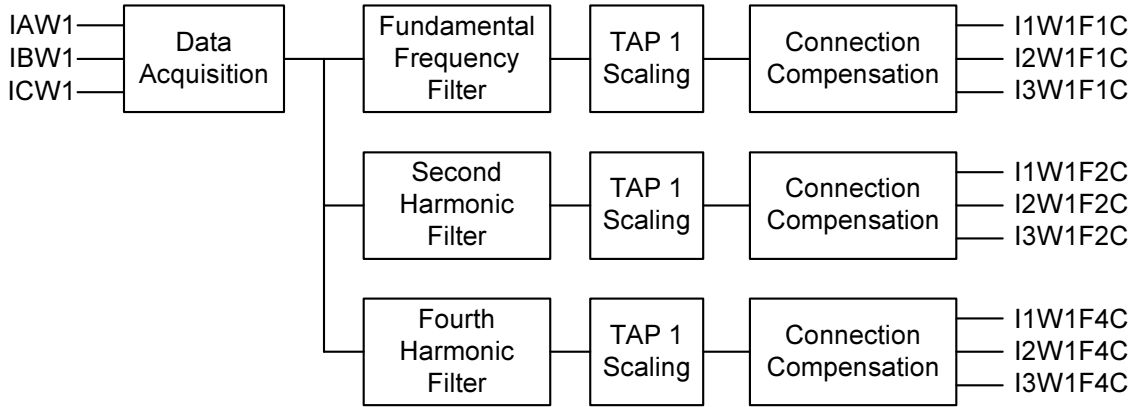


DWG: M3871028

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.

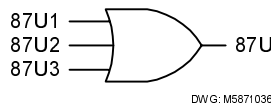


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Figure 3.2: Differential Relay Compensated Currents (W1)

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.

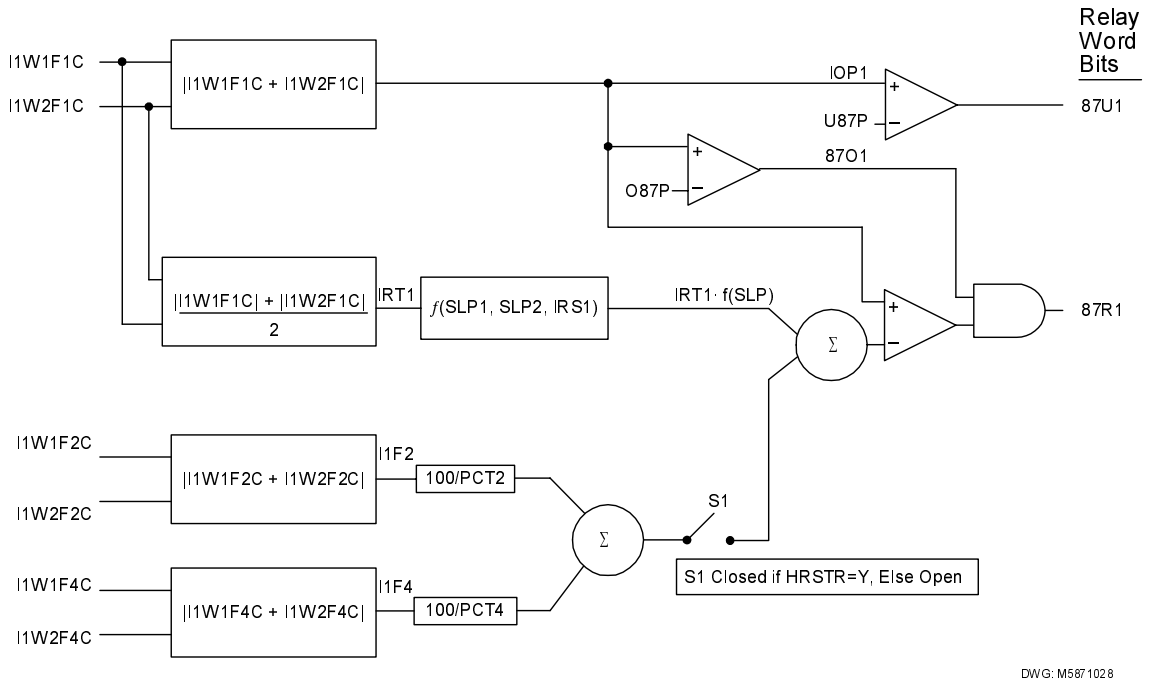
Unrestrained elements (87U1, 87U2, and 87U3) compare the IOP quantity to a setting value (U87P), typically about 10 times TAP, and trip if this level is exceeded. It is essentially an instantaneous unit set high enough that the pickup level could only mean an internal fault. Elements 87U1, 87U2, and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



DWG: M5871036

Figure 3.3: SEL-587 Unrestrained Element (87U)

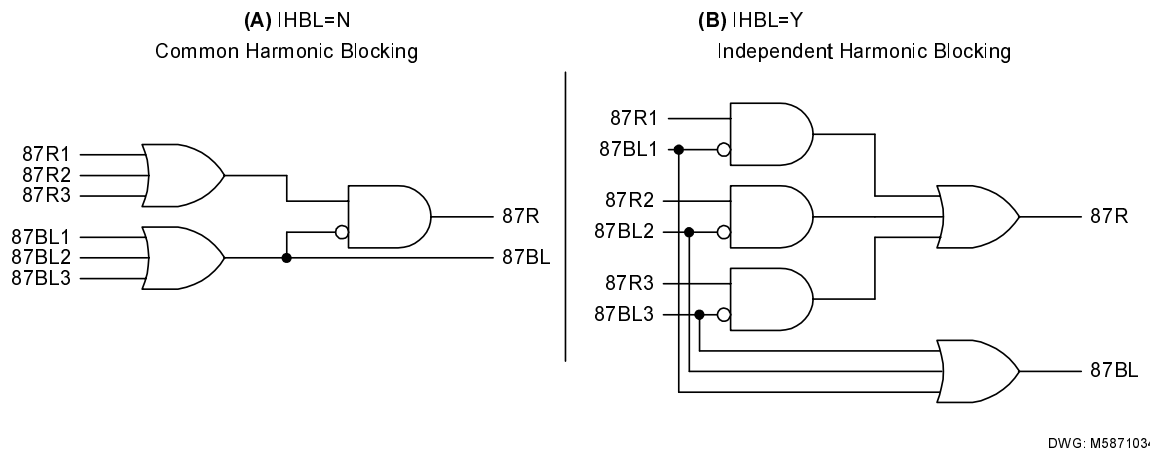
Restrained elements (87R1, 87R2, and 87R3) determine whether the IOP quantity is greater than the restraint quantity using the differential characteristic shown in Figure 3.1. Set HRSTR=Y (harmonic restraint), only available in the SEL-587-1, to modify this characteristic as a function of the second-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



DWG: M5871028

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 2PCT, 4PCT, or 5PCT 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.



DWG: M5871034

Figure 3.5: Differential Relay Blocking Logic

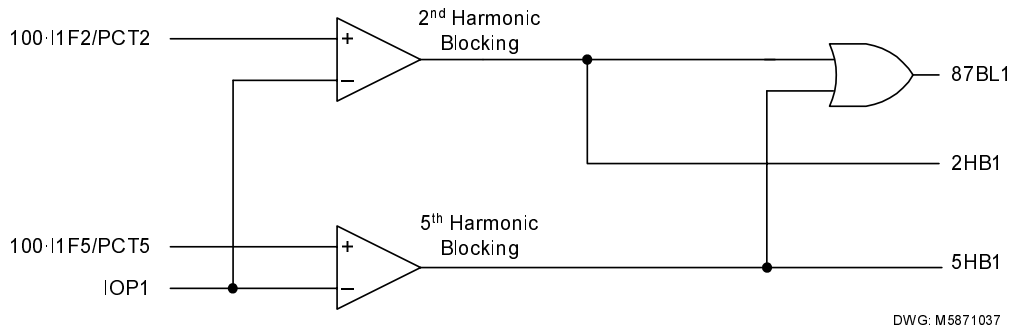


Figure 3.6: SEL-587-0 Differential Element (87BL1 Blocking Logic)

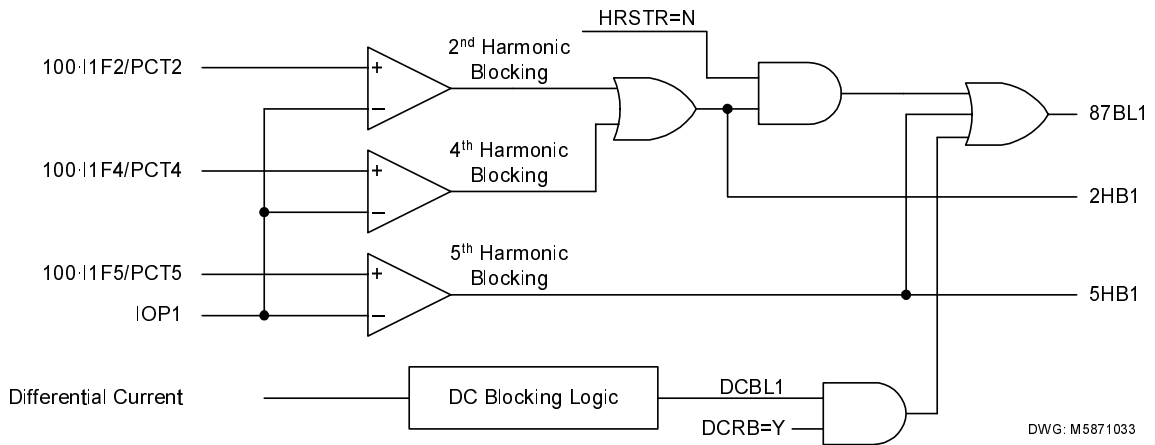


Figure 3.7: SEL-587-1 Differential Element (87BL1) Blocking Logic

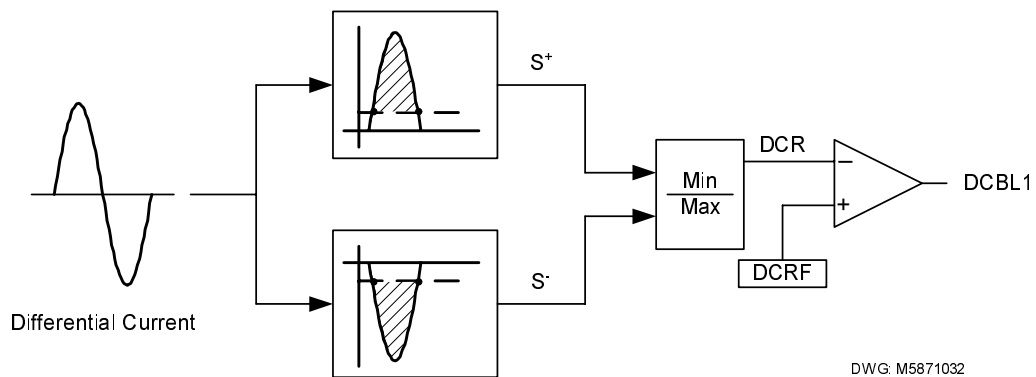


Figure 3.8: SEL-587-1 DC Blocking (DCBL1) Logic

Differential Protection Setting Descriptions

Maximum Power Transformer Capacity (MVA)

Use the highest expected transformer rating, such as FOA (Forced Oil and Air Cooled) rating or a higher emergency rating when setting the maximum transformer capacity.

Winding Line-Line Voltages (VWDG1, VWDG2)

Enter the nominal line-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 Relay 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*.
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

TRCON	CTCON	CON1	CON2	C1	C2
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 CONn = Y and RZS = N (SEL-587-1) or CONn = Y (SEL-587-0)

$$I1WnF1C = IAWnF1$$

$$I2WnF1C = IBWnF1$$

$$I3WnF1C = ICWnF1$$

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

$$I1WnF1C = IAWnF1 - I0WnF1$$

$$I2WnF1C = IBWnF1 - I0WnF1$$

$$I3WnF1C = ICWnF1 - I0WnF1$$

where

$$I0WnF1 = IAWnF1 + IBWnF1 + ICWnF1$$

For CONn = DAB

$$I1WnF1C = \frac{(IAWnF1 - IBWnF1)}{\sqrt{3}}$$

$$I2WnF1C = \frac{(IBWnF1 - ICWnF1)}{\sqrt{3}}$$

$$I3WnF1C = \frac{(ICWnF1 - IAWnF1)}{\sqrt{3}}$$

For CONn = DAC

$$I1WnF1C = \frac{(IAWnF1 - ICWnF1)}{\sqrt{3}}$$

$$I2WnF1C = \frac{(IBWnF1 - IAWnF1)}{\sqrt{3}}$$

$$I3WnF1C = \frac{(ICWnF1 - IBWnF1)}{\sqrt{3}}$$

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 CTCN automatically remove zero-sequence current for all other cases when necessary. This feature is only available with the SEL-587-1 Relay.

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 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*.

$$\text{TAP1} = \frac{\text{MVA} \cdot 1000 \cdot \text{C1}}{\sqrt{3} \cdot \text{VWDG1} \cdot \text{CTR1}}$$
$$\text{TAP2} = \frac{\text{MVA} \cdot 1000 \cdot \text{C2}}{\sqrt{3} \cdot \text{VWDG2} \cdot \text{CTR2}}$$

The relay calculates TAP1 and TAP2 with the following limitations:

- (1) The TAP settings are within the range $0.1 \cdot I_N$ and $32 \cdot I_N$
- (2) The ratio, $\frac{\text{TAP}_{\text{MAX}}}{\text{TAP}_{\text{MIN}}} \leq 4.5$

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. $\text{O87P} \geq 0.1 \cdot I_N / \text{TAP}_{\text{MIN}}$ 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:

$$I_{d \max} = (1 + e) \cdot \sum_{\text{"IN"}} IW_n - \frac{(1 - e)}{(1 + a)} \cdot \sum_{\text{"OUT"}} IW_n$$

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:

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

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 percent 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 may 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 $32 \cdot I_N$, 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 $32 \cdot 5 / 12.0$, 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 Relay 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.

Fourth-Harmonic Block Setting (PCT4)

Magnetizing inrush current contains second- and fourth-harmonic current. The SEL-587-1 Relay 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.

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 may vary somewhat during start-up, 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.

You may use the presence of fifth-harmonic differential current to assert an alarm output during start-up. 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 Relay 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 Relay adds the capability of using even-harmonic restraint for security during inrush conditions. Set HRSTR=Y to use harmonic restraint in the differential element characteristic. The second- and fourth-harmonic compensated currents are added to the restraint quantity. 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 is automatically enabled in this mode.

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 Relay 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 may 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 Relay, you may apply a maximum of two restraint inputs to the relay. You may 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, and core dimensions.

CT Sizing

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

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

CT Ratio Selection

1. Determine the high-side and low-side CT burdens, RHS and RLS, respectively.
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 $\sqrt{3} \cdot IHS$. Select the nearest standard ratio such that IREL1 is between $0.1 \cdot I_N$ and $1.0 \cdot I_N$ A secondary where I_N is the relay nominal secondary current, 1 A or 5 A.
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 $\sqrt{3} \cdot ILS$. Select the nearest standard ratio such that IREL2 is between $0.1 \cdot I_N$ and $1.0 \cdot I_N$ A secondary.
4. The SEL-587 Relay 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.
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 steps 2 through 5.
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 100 Amps. If necessary, reselect the CT ratios and repeat Steps 2 through 6.

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 Steps 2 through 7. This selection criterion helps reduce the likelihood of CT saturation for a fully offset fault current signal.

Please 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 one of two ways:

1. In most applications the relay automatically calculates the TAP values 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 Relay 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 using a control input.

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 Relay.

Table 3.3: Overcurrent Element Summary

	Definite-Time Elements	Instantaneous Elements	Inverse-Time Elements
Phase (Ia, Ib, and Ic) Winding 1 Winding 2	50P1 50P2	50P1H 50P2H	51P1 51P2
Negative-Sequence ($I_Q = 3 \cdot I_2$) Winding 1 Winding 2	50Q1 50Q2		51Q1 51Q2
Residual ($I_R = I_a + I_b + I_c$) Winding 1 Winding 2	50N1 50N2	50N1H 50N2H	51N1 51N2

Definite-Time Overcurrent Element

Logic for the definite-time phase overcurrent element 50Pn is shown in Figure 3.9. The logic provides a definite-time element output (50PnT) and an instantaneous output (50PnP) for time delay accuracy testing. Pickup, torque control, and time delay are programmed with settings. Definite-time negative-sequence overcurrent element 50Qn and definite-time residual overcurrent element 50Nn logic are similar.

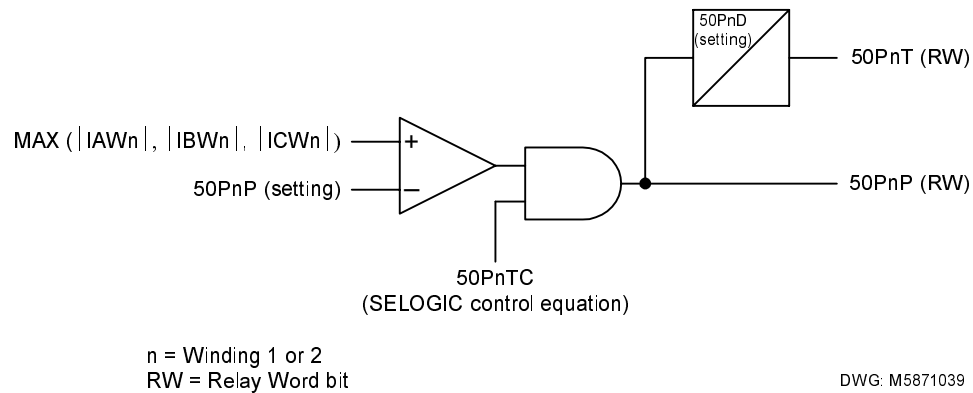


Figure 3.9: Definite-Time Overcurrent Element

Instantaneous Overcurrent Element

Logic for the instantaneous high-set phase overcurrent element 50PnH is shown in Figure 3.10. Pickup and torque control are programmed with settings. Definite-time residual overcurrent element 50NnH logic is similar.

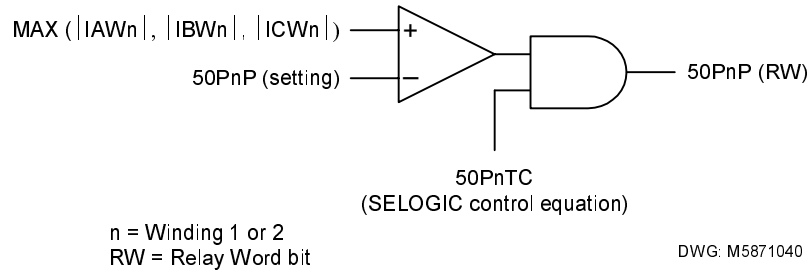


Figure 3.10: Instantaneous Overcurrent Element

Inverse-Time Overcurrent Element

Logic for the inverse-time phase overcurrent element 51Pn is shown in Figure 3.11. The logic provides inverse-time (51PnT), instantaneous (50PnP), and reset (51PnR) 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 51Qn and definite-time residual overcurrent element 51Nn logic are similar.

