SEL-387L Relay

Line Current Differential

Instruction Manual

20250127

SEL SCHWEITZER ENGINEERING LABORATORIES

PM387L-01

PM387L-01

Table of Contents

Appendix B: Distributed Network Protocol

Appendix C: Fast SER Messages, Fast Meter, and Fast Operate Commands

Appendix D: PC Software

List of Tables

This page intentionally left blank

List of Figures

This page intentionally left blank

Preface

Overview

This manual provides information and instructions for installing and operating the SEL-387L Relay. The manual is for use by power engineers and others experienced in protective relaying applications.

Safety Information

Dangers, Warnings, and Cautions

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

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

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

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

Safety Symbols

The following symbols are often marked on SEL products.

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

Safety Marks

The following statements apply to this device.

General Safety Marks

For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.
⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C, or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.	**⚠ATTENTION** Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Rayovac no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.

Other Safety Marks

⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	**⚠DANGER** Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	**⚠DANGER** Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Before working on a CT circuit, first apply a short to the secondary winding of the CT.	**⚠AVERTISSEMENT** Avant de travailler sur un circuit TC, placez d'abord un court-circuit sur l'enroulement secondaire du TC.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	**⚠AVERTISSEMENT** Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	**⚠AVERTISSEMENT** L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	**⚠ATTENTION** Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.

General Information

The SEL-387L Instruction Manual uses certain conventions that identify particular terms and help you find information. To benefit fully from reading this manual, take a moment to familiarize yourself with these conventions.

Typographic Conventions

There are three ways to communicate with the SEL-387L:

- Using a command line interface on a PC terminal emulation window
- Using the front-panel menus and pushbuttons
- Using ACSELERATOR QuickSet® SEL-5030 Software

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

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
CLOSE	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
RELAY RESPONSE MAIN > METER	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.
ACSELERATOR	SEL trademarks and registered trademarks contain the appropriate symbol on first reference in a section. In the SEL-387L Instruction Manual, certain SEL trademarks appear in small caps; for example, ACSELERATOR QuickSet program.
Windows®	Registered trademarks of other companies include the registered trademark symbol with the first occurrence of the term in a section.

This page intentionally left blank

Section 1
Introduction and Specifications

Overview

The SEL-387L Relay is a digital line current differential relay suitable for protection of a wide range of lines and cables. The relay uses patented techniques to achieve outstanding security against CT saturation, high sensitivity to resistive ground and phase-to-phase faults, and unequaled operational speed, and it is impossible to set incorrectly.

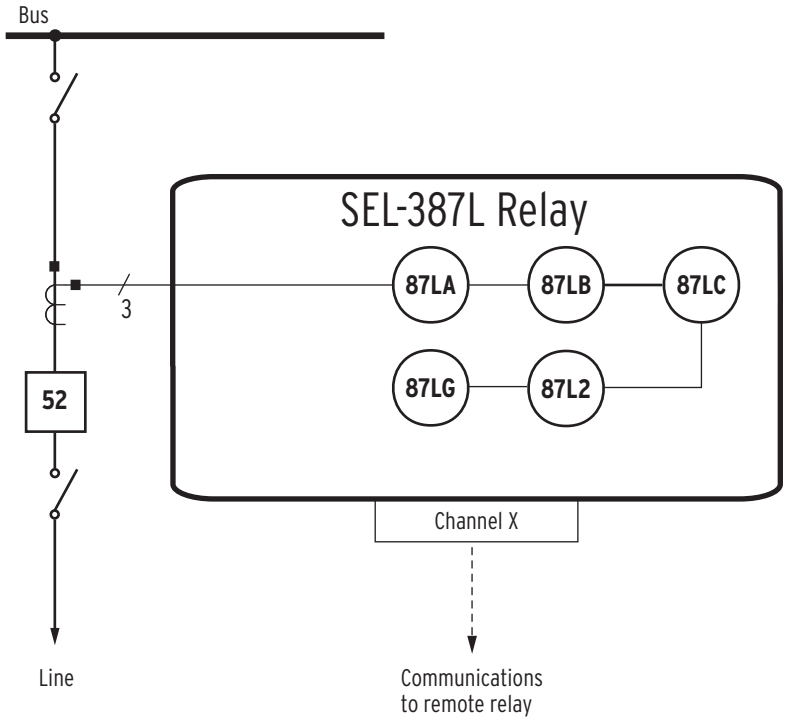


Figure 1.1 Functional Diagram of the SEL-387L

The relay contains three phase-segregated current differential elements. These high-speed elements detect three-phase faults and bolted phase-to-phase faults, typically operating in less than one cycle. The phase current differential elements are restrained with the same, patented principle as used in the SEL-311L Relay.

The SEL-387L also uses a zero-sequence current differential element to detect resistive ground faults. A negative-sequence current differential element detects resistive ground faults and resistive phase-to-phase faults. The zero- and negative-sequence elements use the same harmonic and dc restraint technique employed by the SEL-311L. See *Section 3: Current Differential Elements* for details about the current differential element operational theory.

Historically, current differential relays have relied on segregated phase elements, or even a single combined current element, to detect all types of faults. This approach limited both sensitivity and speed. The same element responsible for rapidly detecting a three-phase fault was also responsible for detecting a high-impedance ground fault. Making the relay more sensitive to ground faults invariably made it much less secure during external faults, especially during CT saturation. The compromise was to decrease both speed and sensitivity to maintain security.

The SEL-387L uses dedicated high-speed phase elements to detect three-phase and bolted phase-to-phase faults. Since these elements do not need to detect resistive faults, they have been optimized for simultaneous high speed and security, with less attention given to sensitivity. The resulting speed is shown in *Figure 1.2*.

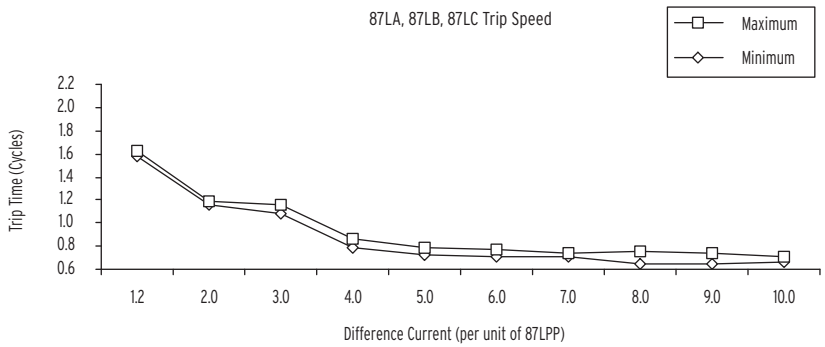


Figure 1.2 Phase 87L Element Trip Speeds for Symmetrical Fault Currents With a Direct Fiber Connection and High-Speed Output Contacts

The zero- and negative-sequence elements are optimized for simultaneous sensitivity and security, with less attention given to speed. The resulting sensitivity is shown in *Figure 1.3* assuming a 5 A, 66.7 V secondary system.

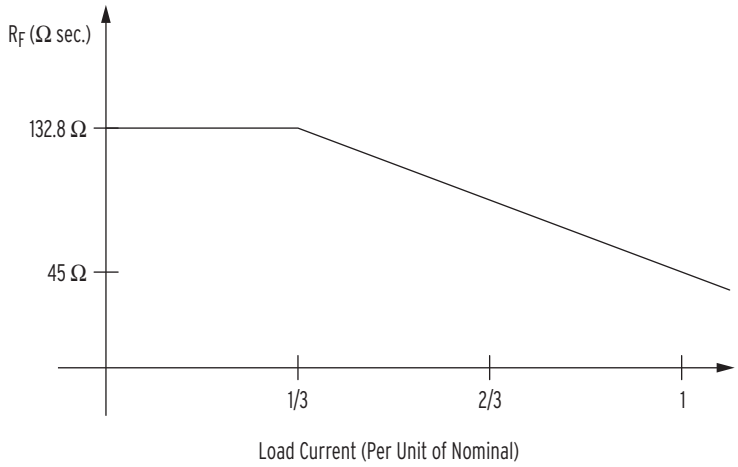


Figure 1.3 Ground Fault Sensitivity of 87L2 and 87LG Elements

The result is a relay that trips for three-phase faults in less than one cycle, and can also detect ground fault currents as low as 10 percent of nominal current, all while maintaining excellent security to CT saturation, channel delay asymmetry, line charging current, switching transients, communications circuit noise, etc.

The SEL-387L is so well optimized for speed, sensitivity, and security that it does not need adjustable protection settings. In fact, the relay contains no settings. The current differential element restraint factors and sensitivity are fixed. The contact input and contact output functions are also fixed and are clearly labeled with their purpose on the rear of the relay. We expanded this philosophy of "no settings" to other aspects of the relay including event report triggering, SER trigger list, 87L communications interface configurations, and even the serial port configurations. (Serial port settings are available with the purchase of the DNP protocol.)

The result is a protective relay suitable for application from low-voltage through EHV systems, lines or cables, two or three terminals. *Figure 1.4* shows the parameters needed for identifying and addressing the relay.

```
=>>SHO <Enter>

Relay Settings:
RID  =FEEDER 2          TID  =PALOUSE
TA_X = 2    RA_X = 1

=>>
```

Figure 1.4 Relay Identification and Communication Addressing

Two of the parameters are text strings that appear at the top of various reports generated by the relay. They help you identify where the reports originated and are called RID and TID, or Relay ID and Terminal ID, respectively. RID and TID do not impact the functions of the relay in any way. The other two parameters are the receive and transmit communications channel addresses, RA_X and TA_X. These ensure that the local relay is communicating with the intended remote relay, and differential protection is not enabled until RA_X and TA_X are properly selected.

Even though the relay has no settings, it is very flexible. This section contains application examples demonstrating the relay flexibility. However, it is useful to first understand the ac and dc connections to the relay, as well as the 87L communications options.

AC/DC and Communications Connections

Figure 1.5 shows the relay external connections. The following discussion gives an overview of each connection point. See *Specifications on page 1.11* for more details of each connection point.

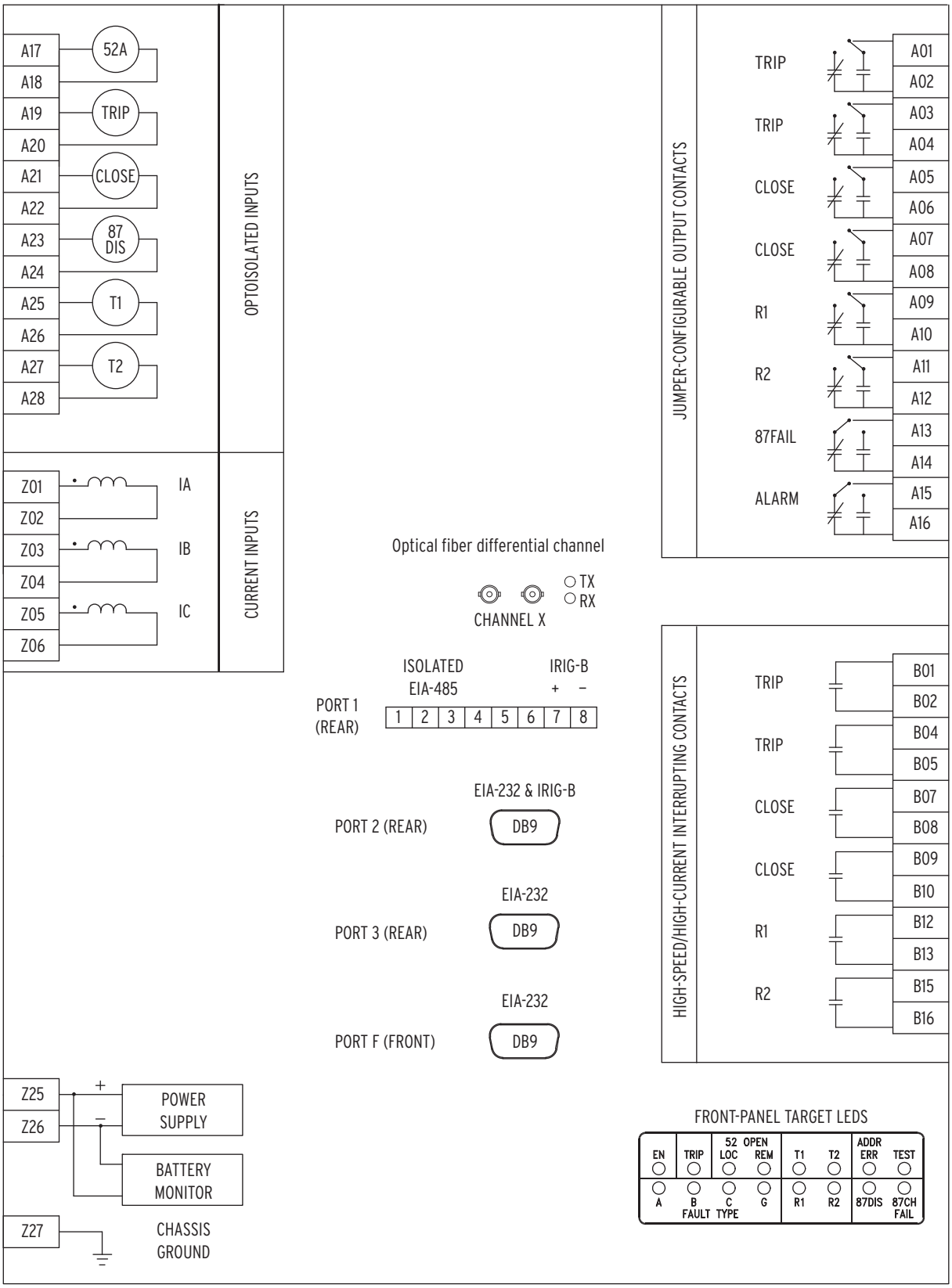


Figure 1.5 SEL-387L Inputs, Outputs, Communication Ports, and Front-Panel Targets