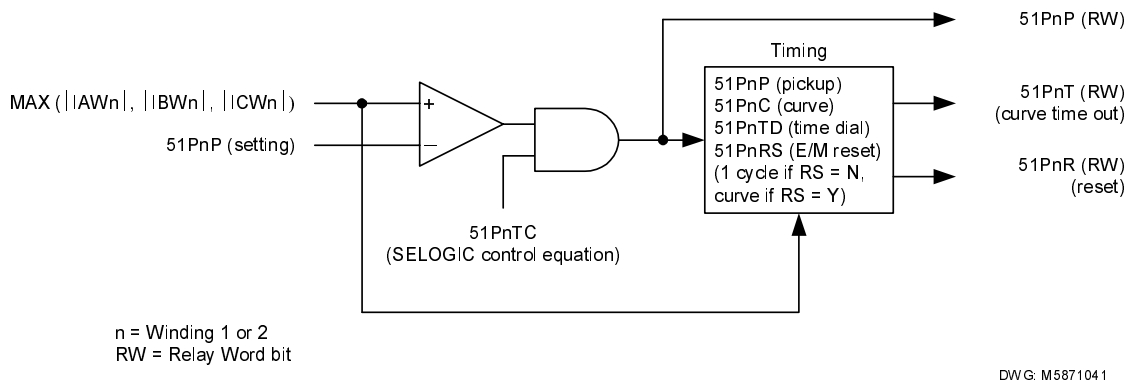


Figure 3.11: Inverse-Time Overcurrent Element

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 wish 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 using this setting.

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 51xxRS=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 51xxRS=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 may 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 Relay 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 may 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 Relay 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 Relay instantaneous, definite time, and time-overcurrent elements need only be set with regard to expected load and fault conditions.

Where the SEL-587 Relay 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 deenergized, such as in a feeder trip-reclose cycle. Hot load pickup inrush current that the SEL-587 Relay may 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 may last for several seconds.

Cold load pickup inrush occurs when a distribution circuit is energized after being deenergized 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 may 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 $3I_2 = I_a + I_b \cdot (1\angle 240) + I_c \cdot (1\angle 120)$. 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:

$$|I_2| = (\sqrt{3}/3) \cdot |I_p|$$

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

$$\therefore |3I_2|/|I_p| = 1.73$$

where I_p 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 $3I_0 = I_a + I_b + I_c$. 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 due to 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

tp = operating time in seconds

tr = electromechanical induction–disk emulation reset time in seconds (if electromechanical reset setting is made)

TD = time–dial setting

M = applied multiples of pickup current [for operating time (tp), M>1,
for reset time (tr), M≤1]

US Moderately Inverse Curve: U1

$$tp = TD \cdot \left[0.0226 + \frac{0.0104}{M^{0.02} - 1} \right]$$

$$tr = TD \cdot \left[\frac{1.08}{1 - M^2} \right]$$

US Inverse Curve: U2

$$tp = TD \cdot \left[0.180 + \frac{5.95}{M^2 - 1} \right]$$

$$tr = TD \cdot \left[\frac{5.95}{1 - M^2} \right]$$

US Very Inverse Curve: U3

$$tp = TD \cdot \left[0.0963 + \frac{3.88}{M^2 - 1} \right]$$

$$tr = TD \cdot \left[\frac{3.88}{1 - M^2} \right]$$

US Extremely Inverse Curve: U4

$$tp = TD \cdot \left[0.0352 + \frac{5.67}{M^2 - 1} \right]$$

$$tr = TD \cdot \left[\frac{5.67}{1 - M^2} \right]$$

IEC Class A Curve: C1

(Standard Inverse)

$$tp = TD \cdot \left[\frac{0.14}{M^{0.02} - 1} \right]$$

$$tr = TD \cdot \left[\frac{13.5}{1 - M^2} \right]$$

IEC Class B Curve: C2

(Very Inverse)

$$tp = TD \cdot \left[\frac{13.5}{M - 1} \right]$$

$$tr = TD \cdot \left[\frac{47.3}{1 - M^2} \right]$$

IEC Class C Curve: C3

(Extremely Inverse)

$$t_p = TD \cdot \left[\frac{80.0}{M^2 - 1} \right]$$

$$t_r = TD \cdot \left[\frac{80.0}{1 - M^2} \right]$$

IEC Long Time Inverse: C4

$$t_p = TD \cdot \left[\frac{120.0}{M - 1} \right]$$

$$t_r = TD \cdot \left[\frac{120.0}{1 - M} \right]$$

Full-sized time-current curve transparencies are available.

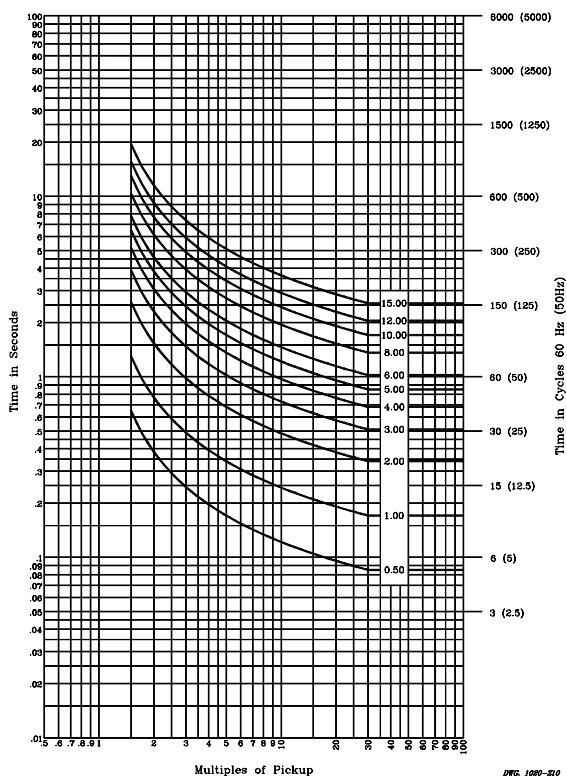


Figure 3.12: Time Curve U1

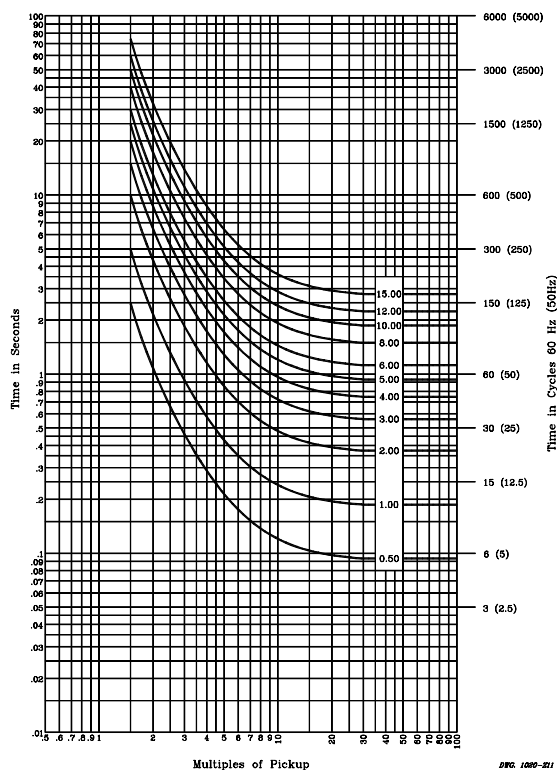


Figure 3.13: Time Curve U2

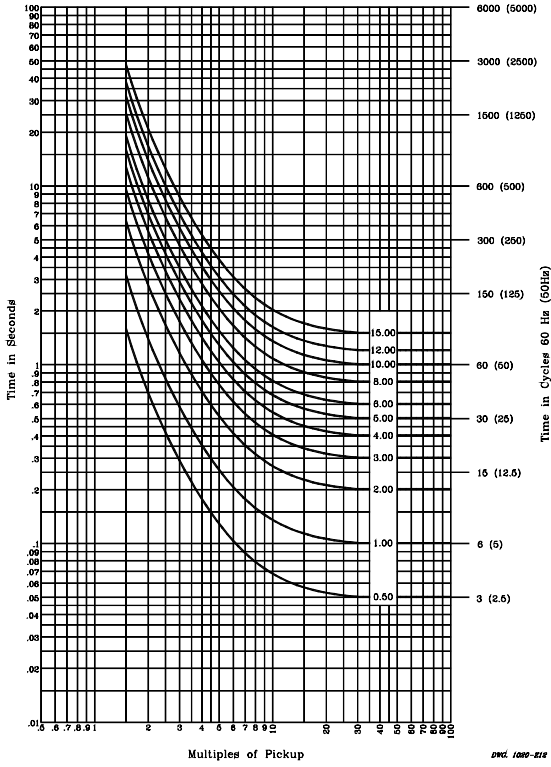


Figure 3.14: Time Curve U3

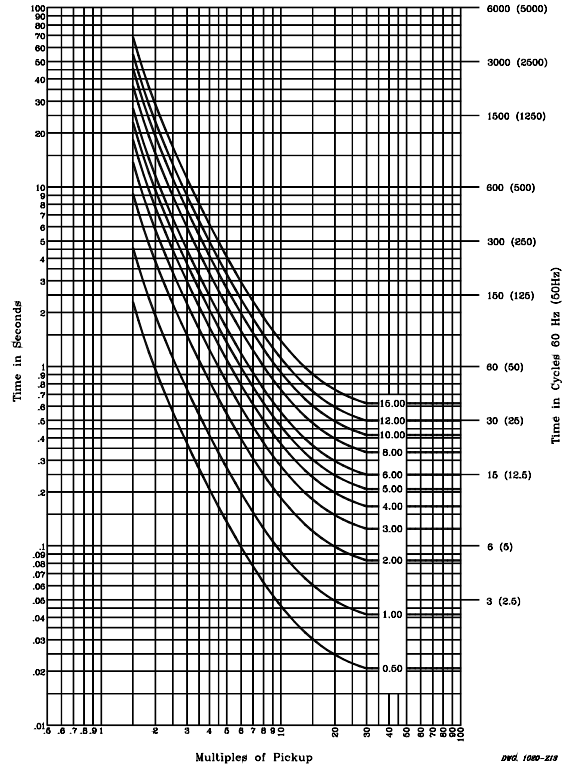


Figure 3.15: Time Curve U4

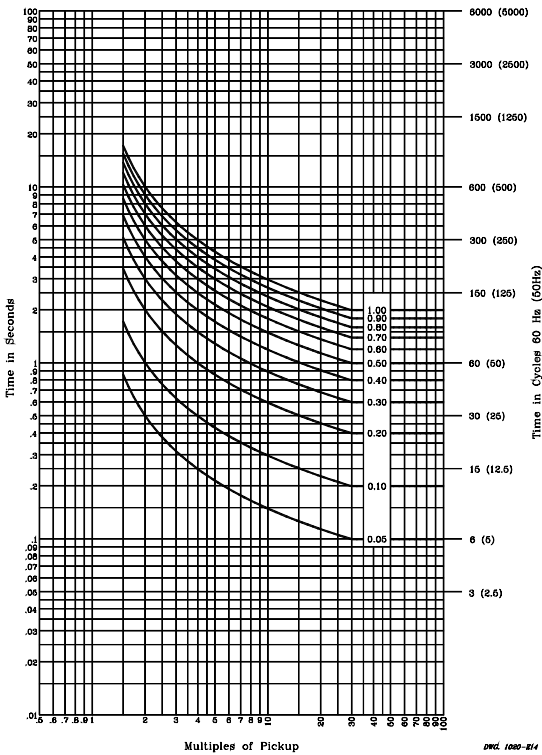


Figure 3.16: Time Curve C1

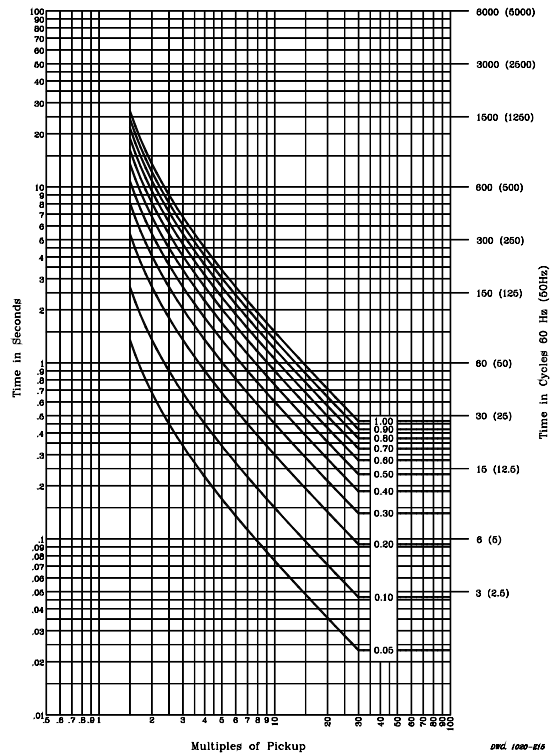


Figure 3.17: Time Curve C2

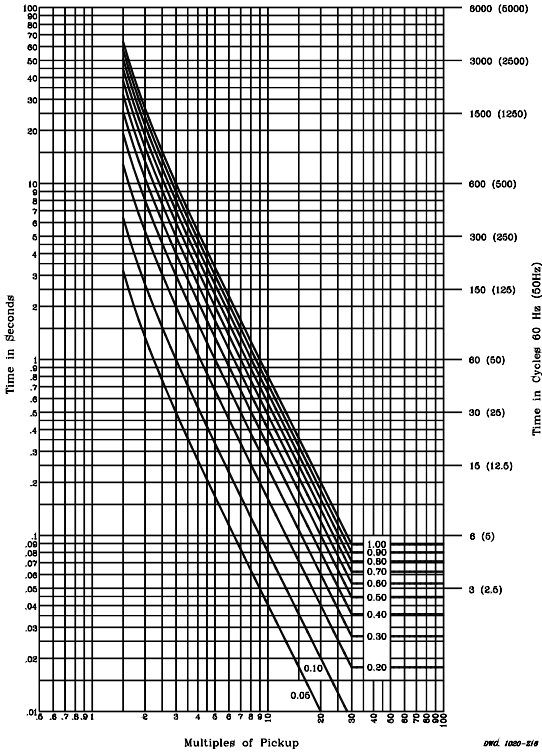


Figure 3.18: Time Curve C3

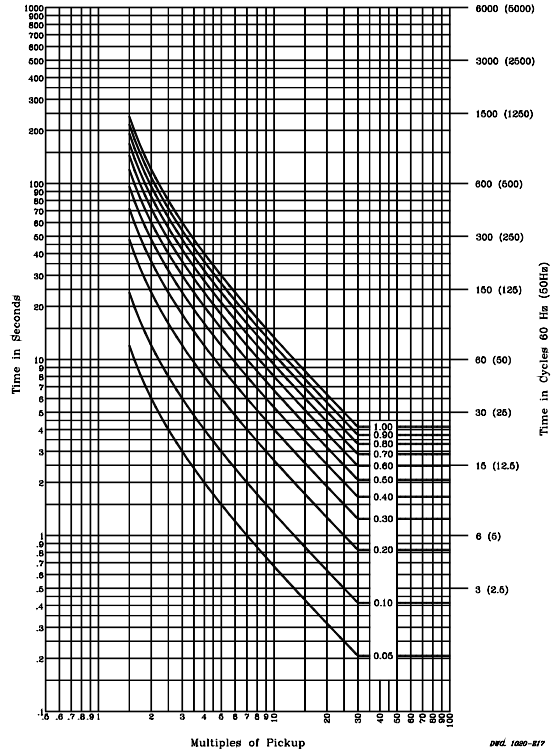


Figure 3.19: Time Curve C4

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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 Relay performs digital filtering eight times per power system cycle, 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 Relay. 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. Please 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

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
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

Table 4.2: SEL-587 Relay Word Bit Definitions

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

Row	Bit	Description	Application	
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		
	4	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	
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	
	5	87R1	Phase 1 Restrained Differential Element	Testing, Indication
		87R2	Phase 2 Restrained Differential Element	
		87R3	Phase 3 Restrained Differential Element	
	5	87R	Percentage Restrained Differential Element, Including Harmonic Blocking	Tripping
6	2HB1	Phase 1 Second-Harmonic Block (SEL-587-0)	Testing, Indication	
		Phase 1 Second- or Fourth-Harmonic Block (SEL-587-1)		
	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	$87BL = 2HB1 + 5HB1 + 2HB2 + 5HB2 + 2HB3 + 5HB3$			
6	RB3	Remote Bit 3	User Definable	

Row	Bit	Description	Application
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	Tripping
	OC2	OPEN Command, Breaker 2	
	CC1	CLOSE Command, Breaker 1 (may only be used in MTUn SELOGIC control equation)	Closing
	CC2	CLOSE Command, Breaker 2 (may only be used in MTUn SELOGIC control equation)	
	IN1	Logic Input 1	Testing, Indication
	IN2	Logic Input 2	
	52A1	Breaker 1 Auxiliary Contact Status	
	52A2	Breaker 2 Auxiliary Contact Status	
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	

Row	Bit	Description	Application
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 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 Relay logic settings are shown in Table 4.3. To change the SEL-587 Relay 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 a “\” as your 80th character, press return, and continue the equation on the next line.
- No single equation may 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.

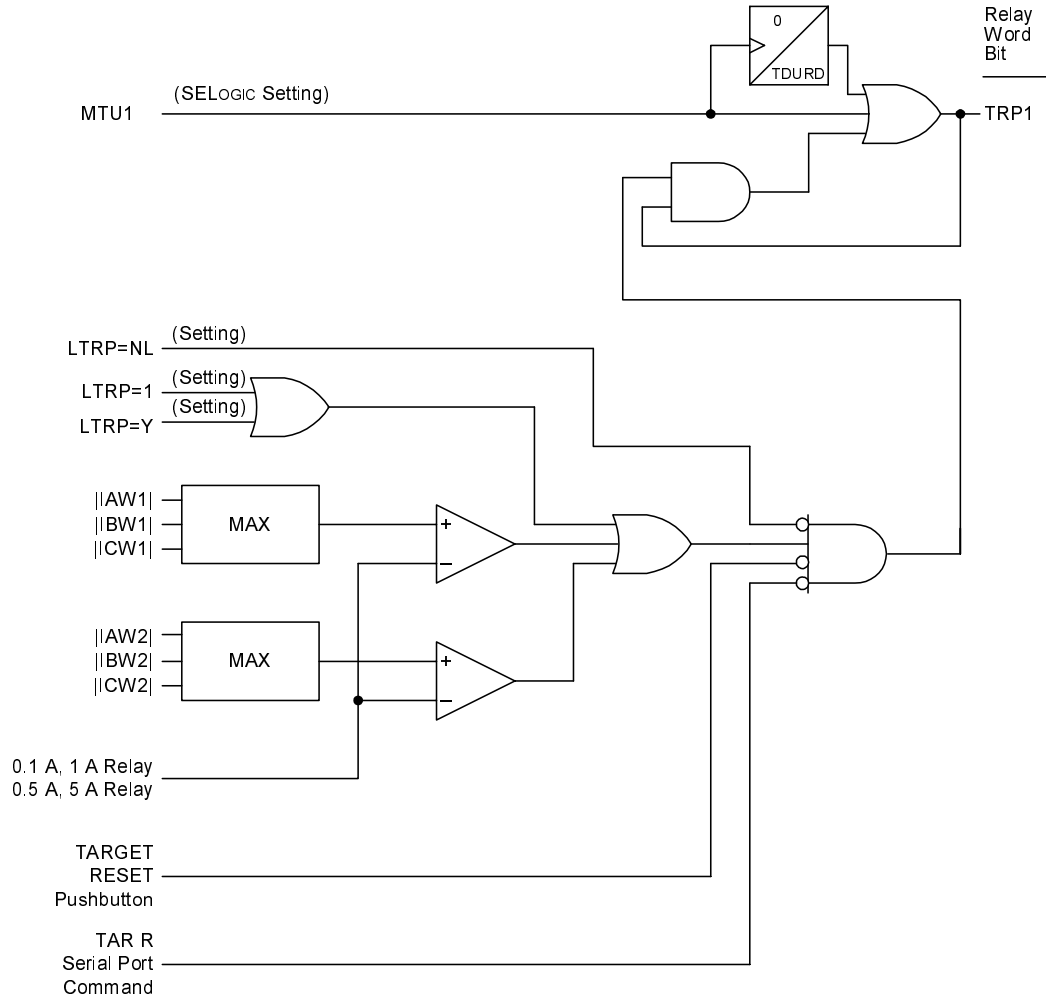
TRIPPING, CLOSING, TIMER, AND OUTPUT CONTACT FUNCTIONS

The SEL-587 Relay 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.