AC Connections. The only ac connections are a set of three-phase, six-wire current inputs. The relay calculates positive-, negative-, and zero-sequence currents from the three phase currents. Order either 1 A or 5 A nominal current inputs.

Power Connections. The power supply inputs are for either ac or dc power for the relay. If dc power is connected, then a battery monitor circuit accurately measures the dc voltage applied. The battery voltage is reported in the oscillographic event report. Quickly scan the event report following open and close operations for signs of a weak or degraded battery.

Contact Inputs. Six contact inputs allow the relay to sense status of several functions. Connect the **52A** input to the circuit breaker 52A auxiliary contact. The relay uses the **52A** input to sense the position of the circuit breaker. If the **52A** input is not used, leave it disconnected (or shorted for increased security), and the relay will sense breaker position using a sensitive undercurrent element fixed at 5 percent of nominal current.

Dedicated **TRIP** and **CLOSE** contact inputs feed the relay latching trip and close logic. Connect either to local control switches or other contacts to effect local or remote trip and close control of the circuit breaker.

Input **87 DIS** disables current differential protection in the local relay, and sends a signal to the remote SEL-387L to also disable 87L protection. Use this input to disable protection during switching events that might be disruptive to current differential operations. A status message `87L BLOCKED` is displayed on the front-panel LCD while Input **87 DIS** is energized.

T1 and **T2** are the inputs for two general-purpose transfer contacts. Energize **T1** at the local relay to close Output **R1** in the remote SEL-387L and likewise for local Input **T2** and remote Output **R2**. The contact transfer occurs in less than 35 ms with security exceeding the recommendations of IEC 834-2 for direct tripping duty.

Contact Outputs. The relay contains 14 contact outputs. Two of the contacts alarm when there is a hardware failure (**ALARM**) or a problem with the 87L protection (**87FAIL**). The remaining 12 contacts are duplicated on 2 sets of contact output circuitry, each set of a different type. Use either type of output for tripping, closing, and/or indication.

One set of outputs is high-speed metallic contacts that switch in about 4 ms and have limited dc interruption capability. Configure these outputs as either Form A or Form B. The other set of outputs are ultrahigh-speed hybrid contacts that close in less than 10 µs and can interrupt trip and close current.

Each set of contacts has two **TRIP** and two **CLOSE** contacts, for a total of four each. All four **TRIP** contacts close in response to any internal or external trip condition. Because the current differential elements have direct control over the ultrahigh-speed hybrid contacts, they respond up to 10 ms faster to trip conditions than the high-speed metallic **TRIP** contacts. See *Section 3: Current Differential Elements* for more details about the operation of the trip contacts.

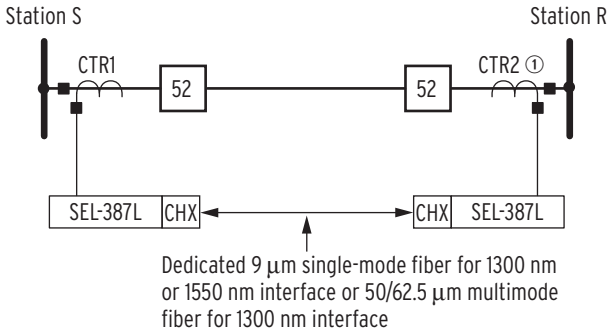
All four **CLOSE** contacts also respond to any internal or external close condition, although at slightly different times.

Outputs **R1** and **R2** are the transfer contact outputs associated with remote Inputs **T1** and **T2**. The applications examples that follow show example uses for all of the inputs and outputs.

Applications

The following applications show examples of how various features of the relay can be employed. In every case, the features shown in one application can be used in any other application.

Figure 1.6 shows two SEL-387L relays with a single-mode direct fiber connection in a two-relay application. In the two-relay application, both SEL-387L relays are fully functional, and each relay performs differential protection calculations for each of five differential elements. Because the relay performs differential protection on secondary currents, the CT ratios at both line ends must match.



① CTR1 = CTR2

Figure 1.6 Typical Two-Relay Application With Dedicated Fiber

If the CT ratios are different, replace either of the SEL-387L relays with an SEL-311L to operate in a leader/follower mode (see *Figure 3.6* for example settings in the SEL-311L). This SEL-387L-to-SEL-311L application is shown in *Figure 1.7*.

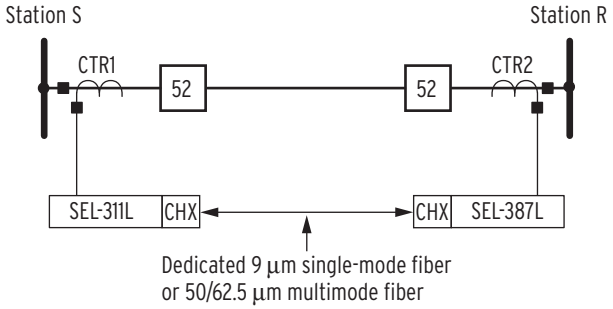
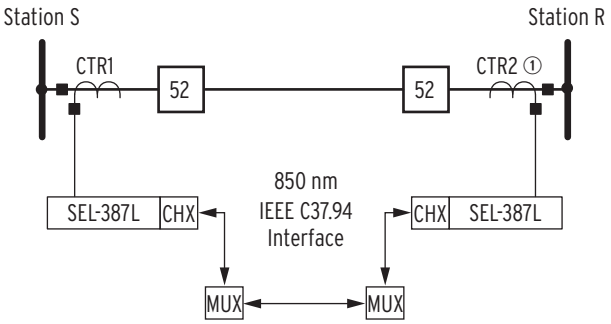


Figure 1.7 SEL-387L-to-SEL-311L Application With Dedicated Fiber

Figure 1.8 shows two SEL-387L relays with a multiplexed fiber connection in a two-relay application. The protection operates in the same manner as with the dedicated fiber connection. Again, replace one SEL-387L with an SEL-311L to accommodate unequal CT ratios.



① CTR1 = CTR2

Figure 1.8 Typical Two-Relay Application Using a Digital Network

Figure 1.9 shows an SEL-311L and two SEL-387L relays in a leader/follower application, protecting a three-terminal line. In this application, the SEL-311L is the leader, while a maximum of two SEL-387L relays act as followers.

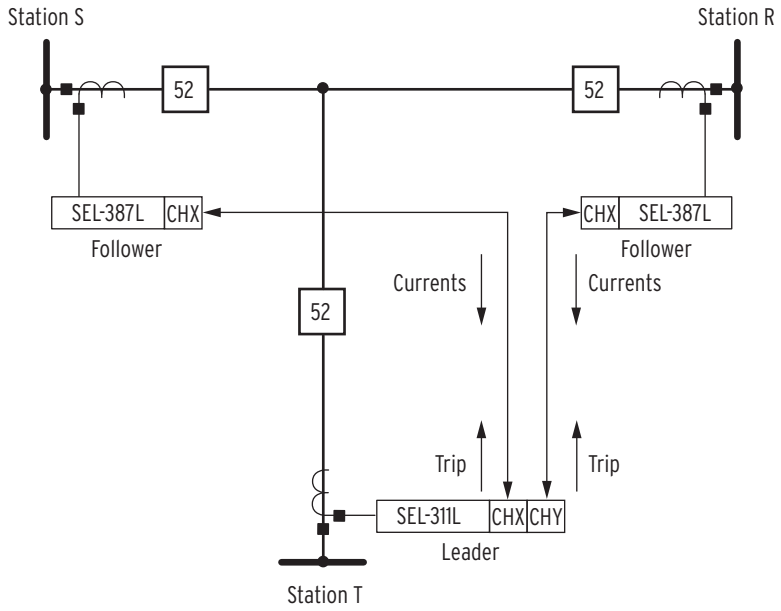


Figure 1.9 Leader/Follower Application With Two SEL-387L Relays and One SEL-311L Relay

In the leader/follower application, differential protection in the SEL-387L is disabled by asserting Receive Bit R4X (see *Figure 3.6* for more information). With differential protection disabled, the SEL-387L becomes a current acquisition unit that provides current values to the SEL-311L. Although differential protection is disabled, the SEL-387L provides local and remote secondary currents for event reports and front-panel display.

The SEL-387L sends three-phase current values to the SEL-311L. In the SEL-311L, differential elements use local currents and currents from the SEL-387L to perform differential protection. The SEL-311L trips the local breaker and issues a trip signal to the SEL-387L via the communications channel for internal faults. On receipt of the trip signal, the SEL-387L trips.

Backup Protection

Backup protection (against such events as overcurrent and ground faults) philosophies differ widely in application. Integrated backup protection philosophy mandates main protection and backup protection in the same relay. In the case of integrated backup protection philosophy, use the overcurrent, ground fault, and other backup and control functions in the SEL-311L (*Figure 1.7*). Discrete backup protection philosophy specifies that main protection and backup protection be in different relays.

In the case of discrete backup protection philosophy, consider the single-source application shown in *Figure 1.10*. For this application, we select an SEL-551 Relay for breaker failure, autoreclose, overcurrent, and ground fault protection functions.

For both types of applications (integrated or discrete), we use the transmit communications bits in the relay at Station S to control the relay at Station R.

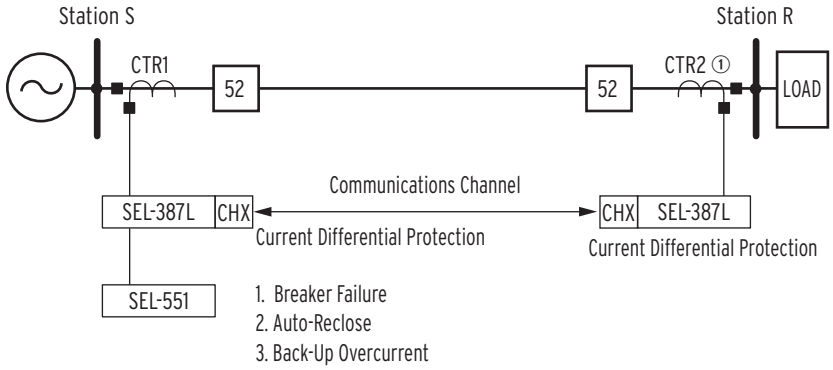


Figure 1.10 Network With Single Source, Using the SEL-551 for Breaker Failure, Autoreclosing, Overcurrent, and Ground Fault Protection

Following is a brief discussion on the implementation of autoreclosing and breaker failure protection for the application shown in *Figure 1.10*. For brevity, we do not discuss all settings for this application; refer to the SEL-311L and SEL-551 Instruction Manuals for complete setting examples for similar applications.

For reclose initiation, wire Output Contact **TRIP** (Terminals **B01** and **B02**) from the SEL-387L at Station S to Input **IN1** on the SEL-551, and set the reclose initiate to IN1 (79RI = IN1). In the SEL-551, assign Relay Word bit CLOSE to Output **OUT1** (OUT1 = CLOSE). Wire Output **OUT1** from the SEL-551 to Input **T1** (Terminals **A25** and **A26**) and Input **CLOSE** (Terminals **A21** and **A22**) on the SEL-387L. Energizing Input **T1** asserts Transmit Bit TX1 (SEL-387L at Station S), which in turn asserts Receive Bit RX1 in the SEL-387L at Station R.

At Station R, jumper Output **R1** (Terminals **A09** and **A10**) to Input **CLOSE** (Terminals **A21** and **A22**) on the SEL-387L. With this wiring, the reclose element in the SEL-551 closes both circuit breakers (the circuit breaker at Station R closes when Output **R1** asserts Input **CLOSE**).

Figure 1.11 shows breaker failure logic created in the SEL-551 with SELOGIC® control equations. Because we already connected Output **TRIP** from the SEL-387L to Input **IN1** of the SEL-551 for reclose initiation, we will also use Input **IN1** for breaker failure initiation. This second use of Input **IN1** forms the second input of the AND gate in *Figure 1.11*. Wire Output **OUT2** of the

SEL-551 to Input T2 (Terminals A27 and A28) on the SEL-387L and to the station lockout relay (not shown). The bottom input of the AND gate (*Figure 1.11*) is the OR combination of the phase currents in the SEL-551.

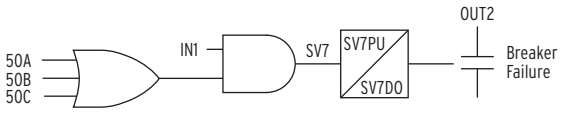


Figure 1.11 Breaker Failure Protection Created With SELOGIC Control Equations in the SEL-551

For an internal line fault, both SEL-387L relays trip. The relay at Station S initiates reclosing as well as breaker failure (energizes Input IN1). For breaker failure initiation, the fault current must exceed the current threshold level of the 50A, 50B, or 50C settings. If the circuit breaker at Station S fails, then SV7PU (*Figure 1.11*) times out and closes Output OUT2. Output OUT2 operates the lockout relay and energizes Input T2 on the SEL-387L. Input T2 asserts TX2 in the SEL-387L (Station S), which in turn asserts Receive Bit RX2 and Output Contact R2 in the remote relay (Station R). At Station R, jumper Output Contact R2 to the TRIP input.

In this application, we used Transmit Bit T1 in the SEL-387L at Station S to reclose the SEL-387L at Station R and Transmit Bit T2 as a direct transfer trip function to trip the SEL-387L at Station R.

SEL-387L Models

Standard SEL-387L features are the following:

- Screw-terminal blocks
- Eight standard output contacts and six fast, high-current interrupting output contacts
- Six optoisolated contact inputs
- One EIA-485 port
- Three EIA-232 ports
- IRIG-B time synchronization

Select between the following **ordering options** (3U only):

- Horizontal rack or panel mount, horizontal projection panel mount, or vertical panel mount
- 1 A or 5 A current transformers
- 24/48 Vdc, 48/125 Vdc or 125 Vac, or 125/250 Vdc or Vac power supply
- 24 Vdc, 48 Vdc, 110 Vdc, 125 Vdc, 220 Vdc, or 250 Vdc control input voltage selections

Communication protocols include the following:

- SEL ASCII, SEL Compressed ASCII, SEL Fast Meter and Configuration, Fast Operate, Fast SER
- Optional DNP3 Level 2 Slave

Purchase the SEL-387L with any one of the following **line current differential channel interfaces**:

- 850 nm multimode fiber (IEEE Standard C37.94) for connection to a digital multiplexer or for direct connection to an SEL-311L, but not for direct connection to another SEL-387L
- 1300 nm multimode/direct fiber
- 1550 nm direct fiber

Use an optional SEL-3094 to convert from IEEE C37.94 interface to isolated EIA-422 or isolated G.703 (codirectional).

See the SEL-387L Relay Model Option Table (MOT) for available combinations.

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

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

CE Mark

UKCA Mark

RCM Mark

Class 1 Laser Product

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

General

AC Current Inputs

5 A nominal:	15 A continuous; linear to 100 A symmetrical
	500 A for 1 second
	1250 A for 1 cycle
Burden:	0.27 VA @ 5 A
	2.51 VA @ 15 A
1 A nominal:	3 A continuous; linear to 20 A symmetrical
	100 A for 1 second
	250 A for 1 cycle
Burden:	0.13 VA @ 1 A
	1.31 VA @ 3 A

Power Supply

Rated:	125/250 Vdc or Vac
Range:	85–350 Vdc or 85–264 Vac
Rated:	48/125 Vdc or 125 Vac
Range:	38–140 Vdc or 85–140 Vac
Rated:	24/48 Vdc
Range:	18–60 Vdc polarity-dependent
Burden:	<25 W

Output Contacts

Standard

Make:	30 A
Carry:	6 A continuous @ 70°C; 4 A continuous @ 85°C
1 s Rating:	50 A
MOV Protected:	270 Vac, 360 Vdc, 40 J
Pickup Time:	<5 ms

Breaking Capacity (10,000 operations):

48 V	0.5 A	L/R = 40 ms
125 V	0.3 A	L/R = 40 ms
250 V	0.2 A	L/R = 40 ms

Cyclic Capacity (2.5 cycles/second):

48 V	0.5 A	L/R = 40 ms
125 V	0.3 A	L/R = 40 ms
250 V	0.2 A	L/R = 40 ms

High-Speed High-Current Interruption

Make:	30 A
Carry:	6 A continuous @ 70°C; 4 A continuous @ 85°C
1 s Rating:	50 A
MOV Protected:	330 Vdc, 130 J
Pickup Time:	<10 µs
Dropout Time:	<8 ms, typical

Breaking Capacity (10,000 operations):

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 interruptions/second, followed by 2 minutes idle for thermal dissipation):

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: Make per IEEE C37.90–1989; Breaking and Cyclic Capacity per IEC 60255-23–1994.

Optoisolated Input Ratings

250 Vdc:	Pickup 200–300 Vdc; Dropout 150 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout 132 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout 75 Vdc
110 Vdc:	Pickup 88–132 Vdc; Dropout 66 Vdc
48 Vdc:	Pickup 38.4–60 Vdc; Dropout 28.8 Vdc
24 Vdc:	Pickup 15–30 Vdc

Note: 24, 48, 125, 220, and 250 Vdc optoisolated inputs draw approximately 5 mA of current; 110 Vdc inputs draw approximately 8 mA of current. All current ratings are at nominal input voltages.

Frequency and Rotation

System Frequency:	50 or 60 Hz
Phase Rotation:	ABC (interchange two phases on both relays for ACB rotation)
Frequency Tracking Range:	40.1–65 Hz

Serial Communications Ports

Port 1:	EIA-485
Baud rate:	9600 without DNP3 300–19200 with DNP3
Port 2–3:	EIA-232
Baud rate:	19200 without DNP3 300–38400 with DNP3
Port 4 (Front Port):	EIA-232
Baud rate:	9600 without DNP3 300–38400 with DNP3

Differential Communications Ports

Fiber Optics—ST connector

1550 nm single-mode direct fiber
1300 nm multimode or single-mode

Tx Power:	–18 dBm
Rx Min. Sensitivity:	–58 dBm
System Gain:	40 dB

850 nm multimode, C37.94 (for connection to a digital multiplexer or for direct connection to an SEL-311L, but not for direct connection to another SEL-387L)

	50 µm	**62.5 µm**
Tx Power:	–23 dBm	–19 dBm
Rx Min. Sensitivity:	–32 dBm	–32 dBm
System Gain:	9 dB	13 dB

Electrical: Use the SEL-3094 for EIA-422 or CCITT G.703 synchronous interfaces to multiplexers.

Metering Accuracy

Currents I_A, I_B, I_C

Local

5 A nominal:	±0.05 A secondary
1 A nominal:	±0.01 A secondary
Remote:	±3%
Total:	±3%

Currents 3I2, 3I0, I1

Local and Remote

5 A nominal:	±0.05 A secondary and ±5%
1 A nominal:	±0.01 A secondary and ±5%
Total:	±3%

Substation Battery Voltage Monitor

Range:	20–300 Vdc
Accuracy:	±2%, ±2 Vdc

Time-Code Input

Relay accepts demodulated IRIG-B time-code input at Port 1 or 2.

Relay time is synchronized to within ±5 ms of time source input.

Current differential protection does not require external time source.

Terminal Connections

Rear Screw-Terminal Tightening Torque:

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

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

Operating Temperature Range

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20°C.

Relay Weight

7.24 kg (16 lb)

Type Tests

Electromagnetic Compatibility Emissions

Emissions:	Canada ICES-001 (A) / NMB-001 (A)

Electromagnetic Compatibility Immunity

Electrostatic Discharge:	IEC 60255-22-2–1996, IEC 61000-4-2, IEEE C37.90.3 Severity Level 4 (8000 V contact, 15,000 V air)
Fast Transient Disturbance:	IEC 60255-22-4–1992; IEC 61000-4-4–1995, 4 kV @ 2.5 kHz (4000 V on power supply, 2000 V on inputs and outputs)
Radiated Radio Frequency:	IEC 60255-22-3–1989, 10 V/m; IEEE C37.90.2, 35 V/m; IEC 61000-4-3, 10 V/m
Surge Withstand:	IEEE C37.90.1–1989, 3000 V oscillatory, 5000 V transient IEEE C37.90.1–2002, 2500 V oscillatory, 4000 V fast transient
1 MHz Burst Disturbance:	IEC 60255-22-1–1988, Severity Level 3 (2500 V common and 1000 V differential mode)

Environmental

Cold:	IEC 60068-2-1–1990, Test Ad; 16 hr. @ –40°C
Dry Heat:	IEC 60068-2-2–1974, Test Bd; 16 hr. @ +85°C
Damp Heat, Cyclic:	IEC 60068-2-30–1980, Test Db; 55°C, 6 cycles, 95% humidity
Object Penetration:	IEC 60529–1989, IP30
Sinusoidal Vibration:	IEC 60255-21-1–1988 Vibration Endurance, Class 1 Vibration Response, Class 2
Shock and Bump:	IEC 60255-21-2–1988 Bump Test, Class 1 Shock Withstand, Class 1 Shock Response, Class 2
Seismic:	IEC 60255-21-3–1993, Class 2

Safety

Dielectric Strength:	IEC 60255-5–1977; IEEE C37.90–1989 2500 Vac (rms) for 1 minute on analog inputs, optoisolated inputs, and output contacts; 3100 Vdc for 1 minute on power supply.
Impulse:	IEC 60255-5–1977, 0.5 J, 5000 V
Laser Safety:	IEC 60825-1–1993; 21 CFR 1040.10; ANSI Z136.1–1993; ANSI Z136.2–1988, eye-safe Class 1 laser product

Relay Element Accuracies
Line Current Differential (87L) Elements

Phase, Negative-Sequence, and Zero-Sequence Accuracy:	±3% ±0.01 I_{NOM}
Restraint Characteristic Accuracy:	±5% of 6 ±3° of 195°

Section 2
Installation

Overview

Figure 2.1 shows the dimensions of panel-mount and rack-mount cutout profiles of the SEL-387L Relay. The SEL-387L is available in these mounting options (3U size only): horizontal rack or panel mount, horizontal projection panel mount, and vertical panel mount.