DWG: M5871009

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 Relay.

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 ($0.1 \cdot I_{nom}$). 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 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* in **Section 2: Installation**).

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.

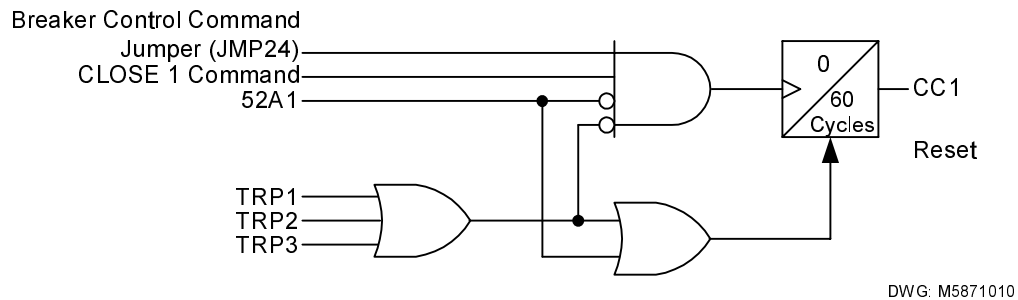


Figure 4.2: Close Logic Diagram

Timer Functions (X, XT, TXPU, TXD0, Y, YT, TYPY, TYD0)

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

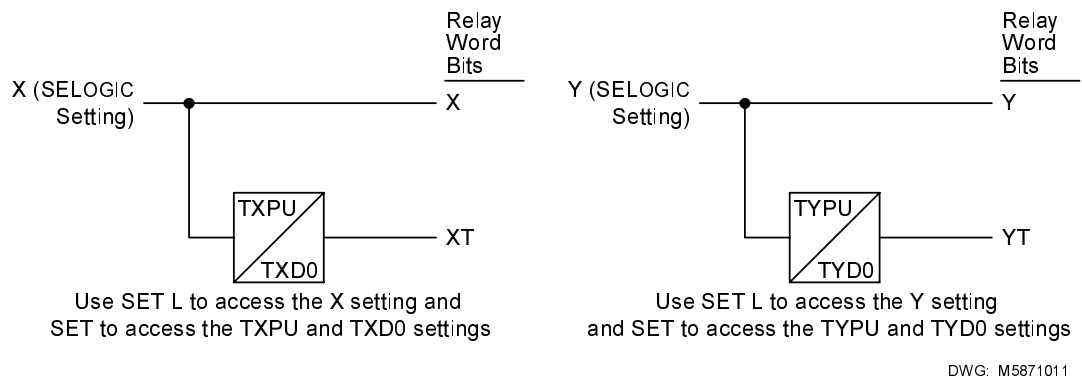


Figure 4.3: X and Y Variables

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 = TRP1	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 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 using the + operator.
Y = 87U . OUT4 = YT TYPY = 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 Relay. 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.

$$\text{OUT1} = \text{TRP1}$$

$$\text{OUT2} = \text{TRP2}$$

$$\text{OUT3} = \text{TRP3}$$

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

$$\text{OUT4} = \text{XT}$$

The example SELLOGIC control equations are summarized below.

$$\text{X} = 87\text{U} + 87\text{R}$$

$$\text{Y} = \text{NA}$$

$$\text{MTU1} = 50\text{P1T} + 51\text{P1T} + 50\text{Q1T} + 51\text{Q1T} + \text{OC1}$$

$$\text{MTU2} = 50\text{P2T} + 51\text{P2T} + 50\text{N2T} + 51\text{N2T} + \text{OC2}$$

$$\text{MTU3} = 87\text{R} + 87\text{U}$$

$$\begin{aligned} \text{MER} = & \text{TH5P} * \text{!TH5T} + 50\text{P1P} + 51\text{P1P} + 50\text{Q1P} + 51\text{Q1P} + 50\text{P2P} \\ & + 51\text{P2P} + 50\text{N2P} + 51\text{N2P} \end{aligned}$$

$$\text{OUT1} = \text{TRP1}$$

$$\text{OUT2} = \text{TRP2}$$

$$\text{OUT3} = \text{TRP3}$$

$$\text{OUT4} = \text{XT}$$

RELAY TARGETS

The SEL-587 Relay 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 Relay selects phase targets 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*
SET	Relay	Differential elements, overcurrent elements, timers, etc.	1–5
SET L	Logic	SELOGIC [®] control equations	6
SET P	Port	Serial port protocol settings	7

* located at end of this section

View settings with the respective serial port **SHOWSET** commands (**SHO**, **SHO L**, **SHO P**). See **SHOWSET** command in Table 6.7, *Section 6: Operator Interface*.

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 in *Section 6: Operator Interface* for information on front-panel communications.

SETTINGS CHANGES VIA THE SERIAL PORT

Note: In this manual, commands you type appear in bold/upper case: **SHOWSET**. You need to type only the first three letters of a command, for example, **SHO**. Computer keys you press appear in bold/upper case/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*

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

and *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.

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 Relay 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 may 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 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 amps 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 Relay 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.

SETTINGS SHEET FOR THE SEL-587-0, -1 RELAY

Settings Increment Chart	
Amps	in .1 steps
Cycles	in .25 steps
kV	in .01 steps

SET Command

General Data			
Description	Range		
Relay Identifier	12 Characters	RID =	_____
Terminal Identifier	12 Characters	TID =	_____
Description	Range		
Maximum Power Transformer Capacity	OFF, 0.2–5000 MVA in .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 Relay 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 Amp 0.1–3.2 A 1 Amp	PDEM =	_____
Negative-Sequence Demand Ammeter Threshold	0.5–16 A 5 Amp 0.1–3.2 A 1 Amp	QDEM =	_____
Residual Demand Ammeter Threshold	0.5–16 A 5 Amp 0.1–3.2 A 1 Amp	NDEM =	_____

Current TAPs			
Description			
Winding 1 Current TAP		TAP1 =	_____
Winding 2 Current TAP		TAP2 =	_____

Input Assignment ¹			
Description	Range		
Input 1	NA,52A1,!52A1,TCEN,TCBL	IN1 =	_____
Input 2	NA,52A2,!52A2,TCEN,TCBL	IN2 =	_____

¹ IN1 or IN2 set to TCEN or TCBL enables torque-control settings.

SETTINGS SHEET FOR THE SEL-587-0, -1 RELAY

Differential Elements			
Description	Range		
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			
Description	Range		
Phase Definite-Time Overcurrent Pickup	OFF, 0.5–80 A 5 Amp OFF, 0.1–16 A 1 Amp	50P1P	= _____
Phase Definite-Time Overcurrent Delay	0–16000.00 cycles	50P1D	= _____
Phase Definite-Time Overcurrent External Torque-Control ²	Y, N	50P1TC	= _____
Phase Instantaneous Overcurrent Pickup	OFF, 0.5–80 A 5 Amp OFF, 0.1–16 A 1 Amp	50P1H	= _____
Phase Instantaneous Overcurrent External Torque-Control ²	Y, N	50P1HC	= _____
Phase Inverse-Time Overcurrent Pickup	OFF, 0.5–16 A 5 Amp OFF, 0.1–3.2 A 1 Amp	51P1P	= _____
Phase Inverse-Time Overcurrent Curve	U1–U4, C1–C4	51P1C	= _____
Phase Inverse-Time Overcurrent Time-Dial	US 0.5–15 in .01 increments IEC 0.05–1 in .01 increments	51P1TD	= _____
Phase Inverse-Time Overcurrent Electromechanical Reset	Y, N	51P1RS	= _____
Phase Inverse-Time Overcurrent External Torque-Control ²	Y, N	51P1TC	= _____

² Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

SETTINGS SHEET FOR THE SEL-587-0, -1 RELAY

Winding 1 Negative-Sequence Overcurrent Elements			
Description	Range		
Negative-Sequence Definite-Time Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	
	OFF, 0.1–16 A	1 Amp	50Q1P = _____
Negative-Sequence Definite-Time Overcurrent Delay	0.5–16000.00 cycles		50Q1D = _____
Negative-Sequence Definite-Time Overcurrent External Torque-Control ²	Y, N		50Q1TC = _____
Negative-Sequence Inverse-Time Overcurrent Pickup	OFF, 0.5–16 A	5 Amp	
	OFF, 0.1–3.2 A	1 Amp	51Q1P = _____
Negative-Sequence Inverse-Time Overcurrent Curve	U1–U4, C1–C4		51Q1C = _____
Negative-Sequence Inverse-Time Overcurrent Time-Dial	US 0.5–15 in .01 increments IEC 0.05–1 in .01 increments		51Q1TD = _____
Negative-Sequence Inverse-Time Overcurrent Electromechanical Reset	Y, N		51Q1RS = _____
Negative-Sequence Inverse-Time Overcurrent External Torque-Control ²	Y, N		51Q1TC = _____

Winding 1 Residual Overcurrent Elements			
Description	Range		
Residual Definite-Time Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	
	OFF, 0.1–16 A	1 Amp	50N1P = _____
Residual Definite-Time Overcurrent Delay	0–16000.00 cycles		50N1D = _____
Residual Definite-Time Overcurrent External Torque-Control ²	Y, N		50N1TC = _____
Residual Instantaneous Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	
	OFF, 0.1–16 A	1 Amp	50N1H = _____
Residual Instantaneous Overcurrent External Torque-Control ²	Y, N		50N1HC = _____
Residual Inverse-Time Overcurrent Pickup	OFF, 0.5–16 A	5 Amp	
	OFF, 0.1–3.2 A	1 Amp	51N1P = _____
Residual Inverse-Time Overcurrent Curve	U1–U4, C1–C4		51N1C = _____
Residual Inverse-Time Overcurrent Time-Dial	US 0.5–15 in .01 increments IEC 0.05–1 in .01 increments		51N1TD = _____
Residual Inverse-Time Overcurrent Electromechanical Reset	Y, N		51N1RS = _____
Residual Inverse-Time Overcurrent External Torque-Control ²	Y, N		51N1TC = _____

² Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

SETTINGS SHEET FOR THE SEL-587-0, -1 RELAY

Winding 2 Phase Overcurrent Elements			
Description	Range		
Phase Definite-Time Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	
	OFF, 0.1–16 A	1 Amp	50P2P = _____
Phase Definite-Time Overcurrent Delay	0–16000.00 cycles		50P2D = _____
Phase Definite-Time Overcurrent External Torque-Control ²	Y, N		50P2TC = _____
Phase Instantaneous Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	
	OFF, 0.1–16 A	1 Amp	50P2H = _____
Phase Instantaneous Overcurrent External Torque-Control ²	Y, N		50P2HC = _____
Phase Inverse-Time Overcurrent Pickup	OFF, 0.5–16 A	5 Amp	
	OFF, 0.1–3.2 A	1 Amp	51P2P = _____
Phase Inverse-Time Overcurrent Curve	U1–U4, C1–C4		51P2C = _____
Phase Inverse-Time Overcurrent Time-Dial	US 0.5–15 in .01 increments IEC 0.05–1 in .01 increments		51P2TD = _____
Phase Inverse-Time Overcurrent Electromechanical Reset	Y, N		51P2RS = _____
Phase Inverse-Time Overcurrent External Torque-Control ²	Y, N		51P2TC = _____

Winding 2 Negative-Sequence Overcurrent Elements			
Description	Range		
Negative-Sequence Definite-Time Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	
	OFF, 0.1–16 A	1 Amp	50Q2P = _____
Negative-Sequence Definite-Time Overcurrent Delay	0.5–16000.00 cycles		50Q2D = _____
Negative-Sequence Definite-Time Overcurrent External Torque-Control ²	Y, N		50Q2TC = _____
Negative-Sequence Inverse-Time Overcurrent Pickup	OFF, 0.5–16 A	5 Amp	
	OFF, 0.1–3.2 A	1 Amp	51Q2P = _____
Negative-Sequence Inverse-Time Overcurrent Curve	U1–U4, C1–C4		51Q2C = _____
Negative-Sequence Inverse-Time Overcurrent Time-Dial	US 0.5–15 in .01 increments IEC 0.05–1 in .01 increments		51Q2TD = _____
Negative-Sequence Inverse-Time Overcurrent Electromechanical Reset	Y, N		51Q2RS = _____
Negative-Sequence Inverse-Time Overcurrent External Torque-Control ²	Y, N		51Q2TC = _____

² Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

SETTINGS SHEET FOR THE SEL-587-0, -1 RELAY

Winding 2 Residual Overcurrent Elements			
Description	Range		
Residual Definite-Time Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	50N2P = _____
	OFF, 0.1–16 A	1 Amp	
Residual Definite-Time Overcurrent Delay	0–16000.00 cycles		50N2D = _____
Residual Definite-Time Overcurrent External Torque-Control ²	Y, N		50N2TC = _____
Residual Instantaneous Overcurrent Pickup	OFF, 0.5–80 A	5 Amp	
	OFF, 0.1–16 A	1 Amp	50N2H = _____
Residual Instantaneous Overcurrent External Torque-Control ²	Y, N		50N2HC = _____
Residual Inverse-Time Overcurrent Pickup	OFF, 0.5–16 A	5 Amp	
	OFF, 0.1–3.2 A	1 Amp	51N2P = _____
Residual Inverse-Time Overcurrent Curve	U1–U4, C1–C4		51N2C = _____
Residual Inverse-Time Overcurrent Time-Dial	US 0.5–15 in .01 increments		51N2TD = _____
	IEC 0.05–1 in .01 increments		
Residual Inverse-Time Overcurrent Electromechanical Reset	Y, N		51N2RS = _____
Residual Inverse-Time Overcurrent External Torque-Control ²	Y, N		51N2TC = _____

Miscellaneous Timers			
Description	Range		
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			
Description	Range		
Nominal Frequency	50, 60 Hz		NFREQ = _____
Phase Rotation	ABC, ACB		PHROT = _____

² Torque-control enable settings are only shown if either IN1 or IN2 is set to TCEN or TCBL.

SETTINGS SHEET
FOR THE SEL-587-0, -1 RELAY

Page 6 of 7
Date _____

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	= _____

SETTINGS SHEET FOR THE SEL-587-0, -1 RELAY

SET P Command (Port Settings)

Protocol and Communications Settings			
Description	Range		
Serial Port Protocol	SEL, LMD, MOD	PROTO	= _____
<i>If PROTO = SEL</i>			
Serial Port Baud Rate	300, 1200, 2400, 4800, 9600, 19200, 38400	SPEED	= _____
Serial Port Data Bits	7, 8	D_BITS	= _____
Serial Port Parity	N, E, O	PARITY	= _____
Serial Port Stop Bits	1, 2	STOP	= _____
Serial Port Time Out	0–30 minutes	TIMEOUT	= _____
Send Auto Message to Port	Y, N	AUTO	= _____
Enable RTS/CTS Handshaking	Y, N	RTS_CTS	= _____
Fast Operate Enable	Y, N	FAST_OP	= _____
<i>If PROTO = LMD</i>			
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	D_BITS	= _____
Serial Port Parity	N, E, O	PARITY	= _____
Serial Port Stop Bits	1, 2	STOP	= _____
Serial Port Time Out	0–30 minutes	TIMEOUT	= _____
Send Auto Message to Port	Y, N	AUTO	= _____
Fast Operate Enable	Y, N	FAST_OP	= _____
<i>If PROTO = MOD (SEL-587-1 Relay)</i>			
Serial Port Baud Rate	300, 1200, 2400, 4800, 9600, 19200	SPEED	= _____
Serial Port Parity	N, E, O	PARITY	= _____
Serial Port Stop Bits	1, 2	STOP	= _____
Slave ID	1–99	SLAVEID	= _____
Send Auto Message to Port	Y, N	AUTO	= _____
Fast Operate Enable	Y, N	FAST_OP	= _____

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SECTION 6: OPERATOR INTERFACE

INTRODUCTION

This section describes operator interface with the SEL-587 Relay 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 manual keys or front-panel buttons you press appear in bold/upper case/brackets: **<ENTER>**. Commands you type appear in bold/upper case: **SHOWSET**. You need to type only the first three letters of a command, for example, **SHO**. The manual shows commands in upper-case letters, but you can enter commands also with lower-case letters.

SERIAL PORT OPERATION

Establish communication with the SEL-587 Relay 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 Relay is equipped with a single serial communications port on the rear panel of the relay. Connect the serial port 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. Examples of PC-based terminal emulation programs include: Procomm[®] Plus, Relay/Gold, Microsoft[®] Windows[®] Terminal, SmartCOM, and CROSSTALK[®].

You can order the SEL-587 Relay with either an EIA-232 or EIA-485 (4-wire) serial port. The default settings for the serial port are the following:

Baud Rate =	2400
Data Bits =	8
Parity =	N
Stop Bits =	1

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

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.

Hardware Protocol

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 may truncate commands to the first three characters. **EVENT 1 <ENTER>** would become **EVE 1 <ENTER>**.
- Upper- and lower-case characters may 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 may 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 (LMD)* 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* 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 Relay. 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
Power-Up	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 <i>Section 7: Event Reports</i> .
Self-Test Warning or Failure	The relay sends a status report each time it detects a self-test warning or failure condition. See <i>STA Command (Status)</i> in this section.

Serial Port Password Security



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

The relay 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 upper-case and lower-case letters as different characters.

Note: The factory-default passwords are shown under *PASSWORD n* later in this section.

Table 6.2: Serial Port Security Function

Access Level	Prompt	Description
0	=	At power-up the relay 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 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**, or **SET P**. 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.

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** later in this section.. 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** later in this section.

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 Relay 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 Relay 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 kiloamps, 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.

CLOSE n

Access Level 2

Issuing the **CLOSE n** command from the serial port asserts the CLOSE Relay Word bit (CCn) 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 Relay 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

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.

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

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 may 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 <SELECT>. Resume scrolling by pressing <SELECT> again. While scrolling is stopped, move through the data 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 using the MET RD command. Reset the peak demand values 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 amps) 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 (OCn) 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



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

Access Level 2

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

Access Level	Default Password
Access Level 1 Password (PAS 1 command)	587
Access Level 2 Password (PAS 2 command)	587

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 may 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 upper-case and lower-case 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:

Ot3579 A24.68 lh2dcs 4u-lwg .351r.

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.

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 to 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** command to set the serial port timeout 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**, or **SET 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. Table 5.2 in **Section 5: *Setting the Relay*** 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	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 timeout; and whether to enable auto messaging, RTS/CTS handshaking, or <i>Fast Operate</i> .

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 6.5 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 6.5: 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 6.5 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 6.7) 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 6.6: 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

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.

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

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 6.7 as guides to SEL-587 Relay front-panel operation. Figure 6.1 illustrates front-panel pushbutton functions. Table 6.7 lists the serial port commands alphabetically within a given access level, front-panel operation equivalents, and a brief description of each command.