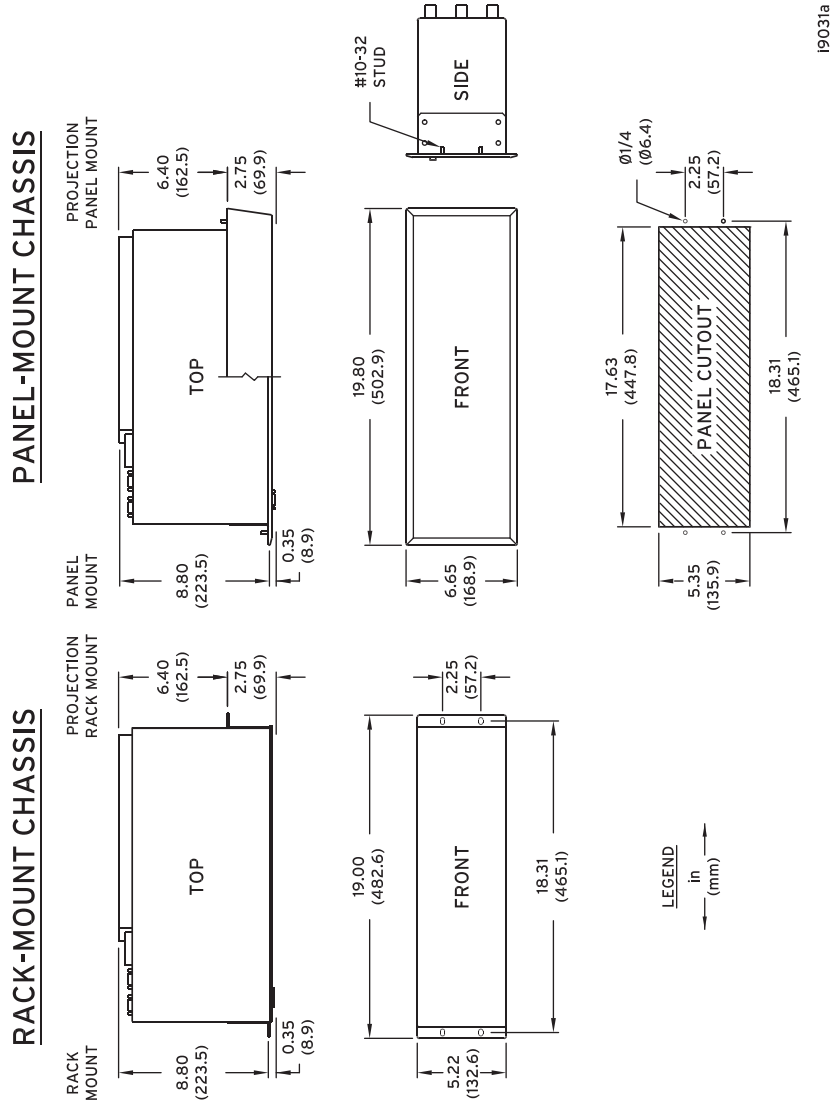


Figure 2.1 SEL-387L Dimensions and Panel-Mount Cutout

Reversal of mounting brackets provides a projection rack-mount option.

Front- and Rear-Panel Diagrams

Figure 2.2 shows horizontal rack-mount front-panel and rear-panel drawings. Contact SEL (see *Technical Support on page 5.18*) for panel-mount and horizontal projection panel-mount drawings.

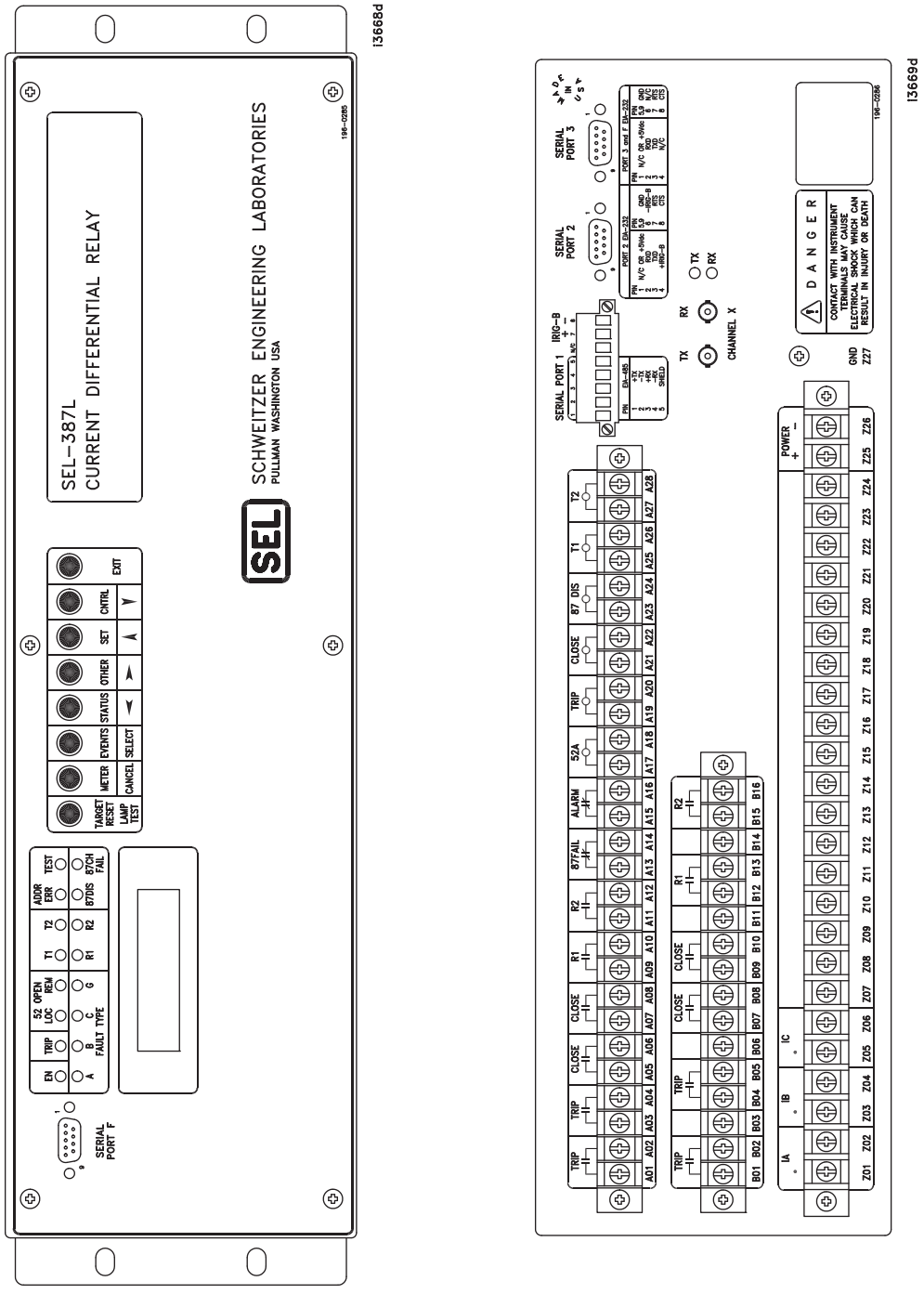


Figure 2.2 SEL-387L Horizontal Rack-Mount Front-Panel and Rear-Panel Drawings

Making Rear-Panel Connections

Figure 2.3 shows a connection wiring diagram for a typical SEL-387L application. All screw terminals are size #6-32 for use with a Phillips or slotted-tip screwdriver. Ground the relay chassis at Terminal **Z27**; see *Figure 2.2*.

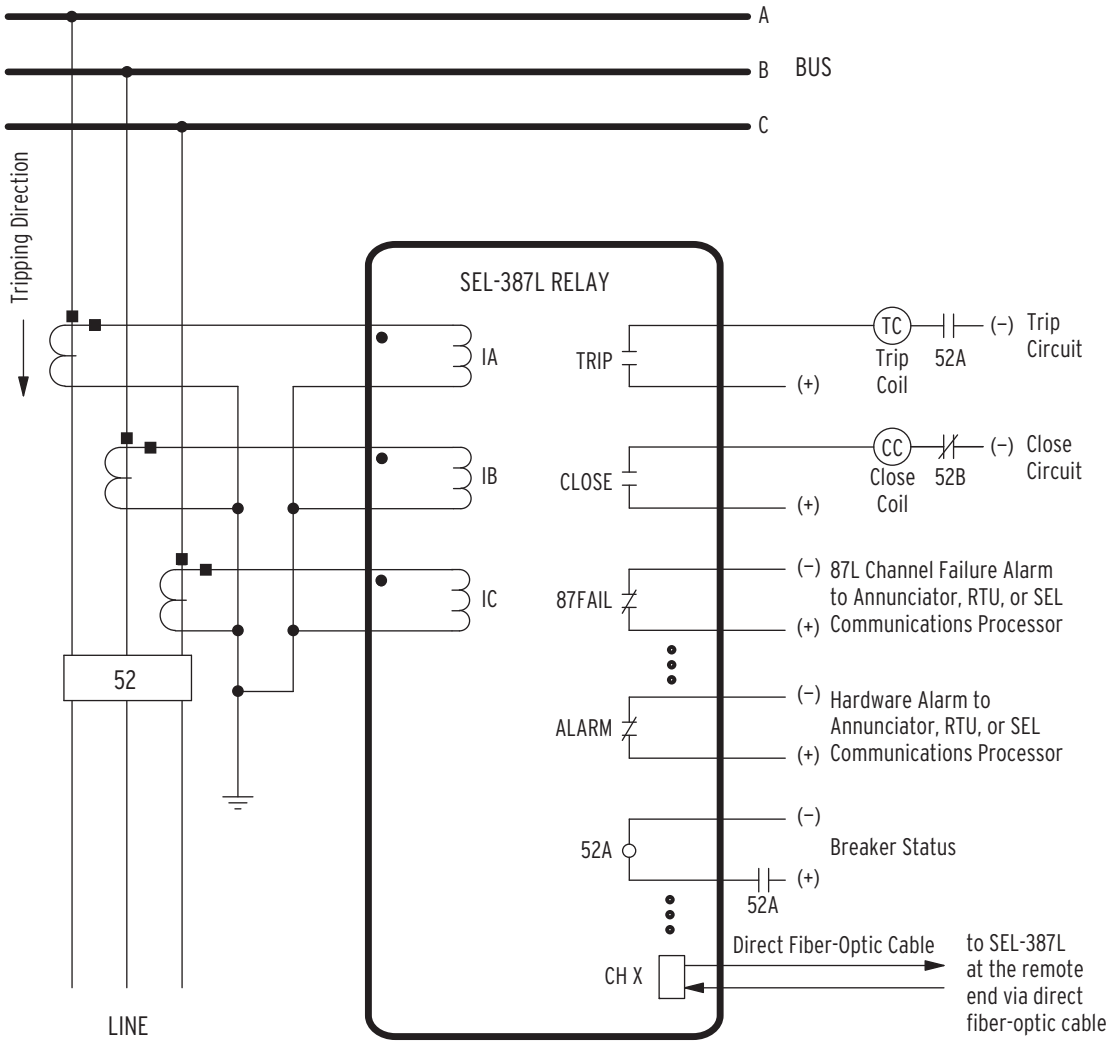


Figure 2.3 Typical Current Transformer, DC, and Communications Connections

Power Supply

The control power circuitry is isolated from the relay chassis ground. Connect control voltage to the **POWER** terminals. Note the polarity indicators on Terminals **Z25(+)** and **Z26(-)**. Control power passes through these terminals to a fuse and to the switching power supply. Refer to the serial number sticker on the relay rear panel for the power supply rating.

Output Contacts

The SEL-387L provides six fast, high-current interrupting output contacts and eight standard output contacts. Use both types of contacts to switch either ac or dc loads.

Optoisolated Inputs

The optoisolated inputs in the SEL-387L are polarity independent. Refer to the serial number sticker on the relay rear panel for the optoisolated input voltage rating.

Current Transformer Inputs

WARNING
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

Refer to *Figure 2.3* for typical CT wiring, and note the polarity dots above Terminals **Z01**, **Z03**, and **Z05**. Refer to the serial number sticker on the relay rear panel for the nominal current ratings (5 A or 1 A) for the current inputs.

Phase Rotation

DANGER
Never disconnect the CTs when primary current is flowing. Open circuiting a CT when primary current flows will cause high voltage spikes on the CT secondary terminals that can result in injury or death.

Because most power systems operate on an ABC phase rotation, the SEL-387L is configured at the factory for an ABC phase rotation. If your power system operates on an ACB phase rotation, you will need to interchange, with the same polarity, the B-phase and C-phase CT connections on the relay terminals.

Table 2.1 Current Transformer Connection Options

Example Original Connections (ABC)	
B-phase CT	Connected to Terminals **Z03** (polarity) and **Z04**
C-phase CT	Connected to Terminals **Z05** (polarity) and **Z06**
Connection for ACB Phase Rotation	
B-phase CT	Connected to Terminals **Z05** (polarity) and **Z06**
C-phase CT	Connected to Terminals **Z03** (polarity) and **Z04**

If the remote end of the feeder also operates on an ACB phase rotation, be sure to interchange B-phase and C-phase CT connections on both the relays.

Serial Ports (1, 2, 3, and F)

The SEL-387L contains four multifunction communications ports. All serial ports are independent—you can communicate to any combination simultaneously. Serial Port 1 on all SEL-387L models is an EIA 485 port (4-wire). The serial Port 1 plug-in connector accepts wire size AWG 24 to 12. Strip the wires 8 mm (0.31 inches) and install with a small slotted-tip screwdriver. The serial Port 1 connector has extra positions for IRIG-B time-code signal input. Serial Ports F, 2, and 3 are EIA 232 ports that accept 9-pin D-subminiature male connectors. Port 2 on all SEL-387L models includes the IRIG-B time-code signal input.

NOTE: For your convenience, Table 2.2 lists devices not manufactured by SEL. SEL does not specifically endorse or recommend such products, neither does SEL guarantee proper operation of those products, or the correctness of connections, over which SEL has no control. For connecting devices at distances greater than 100 feet, SEL offers the SEL-2800 family of fiber-optic transceivers.

Table 2.2 EIA-232 Communications Cables to Connect the SEL-387L to Other Devices

SEL 387L EIA-232 Serial Ports	Connect to Device (gender refers to the device)	SEL Cable No.
All EIA-232 ports	PC, 25-Pin Male (DTE)	SEL-C227A
All EIA-232 ports	Laptop PC, 9-Pin Male (DTE)	SEL-C234A
All EIA-232 ports	SEL-2032, SEL-2030, SEL-2020, or SEL-2100 without IRIG-B, and SEL-DTA2	SEL-C272A
2	SEL-2032, SEL-2030, SEL-2020, or SEL-2100 with IRIG-B	SEL-C273A
2[a], 3[a]	Dial-Up Modem, 5 Vdc Powered	SEL-C220[a]
All EIA-232 ports	Standard Modem, 25-Pin Female (DCE)	SEL-C222

[a] A corresponding main board jumper must be installed to power the dial-up modem with +5 Vdc (0.5 A limit) from the SEL-387L, see Figure 2.7.

Port Connector and Communications Cables

Table 2.3 shows the pin designations for serial Ports 2, 3, and F.

Table 2.3 Functions for EIA-232 Serial Ports 2, 3, and F

Pin	Port 2	Port 3	Port F
1	N/C or +5 Vdc	N/C or +5 Vdc	N/C
2	RXD	RXD	RXD
3	TXD	TXD	TXD
4	+IRIG-B	N/C	N/C
5, 9	GND	GND	GND
6	–IRIG-B	N/C	N/C
7	RTS	RTS	RTS
8	CTS	CTS	CTS

Table 2.4 shows the pin designations for serial Port 1.

Table 2.4 Terminal Functions for EIA-485 Serial Port 1

Terminal	Function
1	+TX
2	–TX
3	+RX
4	–RX
5	SHIELD
6	N/C
7	+IRIG-B
8	–IRIG-B

IRIG-B Time-Code Input

The SEL-387L accepts a demodulated IRIG-B time signal to synchronize the relay internal clock with an external source. Connect the IRIG-B source to either serial Port 1 or serial Port 2. For example, connect serial Port 2 of the SEL-387L to an SEL-2020 with cable SEL-C273A, or by using an SEL-2810 or SEL-2812 Fiber-Optic Transceiver. Note that the line current differential protection does **NOT** rely upon IRIG-B time synchronization.

Relay Word Bit TIRIG

TIRIG asserts (TIRIG = logical 1) when the relay time is based on an IRIG-B time source. When Relay Word bit TIRIG is asserted, the relay's month, day, and time cannot be changed, but the relay's year can be adjusted. If the relay is not synchronized to an IRIG-B time source, TIRIG is not asserted (TIRIG = logical 0).

Relay Word Bit TSOK

TSOK asserts to indicate that the IRIG-B time source is providing high-accuracy time.

Line Current Differential Communications Channel Interfaces

CAUTION
Longer channel delays result in slower tripping times. One-way channel delay times that exceed the automatic compensation capability of the SEL-387L (35 milliseconds) can result in misoperation.

The SEL-387L properly compensates for any channel delay up to 35 ms. Relay Word bit DBADX asserts if the channel delay exceeds 24 ms.

The SEL-387L offers fiber-optic line differential interfaces of 850 nm multimode fiber, 1300 nm single/multimode fiber, or 1550 nm single-mode fiber. All options use ST connectors. The communications channels are factory configured per your ordering option. *Figure 2.4* shows a direct fiber connection.

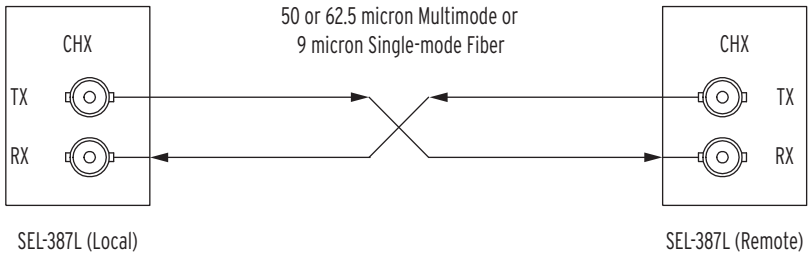


Figure 2.4 Direct Fiber Connection

The IEEE C37.94 multimode fiber interface is directly compatible with many multiplexers. Connect the SEL-387L to compatible multiplexer line interface cards with up to 2 km of multimode fiber-optic cable, as shown in *Figure 2.5*. The IEEE C37.94 interface cannot be used for direct fiber connections to another SEL-387L.

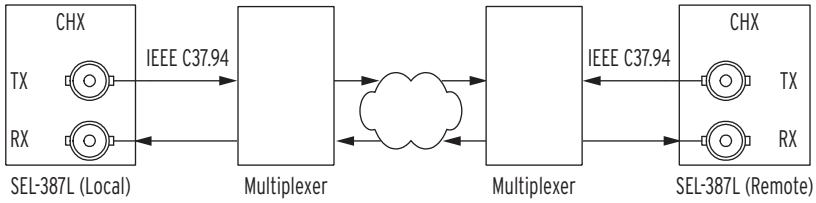


Figure 2.5 IEEE Standard C37.94 850 nm Fiber-to-Multiplexer Interface

Figure 2.6 shows the items necessary when the IEEE C37.94 multimode fiber interface is not compatible with your multiplexer. Use the SEL-3094 interface converter to convert IEEE C37.94 standard fiber-optic signals to standard electrical signals. Connect the output from the SEL-3094 (standard electrical signal) to your multiplexer.

Figure 2.6 Connections to Multiplexers Incompatible With the IEEE C37.94 Interface

1300 nm Single-Mode or Multimode and 1550 nm Single-Mode Fiber-Optic Interfaces

The 1300 nm and 1550 nm fiber-optic interfaces on the SEL-387L utilize eye-safe lasers and sensitive detectors to achieve 40 dB of system gain including end-connector loss. The 1300 nm interface is useful with up to 35 km of 62.5 micron multimode fiber, or 87 km of 9 micron single-mode fiber. The 1550 nm interface is useful with up to 134 km of 9 micron single-mode fiber. Although all of the fiber-optic interfaces on the SEL-387L are eye-safe, you should never look into a fiber transmitter or into a fiber. *Table 2.5* shows example losses for the 1300 nm interface using multimode fiber-optic cable.

Table 2.5 Example Loss Calculations and Maximum Cable Length for 62.5 Micron Multimode Fiber

Item	1300 nm
System Gain	40 dB
Connector Loss (2.0 dB per connection)	4 dB
Splice Loss (0.4 dB per fusion splice)	1.2 dB
Available Gain (40 –[4 + 1.2 dB])	34.8 dB
Fiber Loss	1.0 dB/km
Maximum 62.5 Micron Fiber Length	34.8 km

Table 2.6 shows example losses for the 1300 nm and 1550 nm interfaces using single-mode fiber-optic cable.

Table 2.6 Example Loss Calculations and Maximum Cable Length for 9 Micron Single-Mode Cable

Item	1300 nm	1550 nm
System Gain	40 dB	40 dB
Connector Loss (2.0 dB per connection)	4 dB	4 dB
Splice Loss (0.4 dB per fusion splice)	1.2 dB	2.4 dB
Available Gain	34.8 dB	33.6 dB
Fiber Loss	0.4 dB/km	0.25 dB/km
Maximum 9 Micron Fiber Length	87 km	134 km

Using the SEL-387L With an SEL-311L

The SEL-387L can be connected to an SEL-311L to implement a leader-follower scheme with unequal CT ratios, or as part of a three terminal line protection package. *Table 2.7* shows how to set the SEL-311L TIMRX or TIMRY channel settings when connecting to an SEL-387L.

Table 2.7 Setting the TIMRX or TIMRY Channel Settings in the SEL-311L

When the Current Differential Communications Interface Is:	And the SEL-311L Is Connected:	Make the Following TIMRX or TIMRY Setting in the SEL-311L, Depending on Which Channel is Being Used
850 nm Multimode Fiber-Optic	Directly to a multiplexer or other communications equipment	TIMRX or TIMRY = E
850 nm Multimode Fiber-Optic	Directly to an SEL-387L	TIMRX or TIMRY = I
1300 nm Single-Mode or Multimode, or 1550 nm Single-Mode Fiber-Optic	Directly to an SEL-387L	If TA_X > RA_X in the SEL-311L, TIMRX = E, otherwise TIMRX = I or If TA_Y > RA_Y in the SEL-311L, TIMRY = E, otherwise TIMRY = I

Circuit Board Connections

Figure 2.7 shows major component locations on the SEL-387L main board.

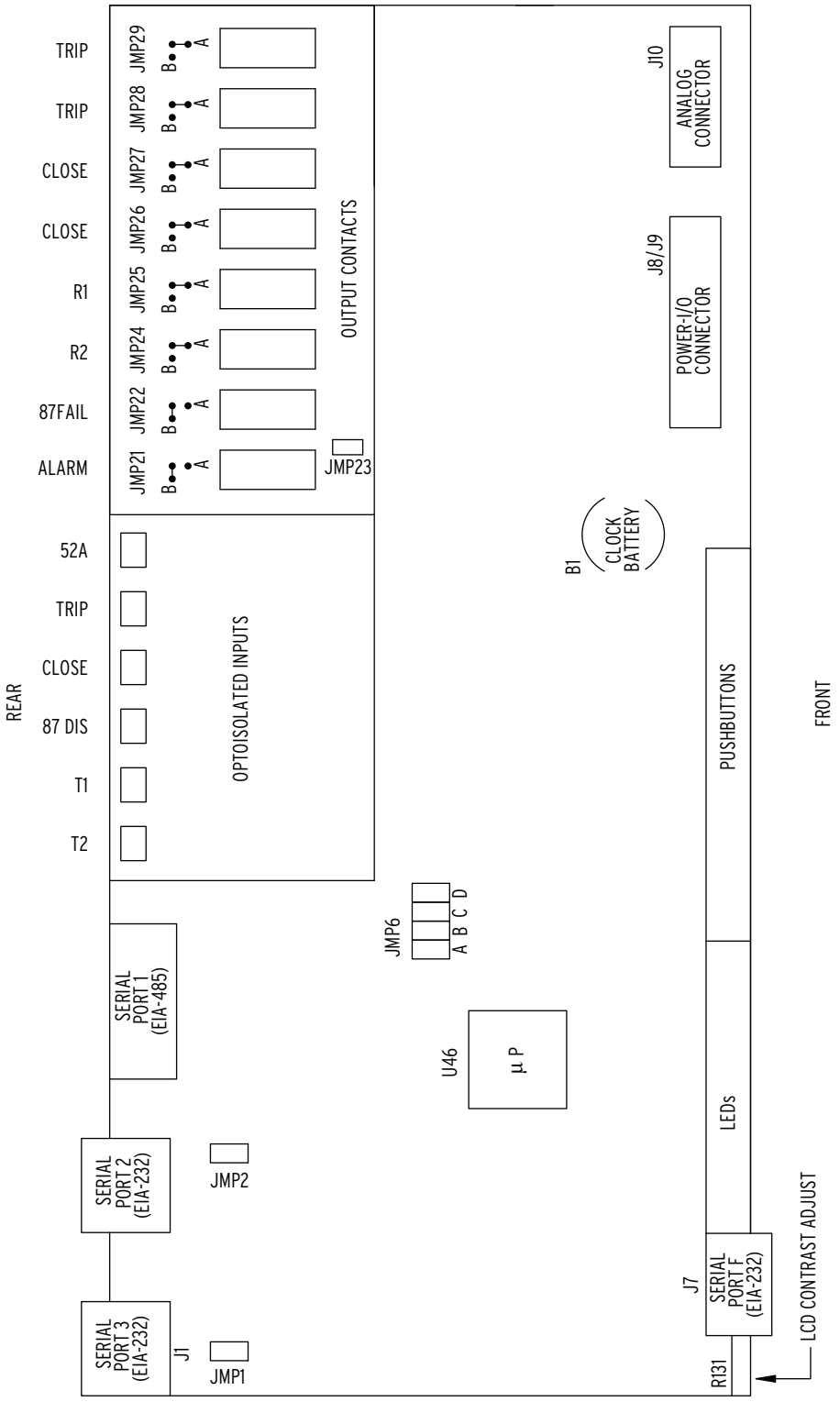


Figure 2.7 Jumper, Clock Battery, and Major Component Locations on the SEL-387L Main Board

Password and Breaker Jumpers

Table 2.8 shows the functions associated with jumpers JMP6-A and JMP6-B; JMP6-C and JMP6-D are not used. Refer to *Figure 2.7* for the jumper positions on the main board.