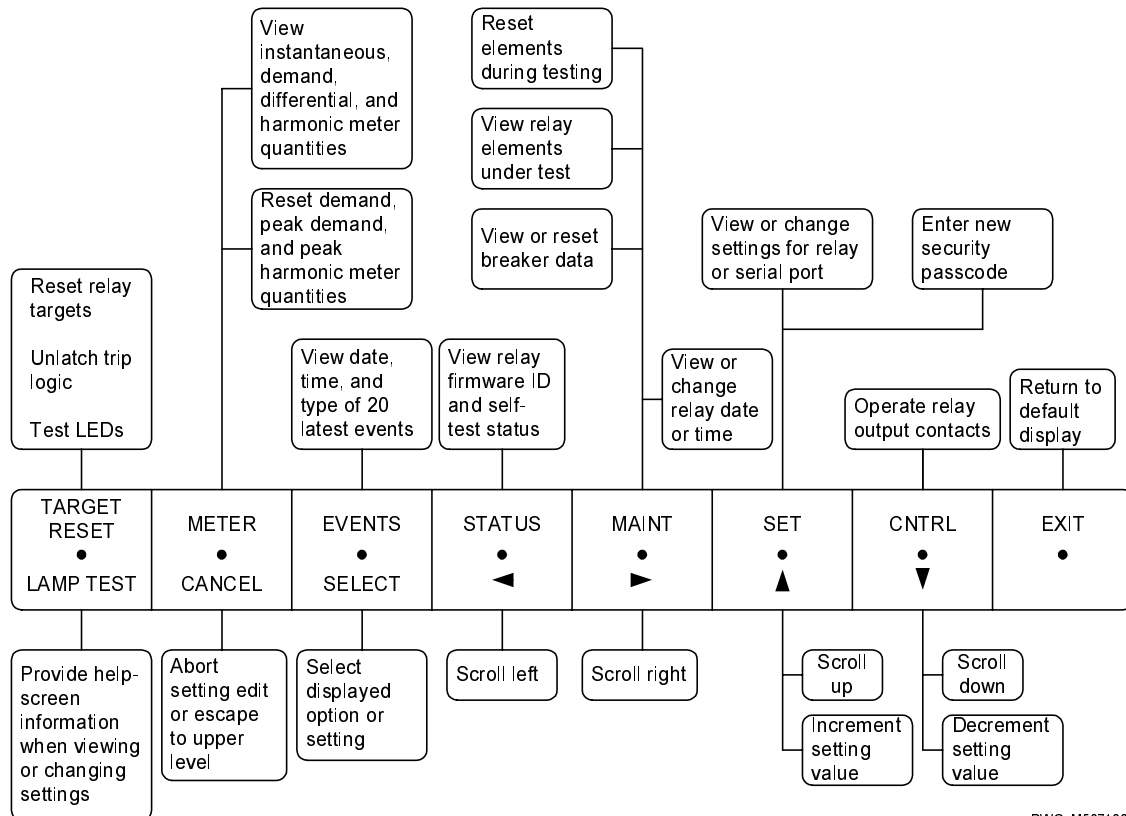


Figure 6.1: Front-Panel Function Drawing

Table 6.7: Serial Port Commands and Front-Panel Operation Equivalents

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 <i>mm/dd/yy</i>	<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.
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.

Access Level	Serial Port Command	Front-Panel Operations	Command Description
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 <i>hh:mm:ss</i>	<MAINT>, TIME, SET	Change time.
1	TRIGGER	–	Trigger a relay event report.
2	BREAKER <i>n R</i>	<MAINT>, OTHER, BRKn, RESET	Reset breaker monitor trip counters and trip current data.
2	CLOSE n	–	Assert Relay Word bit CCn (n = 1, 2).
2	CONTROL n	–	Assert, deassert or pulse Relay Word bit RBn (n = 1, 2, 3, 4).
2	OPEN n (valid only if TDURD>0)	–	Assert Relay Word bit OCn (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	<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 <SELECT>.

Press <EXIT> to end a command and return to the default display. Press <CANCEL> 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



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

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. At power-up the relay 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.

The password is a six-digit, or fewer, alphanumeric combination that may 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 <SELECT> when you have entered the correct alphanumeric character for each digit. Note that relay passwords are case sensitive; the relay treats upper-case and lower-case 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 (communication port settings), or
- Pass (security password).

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

The relay prompts you to enter the Access Level 2 password, if password security is enabled. When you have correctly entered the password, press <SELECT>. 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 <SELECT> 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 <SELECT> 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, 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 <SELECT> 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.), 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 <SELECT> 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) using the up- and down-arrow buttons to scroll through the available settings. Press <SELECT> after you select the setting you want. The relay then displays the next setting.

Press <CANCEL> 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 <EXIT>. The relay prompts you to save changes. To save the new settings, underline “Yes” and press <SELECT>. To reject the new settings, underline “No” and press <SELECT>.

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 back lighting 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 6.7 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 kiloamps pole by pole for the selected breaker. Stop the scrolling by pressing <SELECT>, and resume scrolling by pressing <SELECT> again. While scrolling is stopped, move through the data 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 6.7, 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 display. 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 display. The displayed element names are updated every two seconds on the LCD display.

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 in Table 6.8.

Table 6.8: 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.

SEL-587 RELAY COMMAND SUMMARY

Access Level 0 Command	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 Command	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.
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 10, with n = 1 most recent).
EVE L n	Show standard 15-cycle event report number n, with 1/8-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, both magnitude and phase angle. Phase angles are referenced to phase input IA. 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 P n	Display peak demand data. Enter n to scroll metering n times on screen. Select MET RP n to reset.
MET DIF n	Display differential element quantities. Enter n to scroll metering n times on screen.
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. Returns to Access Level 0. Returns front-panel LEDs to the default targets (corresponding to command TAR 0).
SHO	Show relay settings (overcurrent, reclosing, timers, etc.).
SHO L	Show SELOGIC [®] control equation settings.
SHO P	Show port settings.
STA	Show relay 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.
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 (CCn) Relay Word bit, where n = 1, 2. If CCn 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 RBn (Remote Bit n; n = 1 through 4). Execute CON n and the relay responds: CONTROL RBn. Then reply with one of the following: SRB n set Remote Bit n (assert RBn). CRB n clear Remote Bit n (deassert RBn). PRB n pulse Remote Bit n [assert RBn for one processing interval (1/8 cycle)].
OPE n (valid only if TDURD>0)	Assert the open (OCn) Relay Word bit, where n = 1, 2. If OCn is assigned to an MTUn Relay Word bit and the associated TRPn 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 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.

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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 Relay 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 auto messaging 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.

EVENT REPORT SUMMARY

If you have enabled relay auto messaging (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 auto messaging 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, and

- Phase (each phase), negative-sequence ($3 \cdot I_2$), and residual current magnitudes in amps secondary measured at the largest phase current magnitude in the triggered event report for Windings 1 and 2.

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, digitally filtered event report or a raw, unfiltered event report. 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.

<u>Command</u>	<u>Format</u>
EVENT	<p>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 the filtered values and reports them every quarter cycle in the event report.</p> <p>The relay lists two separate 15-cycle reports, with the relay settings printed in between them. The two separate reports contain the following information:</p> <ul style="list-style-type: none">• 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.

<u>Command</u>	<u>Format</u>
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 the filtered values and reports them every sixteenth cycle in the event report.
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°, 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.

Columns in the First of the Two Reports in the Standard Event Report

<u>Column</u>	<u>Symbol</u>	<u>Definition</u>
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

<u>Column</u>	<u>Symbol</u>	<u>Definition</u>
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

<u>Column</u>	<u>Symbol</u>	<u>Definition</u>
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

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

<u>Column</u>	<u>Symbol</u>	<u>Definition</u>
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	*	Output of X programmable timer
YT	*	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.

EXAMPLE 15-CYCLE EVENT REPORT

The following standard event report was generated by an SEL-587 Relay 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).

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

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 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
Station L

Date: 01/12/95 Time: 18:33:44.796

Relay and Terminal
Identifier settings

FID=SEL-587-X104-V5a-D950106

Relay Elements OUT IN

First Report

Winding 1				Winding 2				Relay Elements				OUT	IN
Amps Sec				Amps Sec				555555	555555	888	A		
IRW1	IAW1	IBW1	ICW1	IRW2	IAW2	IBW2	ICW2	111000	111000	777	13L	1	
								PQNPQN	PQNPQN	URB	&&R	&	
								111111	222222	L	24M	2	

[Two cycles of data not shown in this example]

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.....	.....	..	..
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.....	.....	..	..
0.3	0.0	-8.0	8.3	-0.0	0.0	0.0	-0.1	.....	.....	..*	..	1
0.7	0.9	2.1	-2.3	-0.0	-0.4	0.4	0.0	p.....	.....	..*	..	1
-1.5	-0.3	57.5	-58.7	-0.0	0.3	-0.5	0.2	p.p..	.....	..*	..	1
-0.8	-2.4	-27.1	28.7	0.0	1.0	-0.8	-0.1	p.p..	.....	..*	..	1
-0.1	0.7	-104.7	103.9	0.0	-0.6	0.8	-0.2	pq.p..	.....	..*	1..	1
-0.1	1.9	50.0	-52.1	-0.0	-0.8	0.6	0.2	pq.p..	.....	**	1..	1
1.4	-0.5	62.6	-60.7	-0.0	0.3	-0.4	0.0	pq.p..	.....	**	1..	1
0.2	-0.4	-25.0	25.6	0.0	0.2	-0.1	-0.1	pq.p..	.....	**	1..	..
-0.1	0.0	-7.4	7.3	-0.0	-0.0	0.0	0.0	pq.p..	.....	**	1..	..
-0.0	-0.0	0.0	0.0	-0.0	-0.0	0.0	0.0	pq.p..	.....	**	1..	..

Breaker closes into fault (IN1=52A1); blocking element asserts for inrush (87BL)

Blocking element drops out and restrained element (87R) trips via output OUT1

[10 cycles of data not shown in this example]

Event: TRP1	Targets: 87 B C	Duration: 2.50 cyc
Winding 1 Currents (A Sec), ABCQN:	0.9 8.3 8.6 25.7 0.8	
Winding 2 Currents (A Sec), ABCQN:	0.4 0.4 0.1 0.4 0.0	

Event Summary

[Settings listed here, but not shown in this example]

Relay Elements OUT IN

Second report (Note correspondence with above first report)

Operating Qty			Restraint Qty			Max Hrm		Relay Elements				OUT	IN
Amps Sec			Amps Sec			Amps Sec		888888	222555	TTT	PQN	A	
IOP1	IOP2	IOP3	IRT1	IRT2	IRT3	IF2	IF5	777777	HHHHH	RRRXYCO	TDDD	13L	1
								UUURRR	BBBBB	PPPTCC	HEEE	&&R	&
								123123	123123	123	5MMM	24M	2

[Two cycles of data not shown in this example]

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.....	.....	.....	.....	.....	.....
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.....	.....	.....	.....	.....	1
0.0	7.8	8.2	0.0	4.0	4.1	8.1	3.4	.....	**,**	.....	.....	.....	1
0.0	8.2	8.4	0.8	4.3	4.5	14.4	4.8	.....	**,**	.....	.....	.....	1
0.4	56.9	58.8	0.9	29.1	29.6	14.2	6.2	...**	**	.....	.....	.....	1
0.7	63.3	64.9	2.1	32.2	33.2	33.1	7.6	...**	**	.....	.....	.....	1
0.8	107	107	2.3	54.6	54.4	21.7	6.7	...**	*	.....	.....	1..	1
0.8	115	116	1.9	58.5	58.6	16.3	5.3	**,**	*	.....	.....	1..	1
0.5	80.0	79.5	1.7	40.3	40.4	16.7	6.6	**,**	**	.....	*	.....	1.. 1
0.1	67.0	66.0	0.6	33.9	33.1	35.0	6.0	**,**	**	.....	*	.....	1.. .
0.0	26.1	26.3	0.3	13.0	13.4	17.9	3.9	...**	**	.....	*	.....	1.. .
0.0	7.4	7.3	0.0	3.7	3.6	0.0	3.7	...**	**,**	*	.....	.....	1.. .

2nd and 5th harmonic blocking

One cycle of data

[10 cycles of data not shown in this example]

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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 Relay. 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

Protective relay testing may be divided into three categories: acceptance, 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.

Acceptance Testing

When: When qualifying a relay model to be used on the utility system.

- Goal:
- a) Ensure relay meets published critical performance specifications such as operating speed and element accuracy.
 - b) Ensure that the relay meets the requirements of the intended application.
 - c) Gain familiarity with relay settings and capabilities.

What to test: All protection elements and logic functions critical to the intended application.

SEL performs detailed acceptance testing on all new relay models and versions. We are certain the relays we ship meet their published specifications. It is important for you to perform acceptance testing on a relay if you are unfamiliar with its operating theory, protection scheme logic, or settings. This helps ensure the accuracy and correctness of the relay settings when you issue them.

Commissioning Testing

When: When installing a new protection system.

- Goal:
- a) Ensure that all system ac and dc connections are correct.
 - b) Ensure that the relay functions as intended using your settings.
 - c) 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:

- a) Ensure that the relay is measuring ac quantities accurately.
- b) Ensure that scheme logic and protection elements are functioning correctly.
- c) 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 may 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 Relay has a low-level test interface between the calibrated input module and the separately calibrated processing module. You may 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).

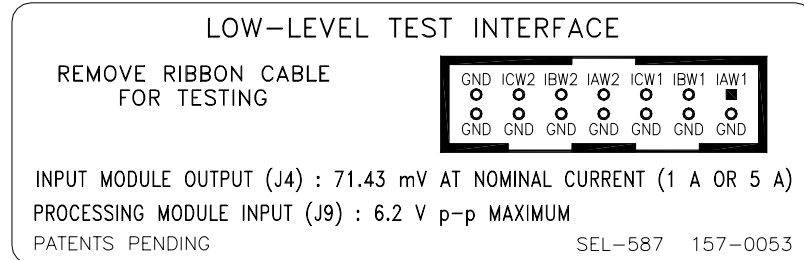
You can test the relay processing module using signals from the SEL-RTS Low-Level Relay Test System. Never apply voltage signals greater than 6.2 volts peak-peak to the low-level test interface. Figure 8.1 shows the signal scaling factors.



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

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.



DWG. 1119-114

Figure 8.1: Low-Level Test Interface

Test Methods

Test the pickup and dropout of relay elements 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

Note: 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 Relay now displays the state of several Winding 1 overcurrent elements on the front-panel LED and LCD display, 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

Note: The steps taken in the example test for the Winding 1 51N1T residual time-overcurrent element operating time may 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, may 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 (t_p) 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.

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):

$$t_p = TD \cdot \left[0.0963 + \frac{3.88}{M^2 - 1} \right]$$

$$t_p = 2.33 \text{ seconds}$$

Step 5. Set the current source to deliver M·51N1P amps 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.

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.

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

Note: 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

Note: 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.

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 connection constant A shown in Table 8.1. TRCON and CTCN 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:

$$I_0 = \frac{1}{3}(I_a + I_b + I_c)$$

If $I_b = 0$ and $I_c = 0$, then

$$I_0 = \frac{1}{3}(I_a)$$

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*	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

*RZS setting hidden for TRCON = YY.

Step 3. Execute the **TARGET 5** command. The SEL-587 Relay 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

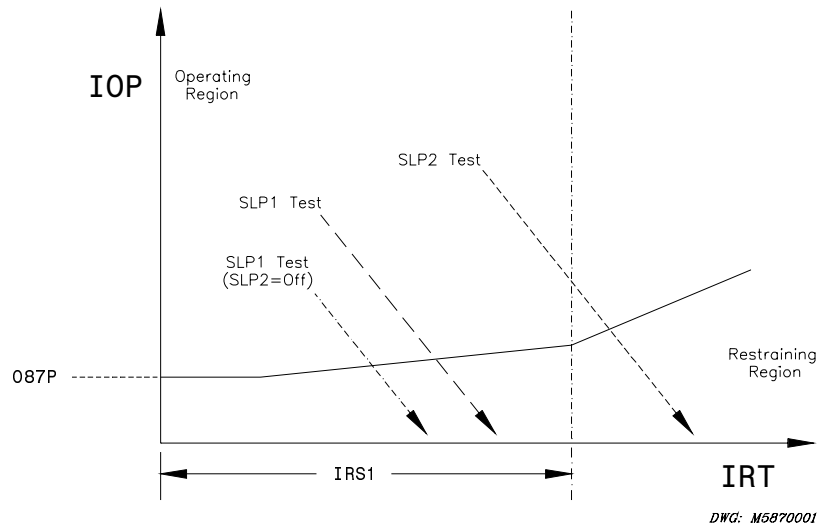


Figure 8.2: Percentage Restraint Differential Characteristic and Slope Test

Restraint Slope 1 Percentage: SLP1 Setting

- 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 Relay 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:

$$IAW1 = 0.8 \cdot IRS1 \cdot \left[1 + \frac{SLP1}{200} \right] \cdot TAP1 \cdot A$$

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:

$$IAW1 = 2 \cdot 087P \cdot \left[\frac{100}{SLP1} + \frac{1}{2} \right] \cdot TAP1 \cdot A$$

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:

$$IAW2 = 0.8 \cdot IRS1 \cdot \left[1 - \frac{SLP1}{200} \right] \cdot TAP2 \cdot B$$

If SLP2 = OFF use the following equation:

$$IAW2 = 2 \cdot 087P \cdot \left[\frac{100}{SLP1} - \frac{1}{2} \right] \cdot TAP2 \cdot B$$

SLP1, IRS1, 087P, 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.

Note: IRS1 must be greater than $\frac{100}{0.8 \cdot SLP1} \cdot 087P$ if SLP2 is not set to OFF.

Restraint Slope 2 Percentage: SLP2 Setting

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 Relay 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:

$$IAW1 = 1.2 \cdot IRS1 \cdot \left[1 + \frac{SLP1 + 0.2 \cdot SLP2}{1.2 \cdot 200} \right] \cdot TAP1 \cdot A$$

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:

$$IAW2 = 1.2 \cdot IRS1 \cdot \left[1 - \frac{SLP1 + 0.2 \cdot SLP2}{1.2 \cdot 200} \right] \cdot TAP2 \cdot B$$

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 Blocking Function Test: PCT2 and PCT4 Setting (HRSTR = Y)

Note: This test requires a current source capable of generating second- and fourth-harmonic current. This example tests the second-harmonic blocking function. Use the same procedure to test the fourth-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 Relay now displays the state of several differential elements on the front-panel LED and LCD display, 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 Relay). 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 ($\pm 5\% \pm 0.10$ A (5 A relay) or $\pm 5\% \pm 0.02$ A (1 A relay)):

$$IIF2 = [IOP1 - IRT1 \cdot f(SLP)] \cdot \frac{PCT2}{100}$$

$$\text{and \% harmonic} = \frac{IIF2}{IOP1} \cdot 100 (\text{percent})$$

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:

$$\% \text{ harmonic} = \left(\frac{PCT2}{200} \right) \cdot \left(200 - SLP2 - \frac{IRS1}{IRT} (SLP1 - SLP2) \right)$$

For example, slope 1 = 25 percent, slope 2 = 60 percent, PCT2 = 20 percent, IRS1 = 3, and choose IRT = 6.

$$\% \text{ harmonic} = \left(\frac{20}{200} \right) \cdot \left(200 - 60 - \frac{3}{6} (25 - 60) \right) = 15.75 \text{ percent}$$

Note: The second and fourth harmonics are combined to form the restraint quantity.

Harmonic Blocking Function Test: PCT2, PCT4, and PCT5 Setting (HRSTR = N)

Note: 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 Relay now displays the state of several differential elements on the front-panel LED and LCD display, 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 Relay). 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).

$$PCT\ 2 = \frac{IAW1(\text{second harmonic})}{IAW1(\text{fundamental})} \cdot 100$$

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 deenergized. The EN front-panel LED is extinguished.
- **ALARM Output:** The ALARM output contact signals an alarm condition by going to its deenergized state. If the ALARM output contact is a B contact (normally closed), it closes for an alarm condition or if the relay is deenergized. If the ALARM output contact is an A contact (normally open), it opens for an alarm condition or if the relay is deenergized. 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 display for failures.

Use the serial port **STATUS** command or front-panel STATUS pushbutton to view relay self-test status.