Table 2.8 Password and Breaker Jumper Operation

Jumper	Jumper Position	Function
Password JMP6-A	ON (in place)	Disable serial port and front-panel password protection.
	OFF (removed/not in place)	Enable serial ports and front-panel password protection.
Breaker JMP6-B	ON (in place)	Enable serial port commands **OPEN**, **CLOSE**, and **PULSE**.[a]
	OFF (removed/not in place)	Disable serial port commands **OPEN**, **CLOSE**, and **PULSE**.[a]

[a] The **OPEN**, **CLOSE**, and **PULSE** commands are used primarily to assert output contacts for circuit breaker control or testing purposes. These commands are disabled in a standard relay shipment.

EIA-232 Multifunction Serial Port Voltage Jumpers

Jumpers JMP2 (serial Port 2) and JMP1 (serial Port 3) shown in *Figure 2.7* connect +5 Vdc to Pin 1 on the corresponding EIA 232 serial ports. The +5 Vdc is rated at 0.5 A maximum for each port. In a standard relay shipment the jumpers are "OFF" (removed/not in place) so that the +5 Vdc is not connected to Pin 1 on the corresponding EIA 232 serial ports. Put the jumpers "ON" (in place) so that the +5 Vdc is connected to Pin 1 on the corresponding EIA 232 serial ports. To meet product safety compliance for end-use applications in North America, use an external fused rated 3 A or less in-line with the +5 Vdc source on Pin 1.

Clock Battery

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C, or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.

Refer to *Figure 2.7* for clock battery B1 location. This nonrechargeable lithium battery powers the relay clock (date and time) if the external power source is lost or removed. The battery is a 3 V lithium coin cell, Ray O-Vac No. BR2335 or equivalent. At room temperature (25°C), nominal battery operating life is 10 years with power removed from the relay. Powering the relay from an external source extends battery life well beyond 10 years.

If the relay does not maintain date and time after power loss, replace the battery.

Section 3

Current Differential Elements

Overview

As with the SEL-311L family of relays, the SEL-387L Relay operates on the vector ratio of remote current to local current. As reference, we define current flowing into the protected line as having an angle of 0°. For a 5 A load, the current flowing at the local terminal is then 5 A ∠0°, and the current flowing at the remote terminal is 5 A ∠180°. For this example, the vector ratio of remote to local current is 5 A ∠180°/5 A ∠0° or 1 ∠180°. The same is true for external faults. Ideally, the complex ratio is 1 ∠180° during all conditions except internal faults.

Figure 3.1 shows a plot of the complex ratio of remote current IR and local current IL on the alpha plane, from which we define the relay characteristic. Complex ratios in the shaded area fall in the restraint region, and complex ratios in the unshaded area fall in the trip region. The outer radius is 6, the inner radius is 1/6, and the total angular extent of the restraint region (shaded area) is 195°. If the vector ratio falls outside the restraint region and the difference current exceeds a threshold, the differential element operates. The threshold is 0.1 per unit nominal for both the zero-sequence (87LG) element and the negative-sequence (87L2) element, and 1.2 per unit nominal for the phase elements (87LA, 87LB, and 87LC).

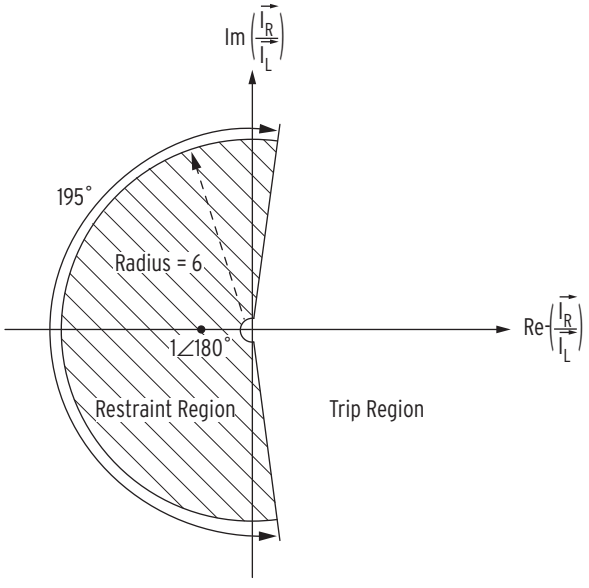


Figure 3.1 Relay Characteristic Showing the Restraint Region and Trip Region

The phase elements provide high-speed protection for high-current faults. Negative-sequence and ground current differential elements provide sensitive protection for unbalanced faults without compromising security.

Relay Qualification

The SEL-387L is applicable to a wide range of lines and cables of any voltage level. The SEL-387L will protect any two-terminal line or cable with the following characteristics:

1. The total charging current is less than 3 A secondary (0.6 A for a 1 A relay).
2. The charging current unbalance is less than 0.5 A secondary (0.1 A for a 1 A relay).
3. The three-phase fault current for a bolted internal fault is greater than 6 A secondary (1.2 A for a 1 A relay).
4. The CT ratios are equal at the two line ends.
5. The angle difference between local and remote currents during an internal fault is less than 82°.

Table 3.1 shows the various factors to consider when calculating the angle difference. As long as the total difference is less than 82°, the SEL-387L will dependably detect internal faults.

Table 3.1 Example Calculation of the Remote Current to the Local Current Angle Difference

Component	Angle
Source angle difference	±10°
Impedance angle difference	±10°
Channel delay asymmetry	±22° (2 ms transmit-to-receive delay difference)
CT saturation	±40°
Total	±82°

If the line or cable does not meet characteristics 1–4 listed above, consider replacing existing CTs with CTs that have different ratios. If replacing the CTs is not possible, or if the line or cable does not meet Characteristic 5 above, consider connecting the SEL-387L to an SEL-311L in a leader/follower application (see *Figure 1.7*). Adjust the appropriate settings in the SEL-311L to meet the requirements. Because a leader/follower application disables the differential protection in the SEL-387L, the new settings in the SEL-311L effectively apply to the differential protection at both line ends.

CT Requirements

In two-terminal applications, the SEL-387L requires current transformers that meet both of the following criteria:

1. The CT cannot saturate at less than I_F = 15 A secondary for a relay with 5 A current transformers, or I_F = 3 A secondary for a relay with 1 A current transformers.
2. The CT burden, Z_B, cannot exceed

$$\frac{7.5\ V_S}{I_F\left(\frac{X}{R}+1\right)} \qquad \textbf{Equation 3.1}$$

where:

Z_B is the burden impedance in ohms
V_S is the voltage class of the CT in volts
I_F is the maximum rms fault current in secondary amperes
X/R is the power system reactance-to-resistance ratio for the fault of interest

In other words, the SEL-387L will operate and restrain properly if the CT does not saturate at less than 3 per unit nominal current, and if the CT burden is less than 7.5 times the burden that just causes the CT to saturate.

Speed and Sensitivity

When applied within the qualifying parameters discussed above, the SEL-387L performs as shown in *Figure 1.2*.

Figure 1.3 shows the sensitivity of the SEL-387L for unbalanced, internal faults, assuming a system with 67 V_{LN} secondary potential. For load currents less than 1/3 I_{NOM}, the ground fault sensitivity is 132.8 ohms secondary referenced to nominal system voltage. The fault resistance coverage decreases from 132.8 ohms secondary worst case at 1/3 of nominal load current to 45 ohms worst case at nominal load current.

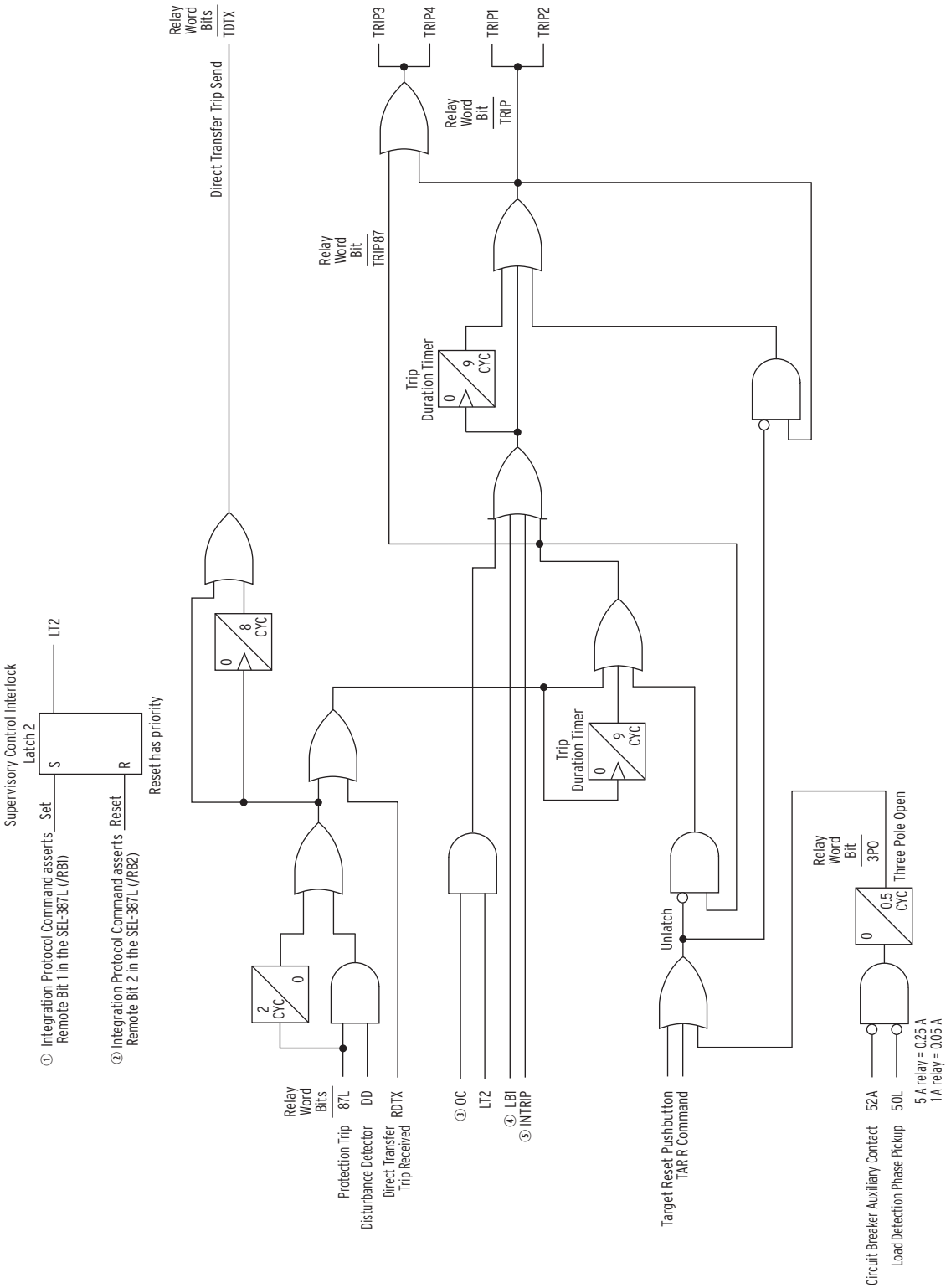
Trip Logic

The SEL-387L combines trip decisions from several sources and controls four trip output contacts, as shown in *Figure 3.2*. All four **TRIP*x*** contacts close in response to the same conditions, but at slightly different times. High-speed, high-current interrupting contacts **TRIP3** and **TRIP4** are approximately 10 ms faster than **TRIP1** and **TRIP2** when processing 87L trip decisions. RDTX is the transfer trip from the remote relay.