Table 8.2: Relay Self-Tests

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
IA,IB,IC,IN Offset	Warning	30 mV	No	Pulsed	Measures the dc offset at each of the current input channels every 0.2 seconds.
Master Offset +5V PS	Warning	20 mV	No	Pulsed	Measures the dc offset at the A/D every 0.2 seconds. Measures the +5-volt power supply every 0.2 seconds.
	Failure	30 mV	Yes	Latched	
	Warning	+4.75 V +5.25 V	No	Pulsed	
±5V REG	Failure	+4.70 V +5.50 V	Yes	Latched	Measures the regulated 5-volt power supply every 0.2 seconds.
	Warning	±4.65 V ±5.35 V	No	Pulsed	
±10V PS	Failure	±4.50 V ±5.50 V	Yes	Latched	Measures the 10-volt power supply every 0.2 seconds.
	Warning	±9.00 V ±11.00 V	No	Pulsed	
VBAT	Failure	±8.00 V ±12.00 V	Yes	Latched	Measures the Real Time clock battery every 0.2 seconds.
	Warning	+2.25 V +5.00 V	No	Pulsed	
TEMP	Failure	+2.10 V +6.00 V	No	Pulsed	Measures the temperature at the A/D voltage reference every 0.2 seconds.
	Warning	-40°C +85°C	No		
RAM	Failure	-50°C +100°C	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.

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
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.					
Micro-processor Crystal	Failure		Yes	Latched	The relay monitors the micro-processor crystal. If the crystal fails, the relay displays "CLOCK STOPPED" on the LCD display. The test runs continuously.
Micro-processor	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 the *Troubleshooting Procedure*.

1. Measure and record the power supply voltage at the power input terminals.
2. Check to see that the power is on. Do not turn the relay off.
3. Measure and record the voltage at all control inputs.
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 deenergized. 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 back lighting.
 - 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 Relay is factory calibrated. If you suspect that the relay is out of calibration, please contact the factory.

FACTORY ASSISTANCE

The employee-owners of Schweitzer Engineering Laboratories are dedicated to making electric power safer, more reliable, and more economical.

We appreciate your interest in SEL products, and we are committed to making sure you are satisfied. If you have any questions, please contact us at:

Schweitzer Engineering Laboratories
2350 NE Hopkins Court
Pullman, WA USA 99163-5603
Tel: (509) 332-1890
Fax: (509) 332-7990

We provide prompt, courteous, and professional service.

We appreciate receiving any comments and suggestions about new products or product improvements that would help us make your job easier.

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APPENDIX A: FIRMWARE VERSIONS

To find the firmware revision number in your relay, view the status report (which identifies the firmware) using the **STATUS** command or the front-panel STATUS pushbutton. This is an FID (firmware identifier) number with the Part/Revision number in bold for firmware versions prior to April 6, 2001:

FID=SEL-587-1-Rxxx-Vxb-Dxxxxxx

For firmware versions with the date code of April 6, 2001, or later, the FID label will appear as follows with the Part/Revision number in bold:

FID=SEL-587-1-Rxxx-Vxb-Dxxxxxxxx

The firmware revision number follows the “R” and the release date follows the “D.” The single “x” after the “V” will be a “1” for a 1 amp relay and “5” for a 5 amp relay.

Firmware series R101–R1xx and R401–R4xx are stored in through-hole EPROM and are upgraded by replacing an EPROM integrated circuit component on the SEL-587 Relay main board. Firmware series R500–R5xx and R600–R6xx are stored in SMT (surface mount technology) EPROM and are upgraded by replacing an EPROM integrated circuit component on the SEL-587 Relay main board.

This manual covers SEL relays that contain firmware bearing the following part numbers and revision numbers (most recent firmware listed at top):

Firmware Part/Revision No.	Description of Firmware
	<p>These firmware versions differ from previous versions as follows:</p> <ul style="list-style-type: none"> – Add Modbus[®] RTU protocol. – Change the FID string to use a four-digit year instead of a two-digit year. – Change the IHBL default setting to IHBL = N. – Add DS1302 battery-backed clock support.
SEL-587-1-R600-D20010606	5 Amp (Supports PROTO=MOD)
SEL-587-1-R650-D20010606	1 Amp (Supports PROTO=MOD)
SEL-587-1-R502-D20010606	5 Amp (Does Not Support PROTO=MOD)
SEL-587-1-R552-D20010606	1 Amp (Does Not Support PROTO=MOD)

Firmware Part/Revision No.	Description of Firmware
SEL-587-0-R505-D000505 SEL-587-0-R555-D000505 SEL-587-1-R501-D000505 SEL-587-1-R551-D000505	<p>This firmware differs from previous versions as follows:</p> <ul style="list-style-type: none"> – For both the SEL-587-0 and SEL-587-1 Relays, this firmware fixes the LMD protocol (PROTO=LMD) so it properly handles applications with multiple devices, <i>Fast Meter</i> protocol (PROTO=SEL) so it completes transmission of <i>Fast Meter</i> data after the Serial Port Time-Out (TIMEOUT) timer expires, and <i>Fast Meter</i> protocol so it responds to <i>Fast Meter</i> commands received shortly after transmission of <i>Fast Meter</i> data from an earlier command. The firmware enhances 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. – For the SEL-587-1 Relay, this firmware correctly initializes the DC blocking element so it does not pick up after a series of setting changes. 5 Amp 1 Amp 5 Amp 1 Amp
SEL-587-1-R500-D991215 SEL-587-1-R550-D991215	<p>This firmware differs from previous versions as follows:</p> <ul style="list-style-type: none"> – Adds harmonic restraint, trip unlatch, and zero-sequence removal. 5 Amp 1 Amp
SEL-587-R503 SEL-587-R553	<p>This firmware differs from previous versions as follows:</p> <ul style="list-style-type: none"> – Correct event type indication to include TRP1 when TRP1 asserts during an event, but does not trigger the event. 5 Amp 1 Amp
	<p>This firmware differs from previous versions as follows:</p> <ul style="list-style-type: none"> – Decreased power-up initialization time.

Firmware Part/Revision No.	Description of Firmware
SEL-587-R502 SEL-587-R552	5 Amp 1 Amp
SEL-587-R501 SEL-587-R551	This firmware differs from previous versions as follows: <ul style="list-style-type: none"> – Fixed <i>Fast Meter</i> target data problem and system clock calibration problem. 5 Amp 1 Amp
SEL-587-R500 SEL-587-R550	This firmware differs from previous versions as follows: <ul style="list-style-type: none"> – Added IRIG. – Added secondary metering with phase angle. – Improved communications. 5 Amp 1 Amp
SEL-587-R105 SEL-587-R405	This firmware differs from previous versions as follows: <ul style="list-style-type: none"> – Password changed to allow up to six alphanumeric digits. – Improved <i>Fast Meter</i> configuration 5 Amp 1 Amp
SEL-587-R103 SEL-587-R402	This firmware differs from previous versions as follows: <ul style="list-style-type: none"> – Limited Multidrop (LMD) protocol. – <i>Fast Meter</i> messages. – <i>Fast Operate</i> messages. – Compressed ASCII commands. – The CONTROL command which allows the user to set, clear or pulse the new relay elements RB1–RB4. 5 Amp 1 Amp
SEL-587-R102	5 Amp
SEL-587-R101 SEL-587-R401	Original Firmware Release. 5 Amp 1 Amp

APPENDIX B: FIRMWARE (EPROM) UPGRADE INSTRUCTIONS

FIRMWARE UPGRADES

To install the new EPROM containing the firmware upgrade, you will be required to power down the relay, remove the front panel, pull out the drawout assembly, exchange an integrated circuit (IC) chip, and reassemble the relay. If you do not wish to perform the installation yourself, SEL can assist you. Simply return the relay and IC to SEL. We will install the new IC and return the unit to you within a few days.

Required Equipment

- Phillips screwdriver
- Personal computer
- Terminal emulation software (e.g., Windows[®] Terminal)
- Serial communications cable (SEL-234A or equivalent)
- ESD workstation (grounding pad and wrist strap)
- AMP Extraction Tool 822154-1 for surface-mount (SMT) upgrades
- IC removal tool or small screwdriver for through-hole upgrades

Upgrade Instructions

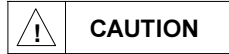


CAUTION

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.

- Step 1.** Connect a computer or terminal to the relay serial communications port and enter Access Level 1. Execute the **SHO C** command, and record all displayed data for possible future recalibration. Remove the communications cable from the rear-panel communications port.
- Step 2.** If the relay is in service, disable its breaker control functions. Turn off control power to the relay.

Step 3. Remove the three front-panel screws, and remove the relay front panel.



CAUTION

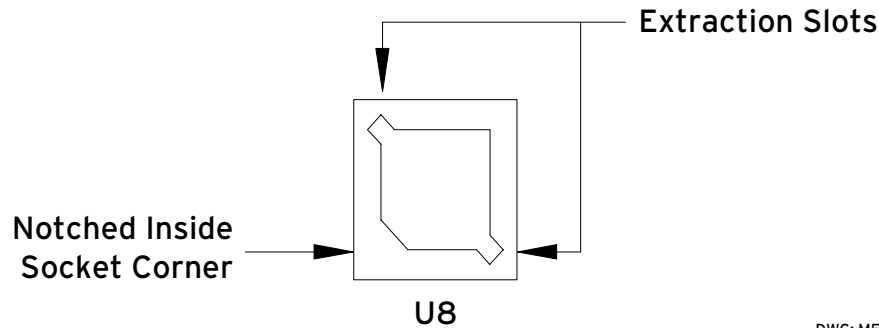
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with front or top cover removed, work surfaces and personnel must be properly grounded or equipment damage may result.

Step 4. Disconnect the analog signal ribbon cable from the underside of the relay main board and from the input module. Grasp the black knob on the front of the drawout assembly, and remove the assembly from the relay chassis. Because the following steps involve handling devices and assemblies sensitive to ESD, perform these steps at an ESD-safe workstation. This will help prevent possible damage by ESD.

Surface-Mount Procedure

If you have a surface-mounted (SMT) EPROM, perform the following steps. Skip to step 9 if you have a through-hole EPROM.

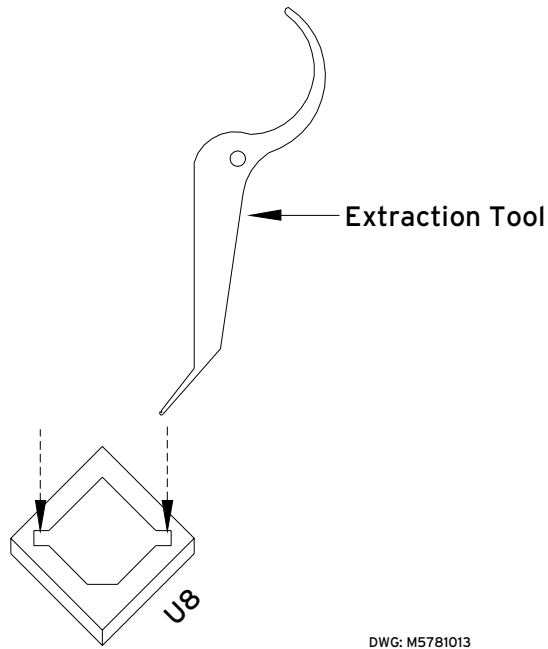
Step 5. Locate the EPROM socket (reference designator U8) at the left rear of the relay main board.



DWG: M5871012

Figure B.1: EPROM Socket

Step 6. Insert AMP Extraction Tool 822154-1 into one of the extraction slots on the EPROM socket. With a slight downward pressure, rotate the extraction tool away from the EPROM socket until the EPROM starts to lift away from the socket. Do not lift the EPROM all the way out on the first attempt.



DWG: M5781013

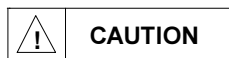
Figure B.2: Insertion of the Extraction Tool in the EPROM Socket

Reference: AMP Instruction Sheet 408-9695 (dated May 18, 1994, Rev. B).

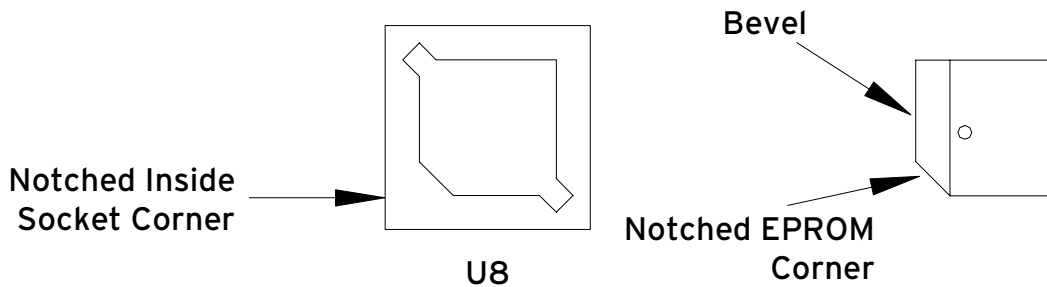
- Step 7.** Remove the extraction tool from the slot, and insert it into the opposite extraction slot. With a slight downward pressure, rotate the extraction tool away from the EPROM socket until the other side of the EPROM starts to lift away from the EPROM socket.

Alternate between the two extraction slots, and gently lift out the EPROM from the socket.

- Step 8.** Carefully place the new EPROM in the socket, and apply even, firm pressure to fully engage it in the socket.



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 reenergize the relay with an IC reversed, do not place the relay in service using that IC, even if you correct the orientation.



DWG: M5871014

Figure B.3: Proper Orientation of the EPROM and EPROM Socket

Through-Hole Procedure

If you have through-hole-mounted components, perform the following steps. Otherwise, skip to step 11.

- Step 9.** Locate the relay EPROM socket (reference designator U2) at the left rear of the relay main board. Use the appropriate IC removal tool to remove the IC from its socket. This is the preferred method of removal. You may also use a small screwdriver, should necessity dictate. If you use a screwdriver, alternately pry up on each end of the indicated IC, rotating the screwdriver slightly, to remove the IC from its socket. Be careful not to bend the IC pins or damage adjacent components.

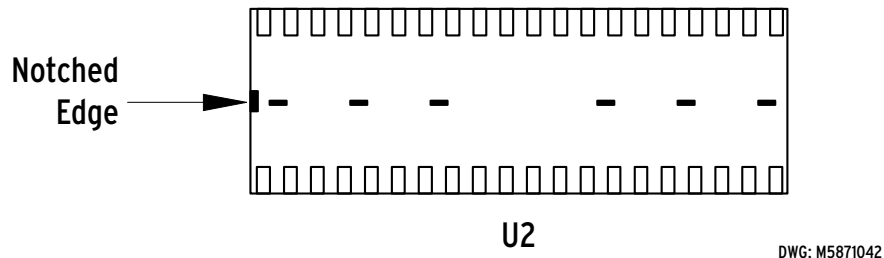


Figure B.4: EPROM Socket

- Step 10.** Carefully place the new IC in the appropriate socket. Refer to Figure B.5 and check the orientation of the IC. The orientation mark is typically a half-circle indentation in one end of the IC. Look for IC pins that are bent under or did not enter a socket hole.



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 reenergize the relay with an IC reversed, do not place the relay in service using that IC, even if you correct the orientation.

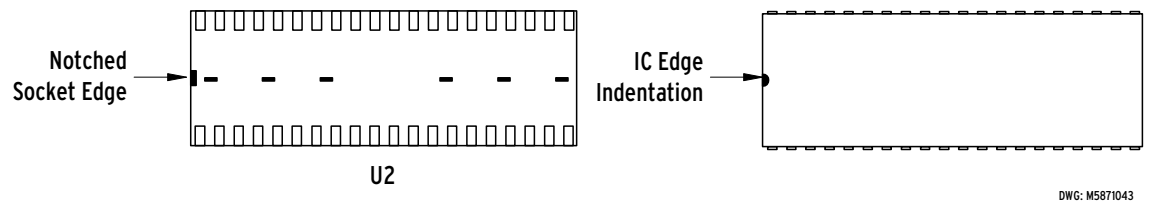


Figure B.5: Proper Orientation of the Firmware IC and Firmware Socket

- Step 11.** Slide the drawout assembly into the relay chassis. Reconnect the analog signal ribbon cable. Replace the relay front panel. Replace the rear-panel communications cable.
- Step 12.** With breaker control disabled, turn relay power on. If the relay front panel displays a FAILURE message, such as CR RAM or EEPROM failure, the relay settings will need to be reentered. Connect a computer or terminal set to 2400 baud, 8 data bits, and 1 stop bit to the relay serial communications port and enter Access Level 2. Execute the **R_S** command.

Execute the **SET L** and **SET P** commands to enter the correct relay settings for your application.

Execute the **STATUS**, **METER**, and **TRIGGER** commands to ensure that all functions are operational. Set and record your Access Level 1 and Access Level 2 passcodes and the date and time.

Step 13. With relay communications still established and at Access Level 2, execute the **SHO C** command and review the displayed data. If the data are identical to the previously recorded data of step 1, you may execute the **QUIT** command, and the relay is ready for your commissioning procedure. If, however, any channel gains are different, you must reenter the previously recorded values by executing the **SET C** command (similar to relay settings procedure). After this procedure is completed and changes have been saved, execute the **QUIT** command. The relay is now ready for your commissioning procedure.

Step 14. If a new serial number label is included with the upgrade, attach the serial number label so the old label is covered.

APPENDIX C: SEL DISTRIBUTED PORT SWITCH PROTOCOL (LMD)

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** command to activate the LMD protocol. Change the port PROTOCOL setting from the default SEL to LMD to reveal the following settings:

- PREFIX:** One character to precede the address. This should be a character which 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

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 timeout 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.

Note: You can use the front-panel SET pushbutton to change the port settings to return to SEL protocol.

APPENDIX D: CONFIGURATION, FAST METER, AND FAST OPERATE COMMANDS

INTRODUCTION

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 Relay.

MESSAGE LISTS

Binary Message List

<u>Request to Relay (hex)</u>	<u>Response from Relay</u>
A5C0	Relay Definition Block.
A5C1	<i>Fast Meter</i> Configuration Block.
A5D1	<i>Fast Meter</i> Data Block.
A5C2	Demand <i>Fast Meter</i> Configuration Messages.
A5D2	Demand <i>Fast Meter</i> Data Message.
A5C3	Peak Demand <i>Fast Meter</i> Configuration Messages.
A5D3	Peak Demand <i>Fast Meter</i> Message.
A5CE	<i>Fast Operate</i> Configuration Block.
A5E0	<i>Fast Operate</i> Remote Bit Control.
A5E3	<i>Fast Operate</i> Breaker Control.
A5B2	Oldest Unacknowledged Event Report Packet.
A5B5	Acknowledge Event Report Most Recently Sent.
A5B9	Status Flag Byte and Clear Status Bits Command.
A560	Most Recent Event Report.
A561–A56A	Older Event Reports.

ASCII Configuration List

<u>Request to Relay (ASCII)</u>	<u>Response from Relay</u>
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

<u>Data</u>	<u>Description</u>
A5C0	Command
4A	Length
03	Support three protocols, SEL, LMD, and MOD
03	Support three <i>Fast Meter</i> messages
06	Six status flag commands
A5C1	<i>Fast Meter</i> configuration command
A5D1	<i>Fast Meter</i> command
A5C2	Demand <i>Fast Meter</i> configuration command
A5D2	Demand <i>Fast Meter</i> command
A5C3	Peak Demand <i>Fast Meter</i> configuration command
A5D3	Peak Demand <i>Fast Meter</i> 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 <i>Fast Meter</i> 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, <i>Fast Operate</i>
0101	LMD protocol, <i>Fast Operate</i>
0002	MOD protocol
00	Reserved for future use
checksum	Checksum (1 byte)

A5C1 Fast Meter Configuration Block

<u>Data</u>	<u>Description</u>
A5C1	<i>Fast Meter</i> command
6A	Length
01	One status flag byte
00	Scale factors in <i>Fast Meter</i> message
02	Two scale factors
06	Six analog input channels
04	Four samples per channel
0C	Twelve 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 <i>Fast Meter</i> 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 <i>Fast Meter</i> message
494257320000	Analog channel name (IBW2)
00	
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 CTRON 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

1.	2 bytes	Command codes A5D1 (hex), outside the range of normal ASCII printable characters.
2.	1 byte	Message length, 52 (hex).
3.	1 byte	One status byte.
4.	4 bytes	Winding one scale factor (4-byte IEEE FPS).
5.	4 bytes	Winding two scale factor (4-byte IEEE FPS).
6.	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.
7.	8 bytes	Time stamp.
8.	12 bytes	12 digital banks. TAR0 – TAR11.
9.	1 byte	Reserved for future use.
10.	<u>1 byte</u>	Checksum calculated by addition of all the above bytes.
	82 bytes	Total message length.