There are several other ways to generate a trip besides the current differential operation. Relay Word bit OC asserts in response to the **OPEN** command entered from the command line, or in response to the Fast Operate command received from an SEL communications processor. Latch 2 provides supervisory interlocking, enabling or disabling remote control of the circuit

breaker. When Latch 2 is SET (Relay Word bit LT2 asserted), remote control is enabled. When Latch 2 is RESET (Relay Word bit LT2 deasserted), remote control is disabled. Control Relay Word bits RB1 and RB2 either from the command line or from an integration protocol such as DNP.

Local bit LB1 asserts in response to the front-panel MANUAL TRIP function; energizing Input **TRIP** asserts Relay Word bit INTRIP. When any one of Relay Word bits TRIP87 or TRIP asserts, the relay closes all four **TRIP** contacts (**TRIP1**–**TRIP4**) until the trip decision is unlatched. Target reset operation, the **TAR R** command, or a circuit breaker open condition unlatches trip decisions. The relay determines a breaker open condition when the **52A** input deasserts and all three phase currents drop below 0.25 A (0.05 A for a 1 A relay). If the **52A** input is not connected to the circuit breaker 52a auxiliary contact, then the relay uses current alone to determine that the breaker is open.



① RB1: The rising edge of RB1 (from integration protocol) sets Latch 2. When Latch 2 is SET, remote **OPEN** and **CLOSE** commands are ENABLED.

② RB2: The rising edge of RB2 (from integration protocol) resets Latch 2. When Latch 2 is RESET, remote **OPEN** and **CLOSE** commands are DISABLED.

③ OC: Assertion of OC caused by the **OPEN** command (from integration protocol). ④ LB1: Trip from front-panel MANUAL TRIP function. ⑤ INTRIP: Trip caused by assertion of binary **TRIP** input.

Figure 3.2 Trip Logic of the SEL-387L

Disturbance Detector

Figure 3.3 shows the disturbance detector logic. All trip decisions are supervised for up to 2 cycles by Relay Word bit DD, the output of the disturbance detector. Relay Word bit DD asserts for 10 cycles when the local current changes by more than eight degrees or two percent. This is a small change; even high-resistance ground faults trigger the disturbance detector. However, if the disturbance detector fails to detect an internal fault, 87L tripping will be delayed by no longer than two cycles.

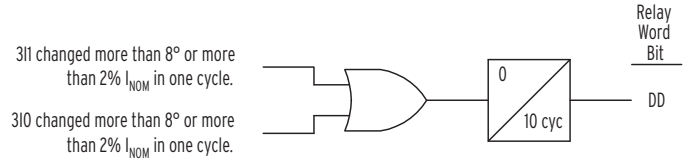
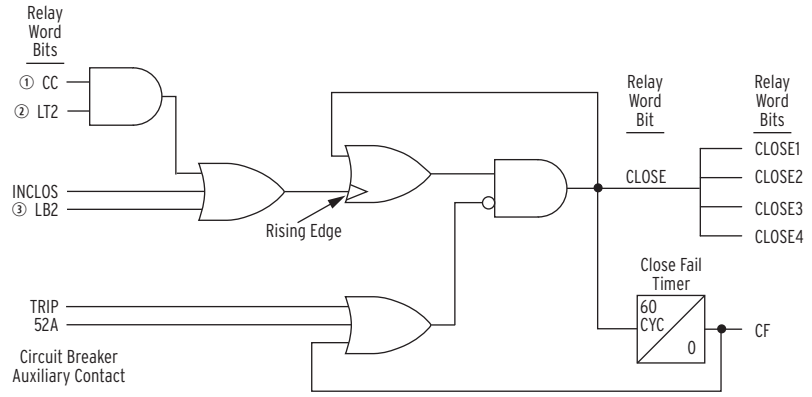


Figure 3.3 Local Disturbance Detector

Close Logic

The SEL-387L combines close requests from several sources and qualifies these requests to ensure that it is safe to perform a close operation before closing the four **CLOSE** outputs.



① CC = Asserted from integration protocol; ② LT2 = Supervisory interlock (see Figure 3.2); ③ LB2 = Close from front-panel MANUAL CLOSE function

Figure 3.4 Close Logic

Relay Word bit LT2, the output from Latch 2, supervises the remote close operation (see *Figure 3.2* for more information). All four **CLOSE** outputs close for the same conditions. Relay Word bit TRIP, circuit breaker status bit 52A, and the close failure bit CF supervise all close requests. If TRIP, 52A, or CF is asserted, the relay ignores the requested close operation. If the CLOSE bit is already asserted, and any of TRIP, 52A or CF asserts, then the CLOSE bit unlatches (deasserts).

Close requests come from INCLOS, CC (LT2 asserted), or LB2. Relay Word bit INCLOS asserts upon energization of the **CLOSE** input. Relay Word bit CC asserts in response to the **CLOSE** command or in response to the Fast Operate command received from an SEL communications processor. Local bit LB2

asserts in response to the front-panel MANUAL CLOSE function. When INCLOS, CC, or LB2 asserts, the relay closes all four **CLOSE** contacts (**CLOSE1**–**CLOSE4**) for no longer than one second.

If the close condition does not unlatch (TRIP or 52A asserts) within one second, then Relay Word bit CF, the close failure bit, asserts and unlatches the close condition. Because Outputs **CLOSE1** and **CLOSE2** are not rated to interrupt close current, be sure to provide a seal-in relay to protect the contacts from damage in the event of a close failure. Outputs **CLOSE3** and **CLOSE4** are rated to interrupt close current.

Inputs and Outputs

Inputs

This section describes the inputs and outputs of the SEL-387L. See *Specifications on page 1.11* for the specifications of the various outputs and inputs. *Figure 3.5* shows the SEL-387L inputs, and *Figure 3.7* shows the SEL-387L outputs.

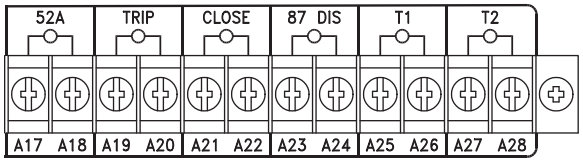


Figure 3.5 SEL-387L Inputs

52A

Connect Input **52A** to the circuit breaker auxiliary normally open (a) contact. If Input **52A** is not connected to the circuit breaker auxiliary contact, the relay determines the circuit breaker status based on a sensitive undercurrent element. When Input **52A** is de-energized, and the current in all three phases drops below five percent of nominal current (0.25 A for a 5 A relay and 0.05 A for a 1 A relay), the relay declares the circuit breaker open and asserts Relay Word bit 3PO.

TRIP

The Input **TRIP** provides an external input to operate the circuit breaker trip coil. Upon assertion of the input **TRIP**, Relay Word bit INTRIP asserts. When INTRIP asserts, all four **TRIP** output contacts close and remain closed until the breaker opens. Connect a local control switch or lock out relay to Input **TRIP**.

CLOSE

The Input **CLOSE** provides an external input to operate the circuit breaker close coil. Upon assertion of the Input **CLOSE**, Relay Word bit INCLOS asserts. When INCLOS asserts, all four **CLOSE** output contacts close and remain closed until the breaker closes, or for 60 cycles (close fail timer expires). Connect a local control switch or similar device to Input **CLOSE** to directly close the circuit breaker.

87 DIS

Energize Input **87 DIS** to disable 87L protection in the local and remote relays. Upon assertion of the Input **87 DIS**, Relay Word bit IN87DI asserts. Input **87 DIS** and Communications Bit R4X combine to set the application mode of the SEL-387L, as shown in *Table 3.2*.

Table 3.2 SEL-387L Application Modes

87 DIS	R4X	Application Mode Description
0	0	Two-relay application, with an SEL-387L at both ends of the line. (Refer to *Figure 1.6* and *Figure 1.8*.)
0	1	Leader/follower application. This disables line current differential protection in the follower (SEL-387L) relay, but maintains communications between the two relays. The leader relay (SEL-311L) receives data from the follower relay and performs differential protection. (See *Figure 1.7* and *Figure 1.9*.)
1	0, 1	This disables line current differential protection and all 87L communications circuits.

Figure 3.6 shows example settings in the SEL-311L to change the application mode of the SEL-387L from a two-relay application to leader/follower application. To change the mode, we must assert Relay Word bit R4X in the SEL-387L. In this example, we assign a 1 to bit T4X in the SEL-311L to permanently assert T4X. Transmit bit T4X in turn asserts Relay Word bit R4X in the SEL-387L, thereby changing the mode of application.

```
=>>SET L T4X TERSE <Enter>
Selogic Group 1

87L Transmit Bit Equations:
T4X   =0

     ? 1 <Enter>
T1Y   =0

     ? END <Enter>
Save Changes (Y/N)? Y <Enter>
```

Figure 3.6 Example Settings in the SEL-311L to Set the Application Mode of the SEL-387L to Follower

T1 and T2

Energize Input **T1** in the local relay to close Output **R1** in the remote relay. In the same manner, energize local Input **T2** to close remote Output **R2**. These two transfer contacts have security suitable for direct tripping and closing according to IEC-834-2. They exhibit less than one undesired operation per 100,000,000 noise bursts. Inputs **T1** and **T2** control Relay Word bits INT1 and INT2 in the local relay.

If the remote relay is an SEL-311L, then energizing **T1** in the SEL-387L (local relay) asserts Relay Word bit R1X or R1Y in the SEL-311L. Likewise, energizing **T2** in the SEL-387L (local relay) asserts Relay Word bit R2X or R2Y in the SEL-311L. See *Backup Protection on page 1.8* for an example.

Outputs

The top row of outputs on Terminals **A01**–**A16** consists of standard outputs, and the bottom row on Terminals **B01**–**B16** consists of fast hybrid outputs. With the exception of the alarm functions on the top row, the two rows of outputs

perform identical functions. The contacts in the bottom row are approximately 4 ms faster for control operations and 10 ms faster for protection trips. The bottom row contacts are rated to interrupt trip or close current.

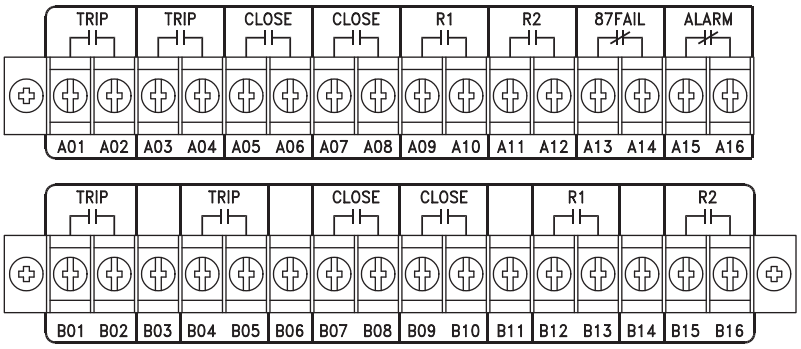


Figure 3.7 SEL-387L Outputs

TRIP

These output contacts close in response to any trip condition including current differential tripping, direct transfer tripping from the remote relay, the **TRIP** input, the **OPEN** command, Fast Operate commands, and front-panel **TRIP** command. All four output contacts remain closed until the circuit breaker opens. Relay Word bit TRIP controls all these output contacts, but the output contacts have individual names in various reports, as shown in *Table 3.3*.