A5C2 Demand Fast Meter Configuration Messages

<u>Data</u>	<u>Description</u>
A5C2	Demand <i>Fast Meter</i> command
76	Length
00	Zero status flag bytes
00	Scale factors in <i>Fast Meter</i> 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 <i>Fast Meter</i> 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	
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* Data Message

1.	2 bytes	Command codes A5D2 (hex), outside the range of normal ASCII printable characters.
2.	1 byte	Message length, 56 (hex).
3.	1 byte	Reserved for future use.
4.	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.
5.	1 byte	Reserved for future use.
6.	<u>1 byte</u>	Checksum calculated by addition of all the above bytes.
	86 bytes	Total message length.

A5C3 Peak Demand *Fast Meter* Configuration Messages

<u>Data</u>	<u>Description</u>
A5C3	Peak demand <i>Fast Meter</i> command
76 (HEX)	Length
00	Zero status flag bytes
00	Scale factors in <i>Fast Meter</i> 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 <i>Fast Meter</i> 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		
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

- | | | |
|----|----------|--|
| 1. | 2 bytes | Command codes A5D3 (hex), outside the range of normal ASCII printable characters. |
| 2. | 1 byte | Message length, A6 (hex). |
| 3. | 1 byte | Reserved for future use. |
| 4. | 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. |
| 5. | 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. |
| 6. | 1 byte | Reserved for future use. |

7.	<u>1 byte</u>	Checksum calculated by addition of all the above bytes.
	166 bytes	Total message length.

A5CE Fast Operate Configuration Block

<u>Data</u>	<u>Description</u>
A5CE	Command
1A	Length
02	Support two circuit breakers
0004	Support four remote bits
01	Flags: Remote bit supported
00	Reserved for future use
31	Operate code, open breaker 1
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 for future use
checksum	Checksum (1 byte)

A5E0 Fast Operate Remote Bit Control

The external device sends the following message to perform a remote bit operation:

<u>Data</u>	<u>Description</u>
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: $4 \cdot \text{Operate code} + 1$
checksum	1-byte checksum of preceding bytes

The relay performs the specified remote bit operation if the following conditions are true:

1. The Operate code is valid
2. The Operate validation = $4 \cdot \text{Operate code} + 1$
3. The message checksum is valid
4. The FAST_OP port setting is set to Y
5. 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:

<u>Data</u>	<u>Description</u>
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: $4 \cdot \text{Operate code} + 1$
checksum	1-byte checksum of preceding bytes

The relay performs the specified breaker operation if the following conditions are true:

1. Conditions 1–5 defined in the A5E0 message are true
2. The BREAKER jumper is in place on the main board
3. The TDURD setting is non-zero

A5B2 Oldest Unacknowledged Event Report Packet

1.	2 bytes	Command codes A5B2 (hex), outside the range of normal ASCII printable characters.
2.	1 byte	Message length, 42 (hex).
3.	1 byte	Active group at time of event report trigger, 0 for SEL-587 Relay.
4.	8 bytes	Time: byte each for month, day, last 2 digits of year, hour, min, sec, msec (word)

5. 8 bytes EVENT as defined below:

Event	Event Triggered by:
TRPn	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

6. 4 bytes Duration as defined in EVE, in floating point format
7. 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
8. 1 byte Reserved for future use
9. 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 SEL-587 Relay includes:

BIT	USAGE	
0	Power-up	Set on power-up, 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 STRING ENCLOSED IN QUOTES","yyyy" <CR>
"ID SETTING ENCLOSED IN QUOTES","yyyy" <CR>
28,"0096" <CR>
<ETX>
```

where yyyy is the 4-byte ASCII hex representation of the checksum for the message.
28 is the device code used by the SEL-2020 to identify the relay to Modbus users.

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" <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>

APPENDIX E: COMPRESSED ASCII COMMANDS

INTRODUCTION

The SEL-587 Relay 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 Relay provides the following Compressed ASCII commands:

<u>Command</u>	<u>Description</u>
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>
.
.
.
.
.
```


"17H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IAW1","IBW1","ICW1",
 "IAW2"<CR>
 ,"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","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","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","I","6S","18S","0903"<CR>
 "CTA",1,"01A5"<CR>
 "08h","6S","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 represents a data format line corresponding to 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 are the data values corresponding to the first line labels and yyyy is 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 are the data values corresponding to the first line labels
 yyyy is 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,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 are the data values corresponding to the first line labels
 yyyy is 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 are the data values corresponding to the first line labels
 yyyy is 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` are the data values corresponding to the first line labels
`yyyy` is 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","yyyy" <CR><ETX>
```

where `xxxx` are the data values corresponding to the first line labels and
`yyyy` is 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` are the data values corresponding to the first line labels and
`yyyy` is 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 llll are the labels for the given target,
x is 0 or 1 corresponding to the first line labels, and
yyyy is 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 are the data values corresponding to the first and third line labels
yyyy is the 4 byte hex ASCII representation of the checksum
z is ">" for mid-fault record and empty for all others
MID refers to the mid-fault record indication
RLY_BITS refers to the relay element data.

APPENDIX F: TRANSFORMER/CT WINDING CONNECTION DIAGRAMS

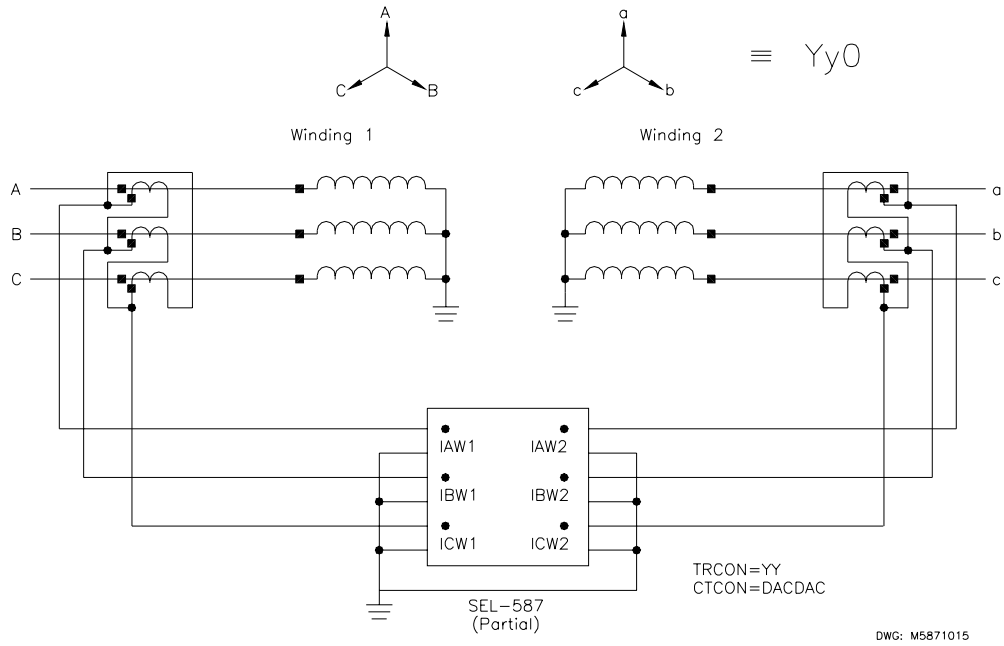


Figure F.1: Wye-Wye Power Transformer With Delta-Delta CT Connections

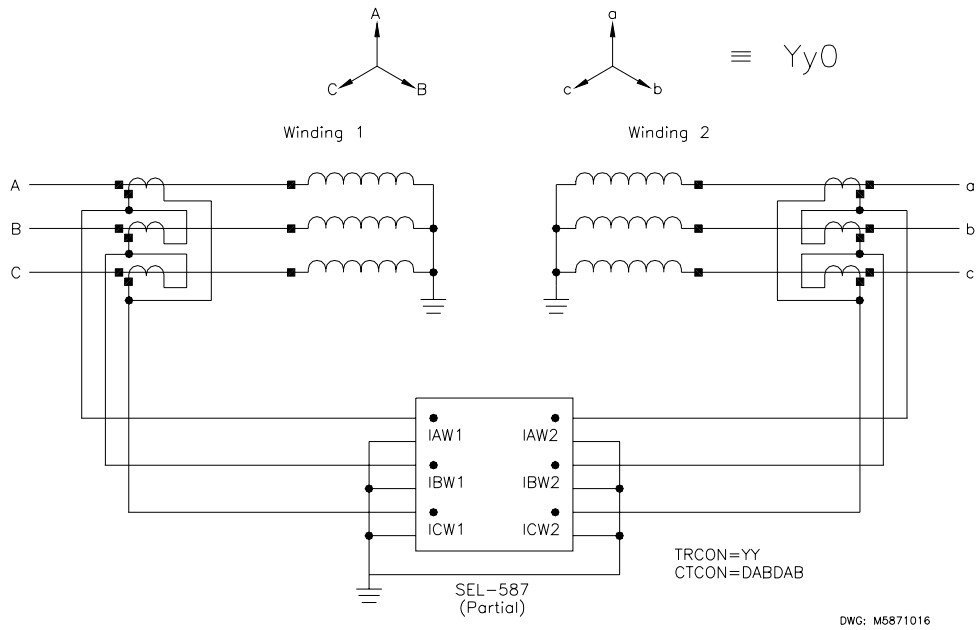


Figure F.2: Wye-Wye Power Transformer With Delta-Delta CT Connections

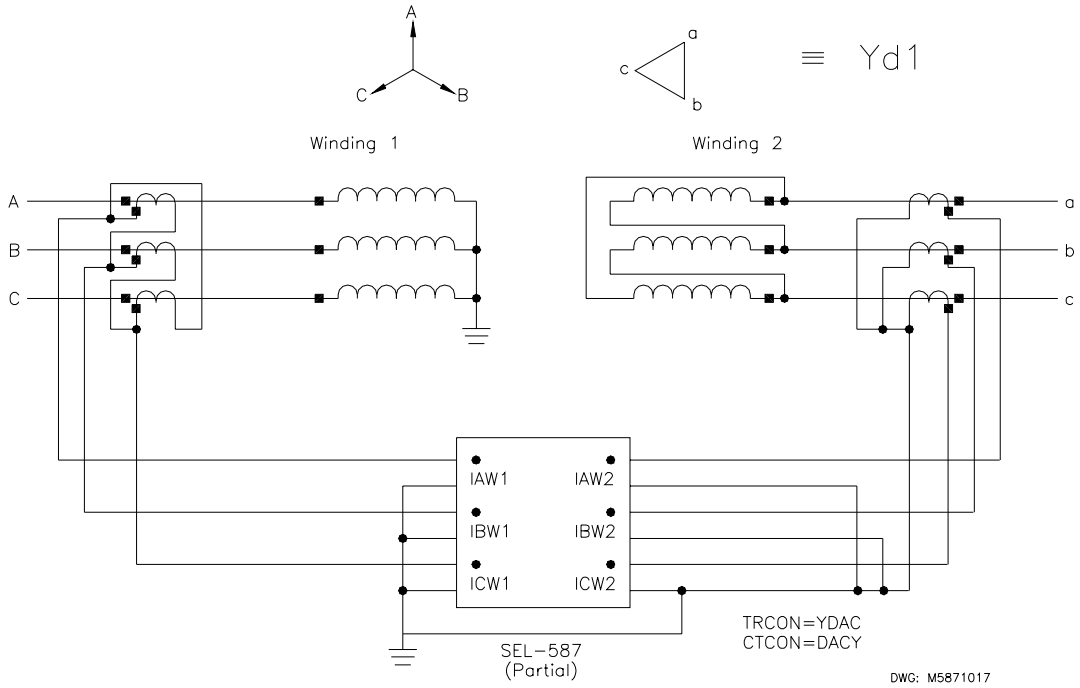


Figure F.3: Wye-Delta Power Transformer With Delta-Wye CT Connections

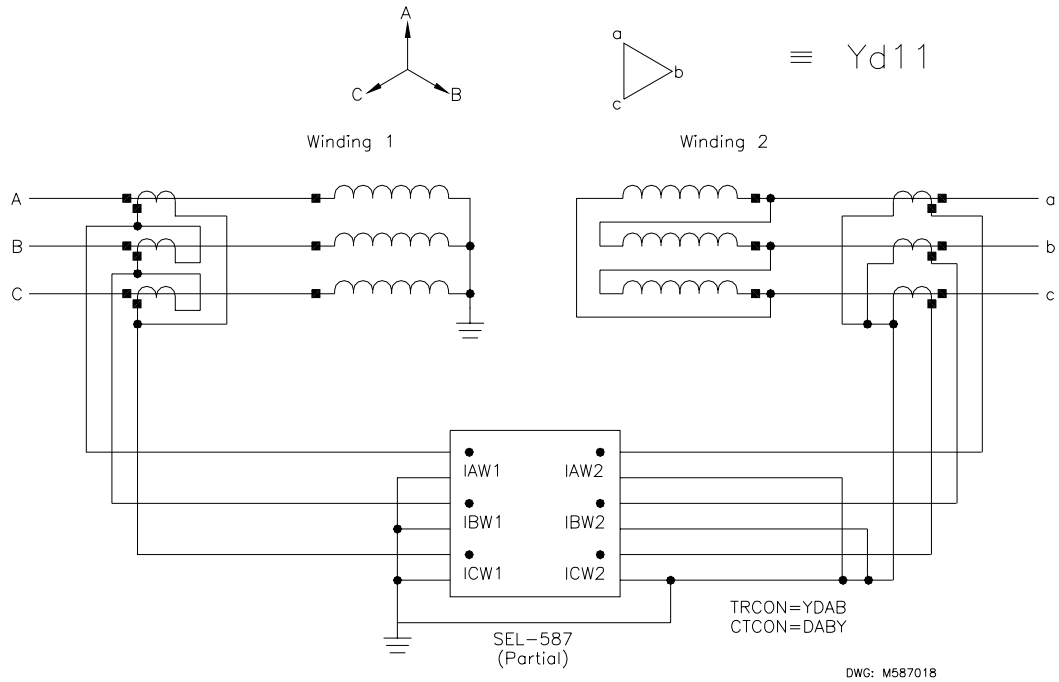


Figure F.4: Wye-Delta Power Transformer With Delta-Wye CT Connections

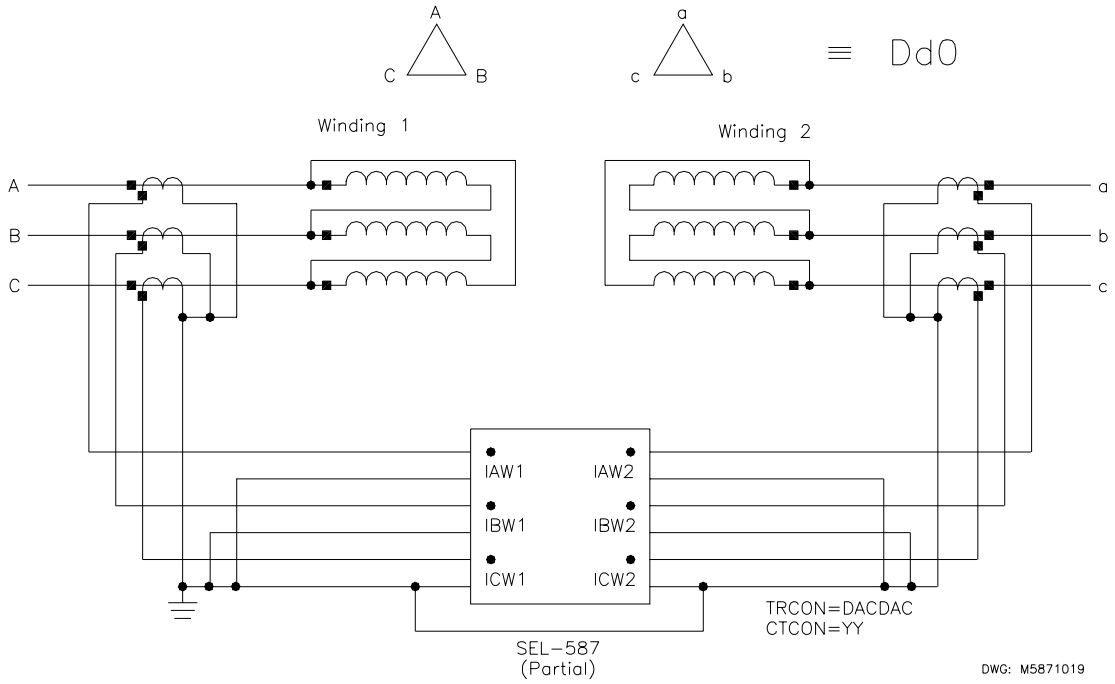


Figure F.5: Delta-Delta Power Transformer With Wye-Wye CT Connections

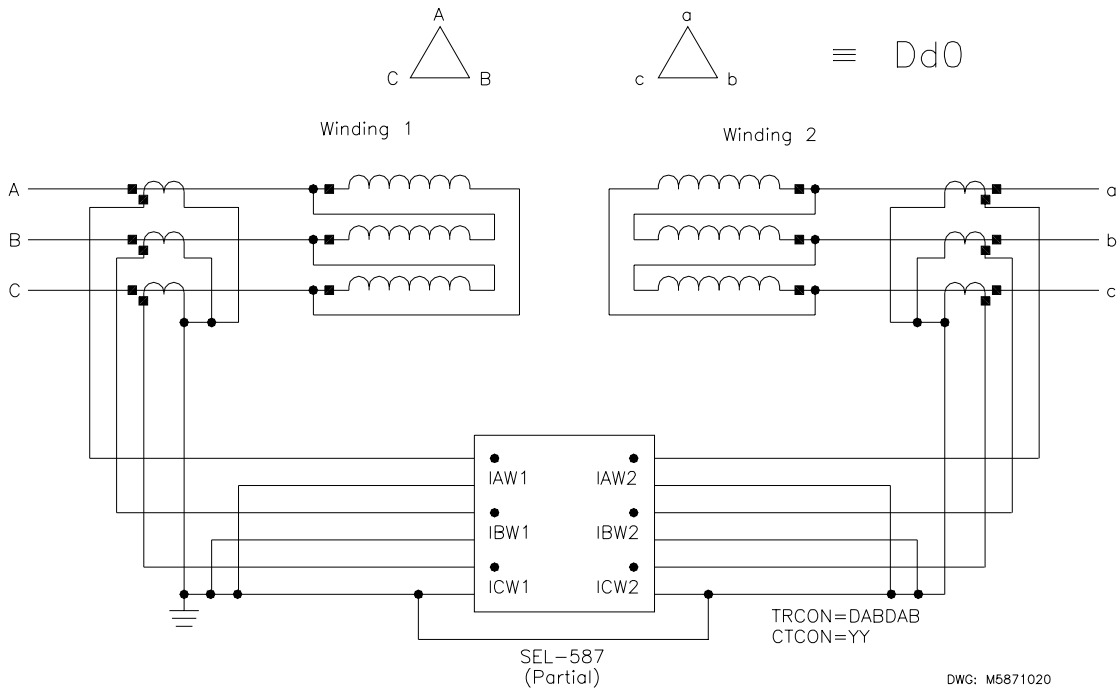


Figure F.6: Delta-Delta Power Transformer With Wye-Wye CT Connections

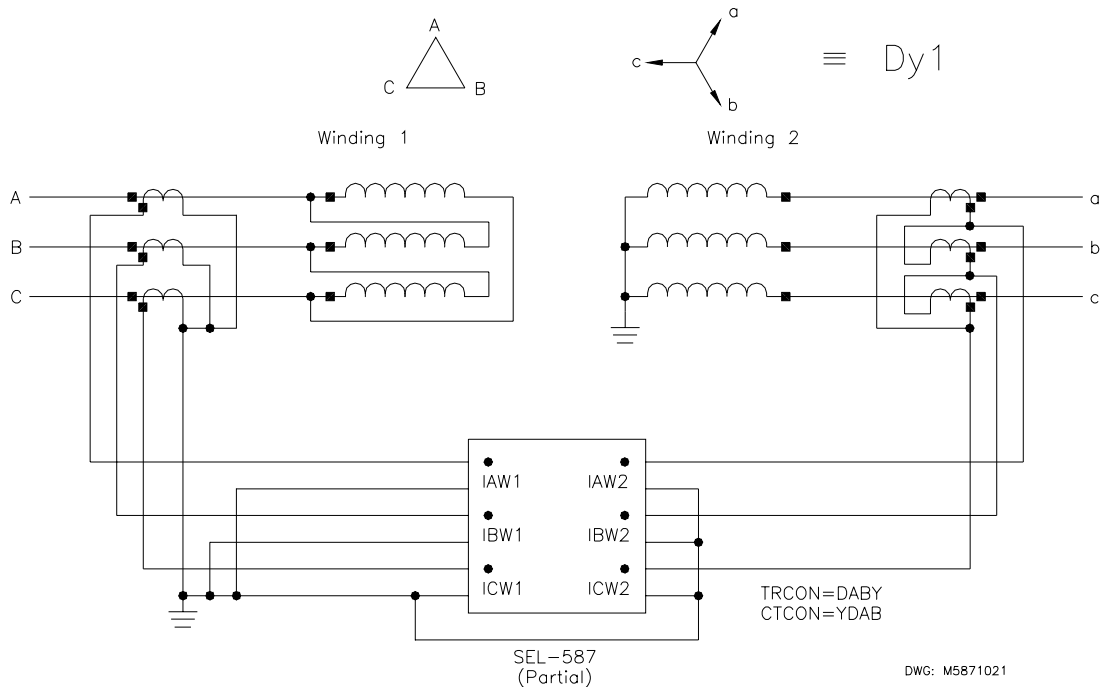


Figure F.7: Delta-Wye Power Transformer With Wye-Delta CT Connections

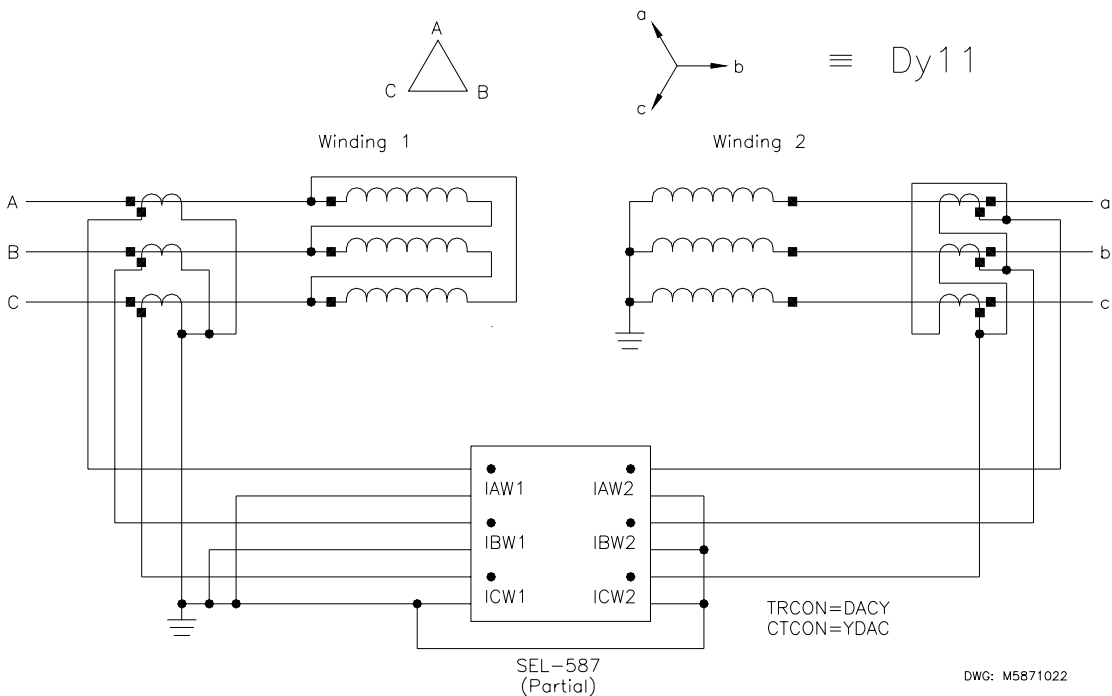


Figure F.8: Delta-Wye Power Transformer With Wye-Delta CT Connections

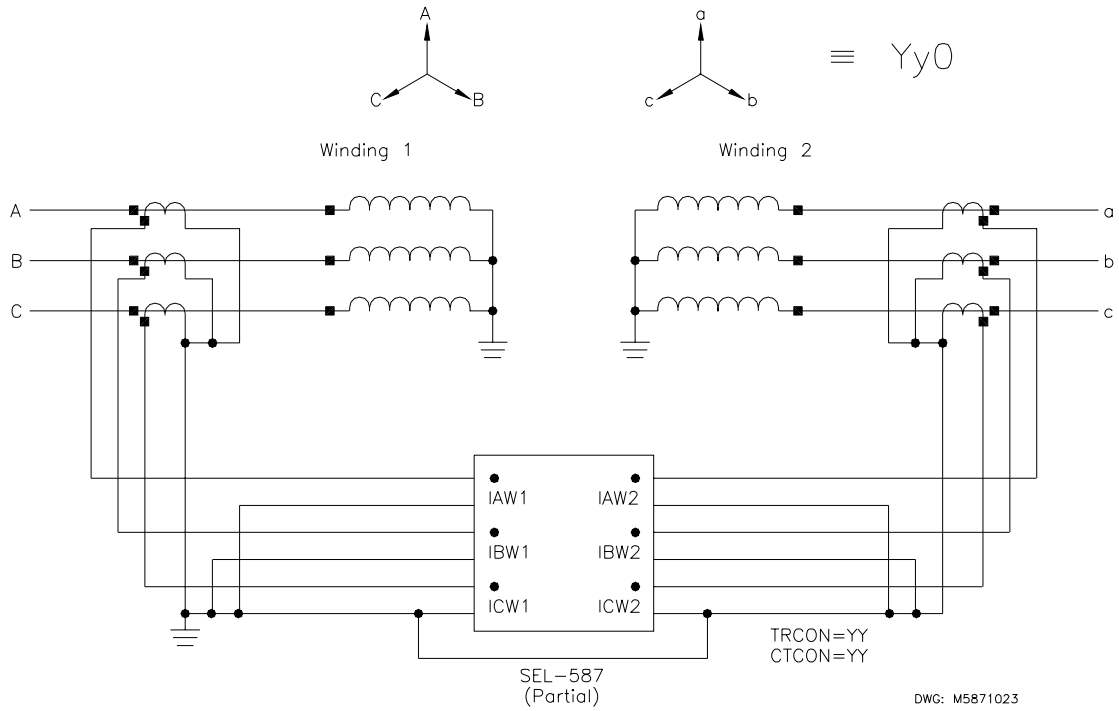


Figure F.9: Wye-Wye Power Transformer With Wye-Wye CT Connections

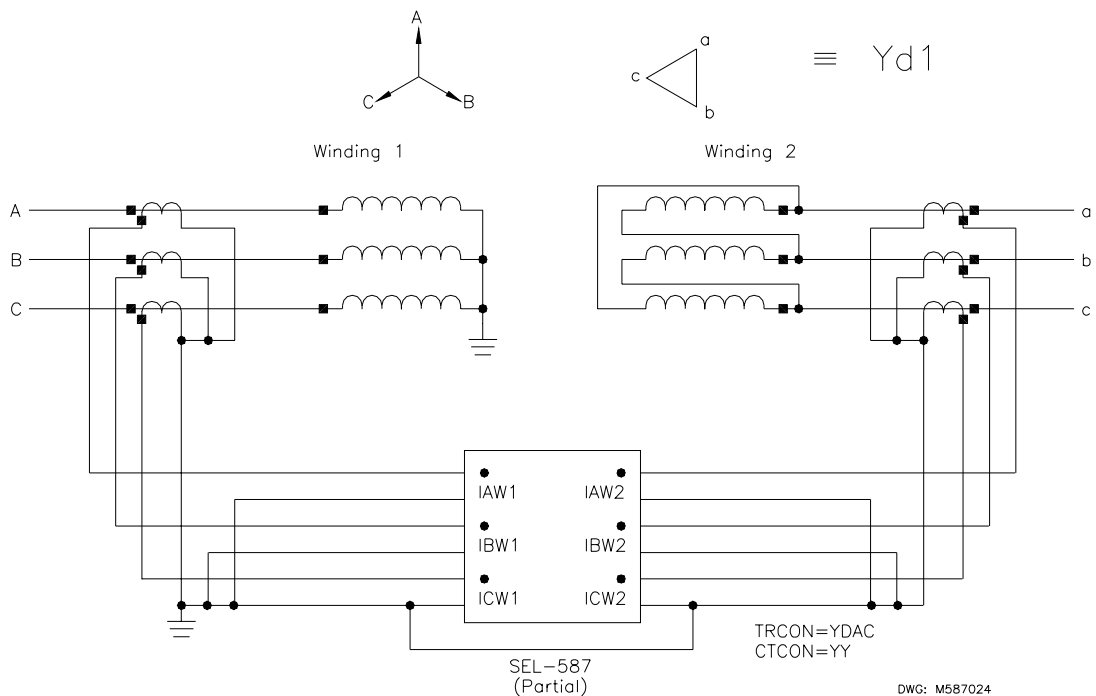


Figure F.10: Wye-Delta Power Transformer With Wye-Wye CT Connections

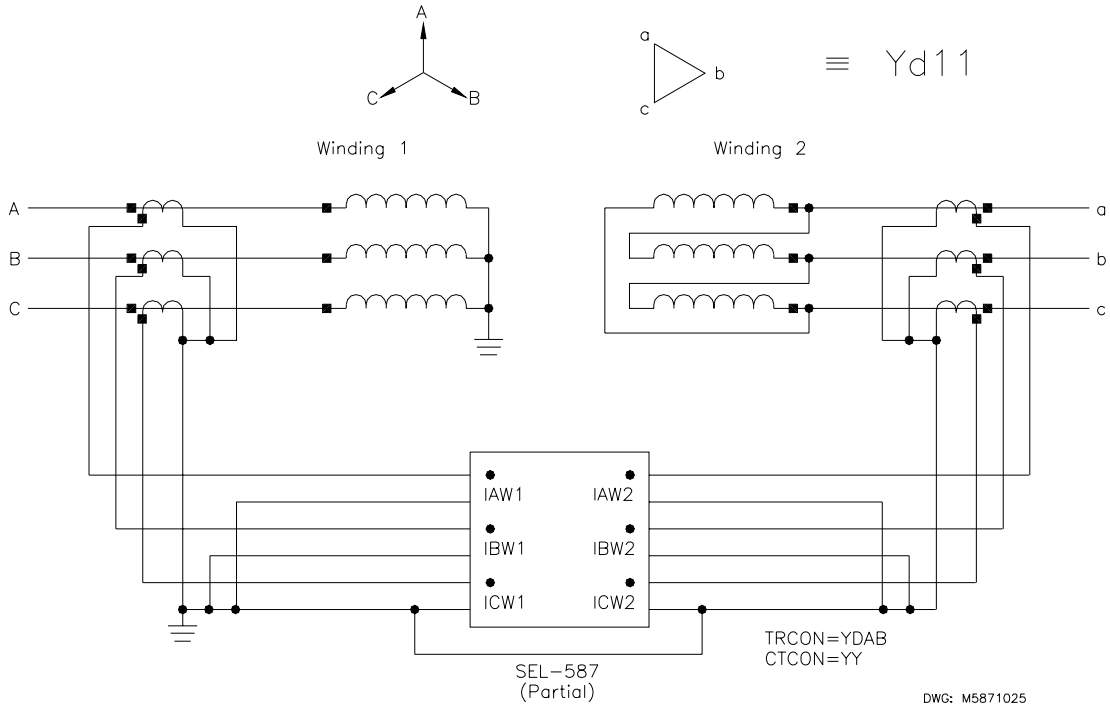


Figure F.11: Wye-Delta Power Transformer With Wye-Wye CT Connections

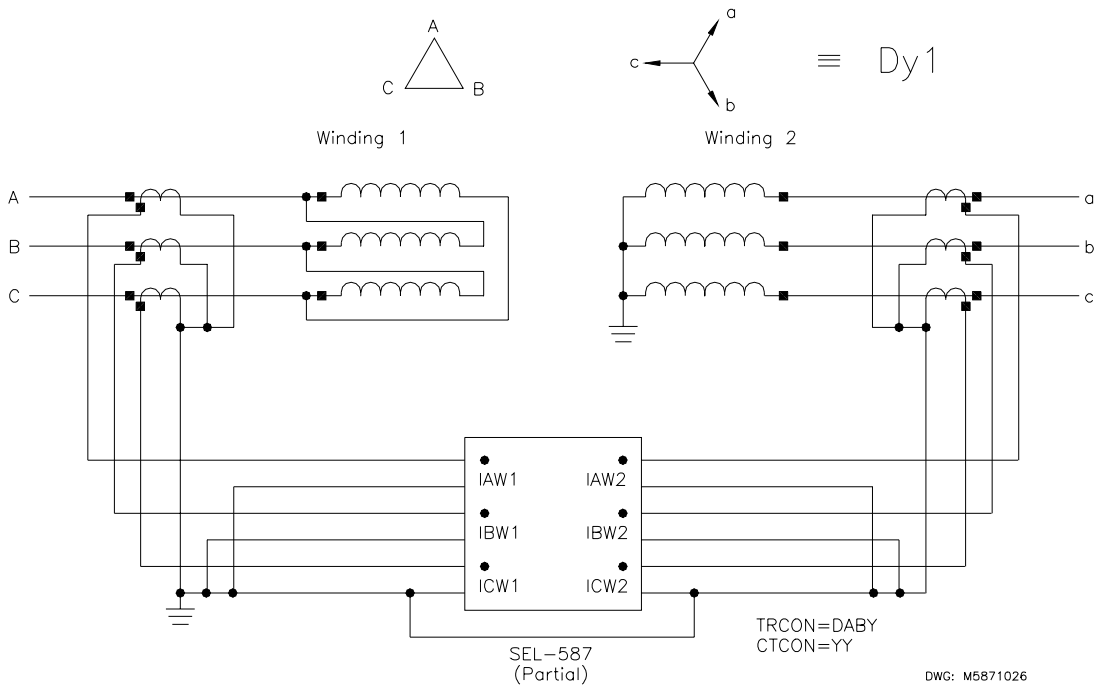


Figure F.12: Delta-Wye Power Transformer With Wye-Wye CT Connections

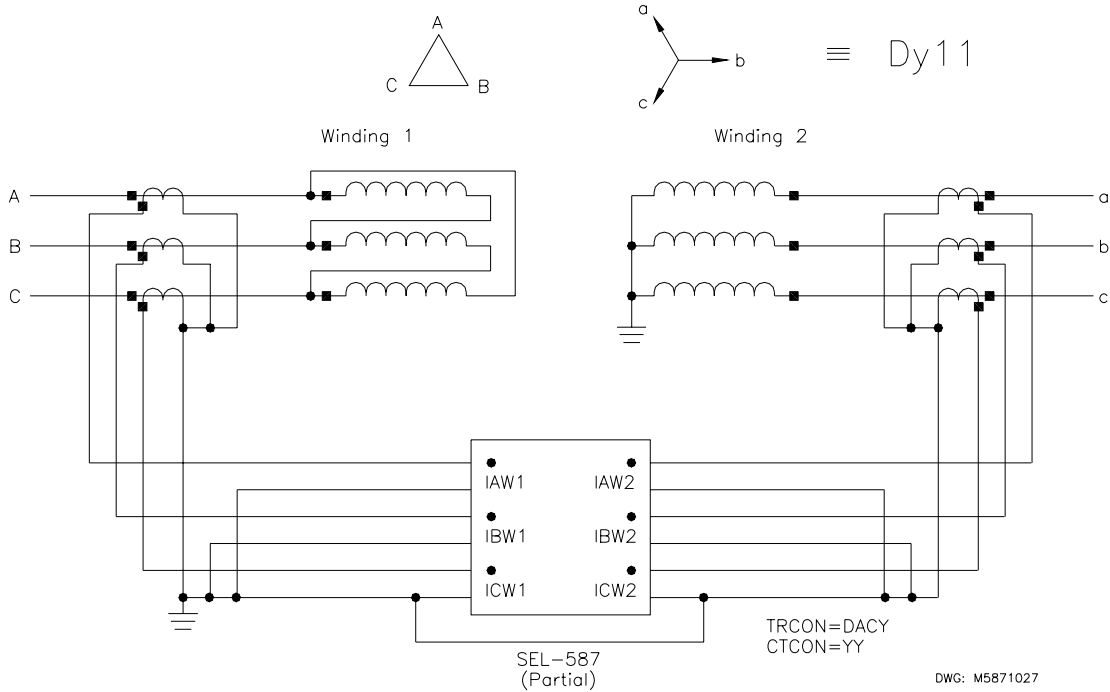


Figure F.13: Delta-Wye Power Transformer With Wye-Wye CT Connections

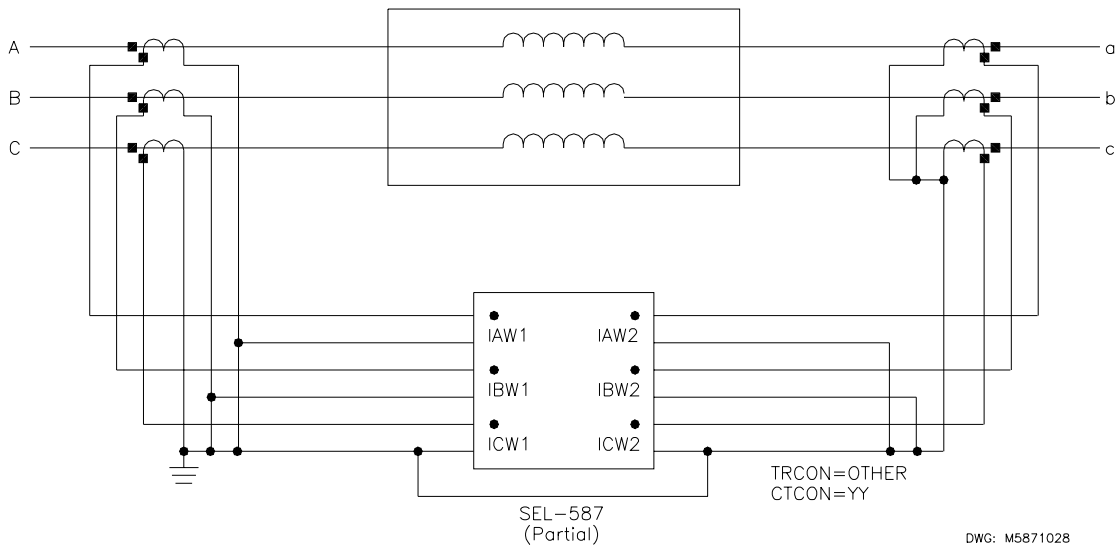


Figure F.14: Protected Machine With No Internal Phase Shift Resulting From Connections

APPENDIX G: MANUAL CALCULATION OF RELAY TAP SETTINGS

INTRODUCTION

The SEL-587 Relay 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 $0.1 \cdot I_N$ and $32 \cdot I_N$.
2. Produce a ratio $\frac{TAP_{MAX}}{TAP_{MIN}} \leq 4.5$

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:

$$TAP1 = \frac{MVA \cdot 1000 \cdot C1}{\sqrt{3} \cdot VWDG1 \cdot CTR1}$$

$$TAP2 = \frac{MVA \cdot 1000 \cdot C2}{\sqrt{3} \cdot VWDG2 \cdot CTR2}$$

where C1 and C2 are defined by the transformer and CT connections shown in Table 4.1.

$$\text{TAP1} = \frac{62 \cdot 1000 \cdot 1}{\sqrt{3} \cdot 230 \cdot 160} = 0.97$$

$$\text{TAP2} = \frac{62 \cdot 1000 \cdot 1}{\sqrt{3} \cdot 13.8 \cdot 600} = 4.32$$

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, $\frac{\text{TAP}_{\text{MAX}}}{\text{TAP}_{\text{MIN}}} = \frac{4.32}{0.97} = 4.45$, 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 may 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): _____ $MVA := \sqrt{MW^2 + MVAR^2}$

CTCON (CT conn): _____

CTR1 (Winding 1 CT ratio): _____ XMFR Amps (Calc) $AMPS_PRI := \frac{MVA \cdot 1000}{\sqrt{3} \cdot kV}$

CTR2 (Winding 2 CT ratio): _____ Winding 1 Amps, primary: _____

TAP1 (Winding 1 tap): _____ Winding 2 Amps, primary: _____

TAP2 (Winding 2 tap): _____

O87P (Rest. pickup): _____ RELAY Amps (expected)

$$AMPS_RELAY := \frac{AMPS_PRI}{CTR} \text{ (wye CTs)}$$

$$AMPS_RELAY := \frac{AMPS_PRI \cdot \sqrt{3}}{CTR} \text{ (delta CTs)}$$

SLP1 (Slope 1 %): _____ Winding 1 Amps, sec: _____

SLP2 (Slope 2 %): _____ Winding 2 Amps, 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 using one of the following two methods.

For relays equipped with rear-panel plug-in connectors, use the Access Level 1 command METER SEC:

=>METER SEC

For relays equipped with conventional terminal blocks, use the CAL level command TEST METER:

(=>>CAL, Passcode 332)

==>>TEST METER

IAW1 = _____ A _____ deg IBW1 = _____ A _____ deg ICW1 = _____ A _____ deg
 IAW2 = _____ A _____ deg IBW2 = _____ A _____ deg ICW2 = _____ A _____ deg

CHECK LIST:

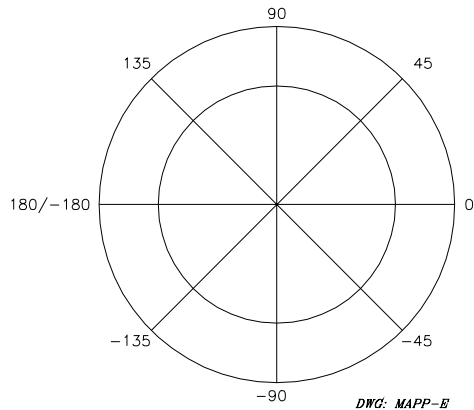
1. Expected amps match measured amps
2. Phasor rotation is as expected.
3. Circle your transformer and CT connection:

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 180° apart.

PLOT PHASORS:



If:

TRCON = DABY, CTCON = YY
 TRCON = YDAC, CTCON = YY
 Then: IW2 leads IW1 by 150°, PHROT = ABC.

If:

TRCON = DACY, CTCON = YY
 TRCON = YDAB, CTCON = YY
 Then: IW2 lags IW1 by 150°, PHROT = ABC.

APPENDIX I: MODBUS[®] RTU COMMUNICATIONS PROTOCOL

INTRODUCTION

This appendix describes Modbus RTU communications features supported by the SEL-587-1 Relay 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 web site at www.modicon.com.

Enable Modbus protocol 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 master device and multiple slave devices. The communication is half duplex; only one device transmits at a time. The master transmits a binary command that includes the address of the desired slave device. All of the slave devices receive the message, but only the slave device with the matching address responds.

The SEL-587-1 Relay Modbus communication allows a Modbus master device to:

- Acquire metering, monitoring, and event data from the relay.
- Control SEL-587-1 Relay output contacts and remote bits.
- Read the SEL-587-1 Relay self-test status and learn the present condition of all relay protection elements.

MODBUS RTU COMMUNICATIONS PROTOCOL

Modbus Queries

Modbus RTU master 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
Slave Device Address	1 byte
Function Code	1 byte
Data Region	0–251 bytes
Cyclical Redundancy Check (CRC)	2 bytes

The SEL-587-1 Relay SLAVEID setting defines the device address. Set this value to a unique number for each device on the Modbus network. For Modbus communication to operate properly, no two slave devices may have the same address.

Function codes supported by the SEL-587-1 Relay 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 slave device sends a response message after it performs the action requested in the query. If the slave cannot execute the command for any reason, it sends an error response. Otherwise, the slave device response is formatted similarly to the query including the slave address, function code, data (if applicable), and a cyclical redundancy check value.

Supported Modbus Function Codes

The SEL-587-1 Relay supports the Modbus function codes shown in Table I.2.

Table I.2: SEL-587-1 Relay 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 Relay sends an exception code under the conditions described in Table I.3.

Table I.3: SEL-587-1 Relay 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 Relay is in the wrong state for the requested function.
06	Busy	The SEL-587-1 Relay 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 master that the data field contains an error code, instead of the requested data.

Cyclical Redundancy Check

The SEL-587-1 Relay calculates a 2-byte CRC value using the device address, function code, and data fields. It appends this value to the end of every Modbus response. When the master device receives the response, it recalculates the CRC. If the calculated CRC matches the CRC sent by the SEL-587-1 Relay, the master 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 master sends queries.

01h Read Coil Status Command

Use function code 01h to read the On/Off status of the selected bits (coils). You may 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 master must have the following format:	
1 byte	Slave 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 slave will have the following format:	
1 byte	Slave 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 zeroes 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

Please 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 may 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 master must have the following format:	
1 byte	Slave 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 slave will have the following format:	
1 byte	Slave 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 zeroes to make an even byte.

Input numbers are defined below:

Table I.6: SEL-587-1 Relay 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

Table I.6: SEL-587-1 Relay Inputs

Description								Input Number
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 may read a maximum of 125 registers at once with this function code. Most masters 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 master must have the following format:	
1 byte	Slave 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 slave will have the following format:

1 byte	Slave 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 may read a maximum of 125 registers at once with this function code. Most masters 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 master must have the following format:	
1 byte	Slave 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 slave will have the following format:	
1 byte	Slave 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 master must have the following format:	
1 byte	Slave 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 Relay Command Coils

Coil	Field
1	OUT1
2	OUT2
3	OUT3
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 Relay uses this function to allow a Modbus master 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 master must have the following format:	
1 byte	Slave 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 Relay uses this function to allow a Modbus master to read the present status of the relay and protected circuit.

Table I.12: 07h Read Exception Status Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (07h)
0 bytes	No Data Fields Are Sent
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave 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 Relay uses this function to allow a Modbus master 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 master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field (identical to data in Master 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 master must have the following format:	
1 byte	Slave 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 slave will have the following format:	
1 byte	Slave 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 Relay uses this function to allow a Modbus master 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 master must have the following format:	
1 byte	Slave 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 nth Register
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave 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 nth 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 Using Modbus

The SEL-587-1 Relay Modbus Register Map (Table I.19) includes three fields that allow a Modbus master 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 Relay 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

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
13 ^a	Reset Data Regions	0000 0000 0000 0001 Demand Metering 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	06h, 10h
14	Control Remote Bits	See Note 1	06h, 10h

^a Parameter of Command Code 13 is bit 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 bitmasked 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 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 Relay stores the 20 latest event summaries and 10 latest 15-cycle, full-length event reports. Please 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 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 Using Address 0152

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
17	Relay Element Status Row 9 ^a
18	Relay Element Status Row 10 ^a
19	Relay Element Status Row 11 ^a

^a Please 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 is no data available, 8000h will be returned.

Reading History Data 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. Please refer to Note 3 of the Modbus Map for a list of event types.

To download the history data 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 is no data available, 8000h will be returned.

Table I.19: Modbus Map

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	–	–	–	–	–
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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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 ^b supply status message 0 = OK, 1 = Warn, 2 = Fail	–	–	–	–	–
0040	+5_REG power ^b supply value	V	0	600	1	0.01

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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	–	–	–	–	–
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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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 phase A ^b Winding 1	Amps	0	65535	1	1
0061	Instantaneous current phase A ^b Angle Winding 1	Degrees	0	36000	1	0.01
0062	Instantaneous current phase B ^b Winding 1	Amps	0	65535	1	1
0063	Instantaneous current phase B ^b Angle Winding 1	Degrees	0	36000	1	0.01
0064	Instantaneous current phase C ^b Winding 1	Amps	0	65535	1	1

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0065	Instantaneous current phase C ^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 phase A ^b Winding 2	Amps	0	65535	1	1
006B	Instantaneous current phase A ^b Angle Winding 2	Degrees	0	36000	1	0.01
006C	Instantaneous current phase B ^b Winding 2	Amps	0	65535	1	1
006D	Instantaneous current phase B ^b Angle Winding 2	Degrees	0	36000	1	0.01
006E	Instantaneous current phase C ^b Winding 2	Amps	0	65535	1	1
006F	Instantaneous current phase C ^b Angle Winding 2	Degrees	0	36000	1	0.01

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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	2 nd harmonic current differential element 1	Amps	0	65535	1	0.1
007B	2 nd harmonic current differential element 2	Amps	0	65535	1	0.1

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
007C	2 nd harmonic current differential element 3	Amps	0	65535	1	0.1
007D	5 th harmonic current differential element 1	Amps	0	65535	1	0.1
007E	5 th harmonic current differential element 2	Amps	0	65535	1	0.1
007F	5 th harmonic current differential element 3	Amps	0	65535	1	0.1

Demand Meter

0080	Demand current phase A ^b Winding 1	Amps	0	65535	1	1
0081	Demand current phase B ^b Winding 1	Amps	0	65535	1	1
0082	Demand current phase C ^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 phase A ^b Winding 2	Amps	0	65535	1	1
0086	Demand current phase B ^b Winding 2	Amps	0	65535	1	1
0087	Demand current phase C ^b Winding 2	Amps	0	65535	1	1

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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 phase A ^b Winding 1	Amps	0	65535	1	1
008B	Peak demand current phase B ^b Winding 1	Amps	0	65535	1	1
008C	Peak demand current phase C ^b Winding 1	Amps	0	65535	1	1
008D	Peak demand negative-sequence current $3I_2^b$ Winding 1	Amps	0	65535	1	1
008E	Peak demand residual current I_R^b Winding 1	Amps	0	65535	1	1
008F	Peak demand current phase A ^b Winding 2	Amps	0	65535	1	1
0090	Peak demand current phase B ^b Winding 2	Amps	0	65535	1	1
0091	Peak demand current phase C ^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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
Peak Harmonic Meter						
0094	Peak 2 nd harmonic current differential element 1	Amps	0	65535	1	0.1
0095	Peak 2 nd Harmonic current differential element 2	Amps	0	65535	1	0.1
0096	Peak 2 nd Harmonic current differential element 3	Amps	0	65535	1	0.1
0097	Peak 5 th Harmonic current differential element 1	Amps	0	65535	1	0.1
0098	Peak 5 th Harmonic current differential element 2	Amps	0	65535	1	0.1
0099	Peak 5 th Harmonic current differential element 2	Amps	0	65535	1	0.1
Peak Demand Time Stamp						
009A	Peak demand time phase A Winding 1	ss	0	59	1	1
009B		mm	0	59	1	1
009C		hh	0	23	1	1
009D	Peak demand date phase A Winding 1	dd	1	31	1	1
009E		mm	1	12	1	1
009F		yyyy	1992	2999	1	1
00A0	Peak demand time phase B Winding 1	ss	0	59	1	1
00A1		mm	0	59	1	1
00A2		hh	0	23	1	1
00A3	Peak demand date phase B Winding 1	dd	1	31	1	1
00A4		mm	1	12	1	1

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
00A5		yyyy	1992	2999	1	1
00A6	Peak demand time phase C Winding 1	ss	0	59	1	1
00A7		mm	0	59	1	1
00A8		hh	0	23	1	1
00A9	Peak demand date phase C 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
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 phase A Winding 2	ss	0	59	1	1
00B9		mm	0	59	1	1
00BA		hh	0	23	1	1

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
00BB	Peak demand date phase A Winding 2	dd	1	31	1	1
00BC		mm	1	12	1	1
00BD		yyyy	1992	2999	1	1
00BE	Peak demand time phase B Winding 2	ss	0	59	1	1
00BF		mm	0	59	1	1
00C0		hh	0	23	1	1
00C1	Peak demand date phase B Winding 2	dd	1	31	1	1
00C2		mm	1	12	1	1
00C3		yyyy	1992	2999	1	1
00C4	Peak demand time phase C Winding 2	ss	0	59	1	1
00C5		mm	0	59	1	1
00C6		hh	0	23	1	1
00C7	Peak demand date phase C 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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
00D1	Peak demand date IR Winding 2	mm	0	59	1	1
00D2		hh	0	23	1	1
00D3		dd	1	31	1	1
00D4		mm	1	12	1	1
00D5		yyyy	1992	2999	1	1

Peak Harmonic Current Time Stamp

00D6	Peak 2 nd Harmonic time element 1	ss	0	59	1	1
00D7		mm	0	59	1	1
00D8		hh	0	23	1	1
00D9	Peak 2 nd Harmonic date element 1	dd	1	31	1	1
00DA		mm	1	12	1	1
00DB		yyyy	1992	2999	1	1
00DC	Peak 2 nd Harmonic time element 2	ss	0	59	1	1
00DD		mm	0	59	1	1
00DE		hh	0	23	1	1
00DF	Peak 2 nd Harmonic date element 2	dd	1	31	1	1
00E0		mm	1	12	1	1
00E1		yyyy	1992	2999	1	1
00E2	Peak 2 nd Harmonic time element 3	ss	0	59	1	1
00E3		mm	0	59	1	1
00E4		hh	0	23	1	1
00E5	Peak 2 nd Harmonic date element 3	dd	1	31	1	1
00E6		mm	1	12	1	1
00E7		yyyy	1992	2999	1	1
00E8	Peak 5 th Harmonic time element 1	ss	0	59	1	1
00E9		mm	0	59	1	1
00EA		hh	0	23	1	1

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
00EB	Peak 5 th Harmonic date element 1	dd	1	31	1	1
00EC		mm	1	12	1	1
00ED		yyyy	1992	2999	1	1
00EE	Peak 5 th Harmonic time element 2	ss	0	59	1	1
00EF		mm	0	59	1	1
00F0		hh	0	23	1	1
00F1	Peak 5 th Harmonic date element 2	dd	1	31	1	1
00F2		mm	1	12	1	1
00F3		yyyy	1992	2999	1	1
00F4	Peak 5 th Harmonic time element 3	ss	0	59	1	1
00F5		mm	0	59	1	1
00F6		hh	0	23	1	1
00F7	Peak 5 th 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					
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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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	<p>Targets</p> <p>Bit 0 = 1 if any of bits 8–15 are set to 1</p> <p>Bit 0 = 0 if all of bits 8–15 are set to 0</p> <p>Bits 1–7 = 0</p> <p>Bit 8 = N</p> <p>Bit 9 = Phase C</p> <p>Bit 10 = Phase B</p> <p>Bit 11 = Phase A</p> <p>Bit 12 = 51</p> <p>Bit 13 = 50</p> <p>Bit 14 = 87</p> <p>Bit 15 = Enable</p>					
0121	<p>Contact Status</p> <p>Bit 0 = 1 if any of bits 8–15 are set to 1</p> <p>Bit 0 = 0 if all of bits 8–15 are set to 0</p>					

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0122	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					
	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 = *					
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					

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0124	Bit 10 = 50N1T					
	Bit 11 = 50Q1T					
	Bit 12 = 50P1T					
	Bit 13 = 50N1P					
	Bit 14 = 50Q1P					
	Bit 15 = 50P1P					
	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					
	Bit 8 = RB2					
	Bit 9 = *					
	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					

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
0126	Bit 13 = 50N2P Bit 14 = 50Q2P Bit 15 = 50P2P 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 Bit 12 = 5HB1 Bit 13 = 2HB3 Bit 14 = 2HB2 Bit 15 = 2HB1					

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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					

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
012B	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					
012C	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 = *					
	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					

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
	Bit 8 = OUT4 Bit 9 = OUT3 Bit 10 = OUT2 Bit 11 = OUT1 Bit 12 = ALARM Bit 13 = * Bit 14 = * Bit 15 = *					
012D	Reserved					
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
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				

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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 = Phase C Bit 10 = Phase B Bit 11 = Phase A 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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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
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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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
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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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 = Phase C Bit 10 = Phase B Bit 11 = Phase A Bit 12 = 51 Bit 13 = 50 Bit 14 = 87 Bit 15 = Enable					
019C	Event duration	Cycles	1	16	1	1

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
019D	Event current phase A Winding 1	Amps	0	65535	1	
019E	Event current phase B Winding 1	Amps	0	65535	1	
019F	Event current phase C 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 phase A Winding 2	Amps	0	65535	1	
01A3	Event current phase B Winding 2	Amps	0	65535	1	
01A4	Event current phase C Winding 2	Amps	0	65535	1	
01A5	Event negative-sequence current Winding 2	Amps	0	65535	1	
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

(Continued)

Table I.19: Modbus Map

Address (Hex)	Field	Units	Range			Scale Factor
			Low	High	Step	
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

<u>ASCII String</u>	<u>Code</u>
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: Please refer to Table I.17 for a list of Command Codes.

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.

SEL-587 RELAY COMMAND SUMMARY

Access Level 0 Command	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 Command	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.
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 10, with n = 1 most recent).
EVE L n	Show standard 15-cycle event report number n, with 1/8-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, both magnitude and phase angle. Phase angles are referenced to phase input IA. 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 P n	Display peak demand data. Enter n to scroll metering n times on screen. Select MET RP n to reset.
MET DIF n	Display differential element quantities. Enter n to scroll metering n times on screen.
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. Returns to Access Level 0. Returns front-panel LEDs to the default targets (corresponding to command TAR 0).
SHO	Show relay settings (overcurrent, reclosing, timers, etc.).
SHO L	Show SELOGIC [®] control equation settings.
SHO P	Show port settings.
STA	Show relay 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.
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 (CCn) Relay Word bit, where n = 1, 2. If CCn 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 RBn (Remote Bit n; n = 1 through 4). Execute CON n and the relay responds: CONTROL RBn. Then reply with one of the following: SRB n set Remote Bit n (assert RBn). CRB n clear Remote Bit n (deassert RBn). PRB n pulse Remote Bit n [assert RBn for one processing interval (1/8 cycle)].
OPE n (valid only if TDURD>0)	Assert the open (OCn) Relay Word bit, where n = 1, 2. If OCn is assigned to an MTUn Relay Word bit and the associated TRPn 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 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.