Table 3.3 Terminal Number and TRIP Contact Name Correlation

Terminal Numbers	Contact Name	Relay Word Bit
A01, A02	TRIP	TRIP1
A03, A04	TRIP	TRIP2
B01, B02	TRIP	TRIP3
B04, B05	TRIP	TRIP4

CLOSE

These output contacts close in response to assertion of INCLOS, the **CLOSE** command, or the front-panel `CLOSE` command (see *CLOSE on page 3.7*). All four contacts remain closed for 60 cycles maximum or until the circuit breaker closes. Relay Word bit CLOSE controls these output contacts, but the output contacts have individual names in various reports, as shown in *Table 3.4*.

Table 3.4 Terminal Number and CLOSE Contact Name Correlation

Terminal Numbers	Contact Name	Relay Word Bit
A05, A06	CLOSE	CLOSE1
A07, A08	CLOSE	CLOSE2
B07, B08	CLOSE	CLOSE3
B09, B10	CLOSE	CLOSE4

R1 and R2

R1 and R2 respectively close when Inputs T1 and T2 are asserted in the remote relay. If the remote relay is an SEL-311L, then R1 in the local relay closes when T1X or T1Y asserts in the remote relay, depending on which channel is used in the remote relay. These two transfer contacts have security suitable for direct tripping and closing according to IEC-834-2. They exhibit less than one undesired operation per 100,000,000 noise bursts. These inputs control Relay Word bits INT1 and INT2 in the local relay. *Table 3.5* shows the individual contact names.

Table 3.5 Terminal Number and Transfer Contact Name Correlation

Terminal Numbers	Transfer Contact Name	Relay Word Bit
A09, A10	R1	R1_1
A11, A12	R2	R2_1
B12, B13	R1	R1_2
B15, B16	R2	R2_2

87FAIL (Relay Word Bit 87ALRM)

If the relay receives no valid packets for longer than two seconds, Relay Word bit RBADX asserts and causes Output Contact 87FAIL to close. Contact 87FAIL also closes if power is removed from the relay or if a relay self-test fails.

ALARM (Relay Word Bit ALARM)

This output closes when the relay detects a self-test error, or when the relay turns off. The output closes for one second when settings are saved and for any attempt to access Level 2.

Relay Word

Table 3.6 SEL-387L Relay Word Bits (Sheet 1 of 3)

Row	Relay Word Bits							
0	EN	TRP	L3PO	R3PO	T1	T2	ADRERR	TST
1	A	B	C	G	R1	R2	87DIS	87FAIL
2	*	*	*	*	*	*	*	*
3	*	*	*	*	*	*	*	*
4	*	*	*	*	*	*	*	*
5	LB1	LB2	*	*	*	*	*	*
6	*	*	*	*	*	*	*	*
7	RB1	RB2	*	*	*	*	*	*
8	*	*	*	*	*	*	*	*
9	LT1	LT2	*	*	*	*	*	*
10	*	*	*	*	*	*	*	*
11	*	*	*	*	*	*	*	*
12	*	*	*	*	*	*	*	*

Table 3.6 SEL-387L Relay Word Bits (Sheet 2 of 3)

Row	Relay Word Bits							
13	*	*	*	*	*	*	*	*
14	*	*	*	*	*	*	*	*
15	*	*	*	*	*	*	*	*
16	*	*	*	*	*	*	*	*
17	*	*	*	*	FIDEN	FSA	FSB	FSC
18	*	*	*	*	*	*	OC	CC
19	CLOSE	CF	TRGTR	52A	3PO	*	*	50L
20	*	*	*	TRIP	*	*	*	*
21	*	*	*	*	*	*	*	*
22	*	*	*	*	*	*	*	*
23	*	*	INT2	INT1	IN87DI	INCLOS	INTRIP	IN52A
24	ALARM	87ALRM	R2_1	R1_1	CLOSE2	CLOSE1	TRIP2	TRIP1
25	*	*	*	*	*	*	*	*
26	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*	*
30	*	*	*	*	*	*	*	*
31	*	*	*	*	*	*	*	*
32	*	*	*	*	*	*	TSOK	TIRIG
33	*	*	*	*	*	*	*	*
34	*	*	*	*	*	*	*	*
35	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*
42	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*
48	*	*	*	*	*	*	*	*
49	*	*	*	*	*	*	*	*
50	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*
52	*	*	*	*	*	*	*	*
53	*	*	*	*	*	*	87HWAL	87BSY

Table 3.6 SEL-387L Relay Word Bits (Sheet 3 of 3)

Row	Relay Word Bits							
54	*	*	*	*	*	*	*	*
55	*	*	*	*	*	*	*	*
56	*	*	*	*	*	*	*	*
57	*	*	*	*	*	*	*	*
58	TRIP3	TRIP4	CLOSE3	CLOSE4	R1_2	R2_2	87LPE	DD
59	FTABC	FTAG	FTBG	FTCG	FTAB	FTBC	FTCA	FTSE
60	87L	87LA	87LB	87LC	87L2	87LG	*	CHXAL
61	87LOPA	87LAE	R87LA	CTAA	*	TRIP87	*	*
62	87LOPB	87LBE	R87LB	CTAB	*	*	*	*
63	87LOPC	87LCE	R87LC	CTAC	*	*	*	*
64	87LOP2	87L2E	R87L2	B87L2	*	*	*	*
65	87LOPG	87LGE	R87LG	B87LG	*	*	*	*
66	*	*	*	*	RDTX	TDTX	TESTX	3POX
67	R4X	R3X	R2X	R1X	T4X	T3X	T2X	T1X
68	*	*	*	*	*	*	*	*
69	*	*	*	*	DBADX	AVAX	RBADX	ROKX
70	50LA	50RA	50LB	50RB	50LC	50RC	50L2	50R2
71	50LG	50RG	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 1 of 8)

Row	Bit	Definition	Primary Application
0	EN	Relay Enabled (see *Table 4.4*)	Target
	TRP	Relay Trip	
	L3PO	Local breaker is open	
	R3PO	Remote breaker is open	
	T1	Input T1 is asserted	
	T2	Input T2 is asserted	
	ADRERR	The local and remote channel address settings are not complimentary	
	TST	87L test mode is activated via the **TST** command	
1	A	A-phase is involved in the fault (see *Table 4.4*)	
	B	B-phase is involved in the fault	
	C	C-phase is involved in the fault	
	G	Ground involved in the fault	
	R1	Output R1 is closed	
	R2	Output R2 is closed	
	87DIS	87L protection in the local relay is disabled either because input 87DIS is asserted or because bit R3X is asserted (R3X is controlled by the remote relay)	
	87FAIL	87L communications channel problem	

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 2 of 8)

Row	Bit	Definition	Primary Application
2	*	Reserved for future use	
3	*	Reserved for future use	
4	*	Reserved for future use	
5	LB1	Local Bit 1 asserted	Local control via front panel—replacing traditional panel-mounted control switches
	LB2	Local Bit 2 asserted	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
6	*	Reserved for future use	
7	RB1	Remote Bit 1 asserted	Remote control via serial port
	RB2	Remote Bit 2 asserted	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
8	*	Reserved for future use	
9	LT1	Latch Bit 1 asserted	Latched control—replacing traditional latching relays
	LT2	Latch Bit 2 asserted	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
10	*	Reserved for future use	
11	*	Reserved for future use	
12	*	Reserved for future use	
13	*	Reserved for future use	
14	*	Reserved for future use	
15	*	Reserved for future use	
16	*	Reserved for future use	
17	*	Reserved for future use	

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 3 of 8)

Row	Bit	Definition	Primary Application
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	FIDEN	SEL-387L Main Board Fault Identification Logic Enabled. This Relay Word bit will not assert if FTSE is enabled.	Internal control
	FSA	A-phase to ground or B-C phases to ground fault identification logic output	
	FSB	B-phase to ground or A-C phases to ground fault identification logic output	
	FSC	C-phase to ground or A-B phases to ground fault identification logic output	
18	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	OC	Asserts 1/4 cycle for Open command execution	
	CC	Asserts 1/4 cycle for Close command execution	
19	CLOSE	Close logic output asserted	Output contact assignment
	CF	Close failure condition (asserts for 1/4 cycle)	Control
	TRGTR	Target Reset. TRGTR pulses to logical 1 for one processing interval when either the TARGET RESET pushbutton is pushed or the **TAR R** serial port command is executed	
	52A	Circuit breaker status (asserts to logical 1 when circuit breaker is closed)	
	3PO	Three pole open condition	
	*	Reserved for future use	
	*	Reserved for future use	
	50L	Phase instantaneous overcurrent element for closed circuit breaker detection (any phase current above pickup setting 50LP)	Indication
20	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	TRIP	Trip logic output asserted	Output contact assignment
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
21	*	Reserved for future use	
22	*	Reserved for future use	
23	*	Reserved for future use	
	*	Reserved for future use	

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 4 of 8)

Row	Bit	Definition	Primary Application
	INT2	Optoisolated input T2 asserted	Relay input status, Control via optoisolated inputs
	INT1	Optoisolated input T1 asserted	
	IN87DI	Optoisolated input 87DIS asserted	
	INCLOS	Optoisolated input CLOSE asserted	
	INTRIP	Optoisolated input TRIP asserted	
	IN52A	Optoisolated input 52A asserted	
24	ALARM	**ALARM** output contact indicating that relay failed or **PULSE ALARM** command executed	Relay output status, Control
	87ALARM	87ALARM output contact asserted	
	R2_1	R2 output (A11 and A12) contact asserted	
	R1_1	R1 output (A09 and A10) contact asserted	
	CLOSE2	CLOSE output (A07 and A08) contact asserted	
	CLOSE1	CLOSE output (A05 and A06) contact asserted	
	TRIP2	TRIP output (A03 and A04) contact asserted	
	TRIP1	TRIP output (A01 and A02) contact asserted	
25	*	Reserved for future use	
26	*	Reserved for future use	
27	*	Reserved for future use	
28	*	Reserved for future use	
29	*	Reserved for future use	
30	*	Reserved for future use	
31	*	Reserved for future use	
32	*	Reserved for future use	Indication
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	TSOK	High-accuracy time synchronization OK	
	TIRIG	Relay time is based on IRIG-B time source	
33	*	Reserved for future use	
34	*	Reserved for future use	
35	*	Reserved for future use	
36	*	Reserved for future use	
37	*	Reserved for future use	
38	*	Reserved for future use	
39	*	Reserved for future use	
40	*	Reserved for future use	
41	*	Reserved for future use	
42	*	Reserved for future use	
43	*	Reserved for future use	

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 5 of 8)

Row	Bit	Definition	Primary Application
44	*	Reserved for future use	
45	*	Reserved for future use	
46	*	Reserved for future use	
47	*	Reserved for future use	
48	*	Reserved for future use	
49	*	Reserved for future use	
50	*	Reserved for future use	
51	*	Reserved for future use	
52	*	Reserved for future use	
53	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	87HWAL	Differential board self-test alarm	Testing
	87BSY	Differential board self-test alarm	
54	*	Reserved for future use	
55	*	Reserved for future use	
56	*	Reserved for future use	
57	*	Reserved for future use	
58	TRIP3	TRIP output (B01 and B02) contact asserted	
	TRIP4	TRIP output (B04 and B05) contact asserted	
	CLOSE3	CLOSE output (B07 and B08) contact asserted	
	CLOSE4	CLOSE output (B09 and B10) contact asserted	
	R1_2	R1 output (B12 and B13) contact asserted	
	R2_2	R2 output (B15 and B16) contact asserted	
	87LPE	Enable phase differential calculation	
	DD	Disturbance detector	
59	FTABC	ABC fault type declaration	
	FTAG	AG fault type declaration	
	FTBG	BG fault type declaration	
	FTCG	CG fault type declaration	
	FTAB	AB fault type declaration	
	FTBC	BC fault type declaration	
	FTCA	CA fault type declaration	
	FTSE	Fault Type selection logic enabled	
60	87L	ORed combination of 87LA, 87LB, 87LC, 87L2, and 87LG	Testing, Control
	87LA	A-phase differential trip output	
	87LB	B-phase differential trip output	

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 6 of 8)

Row	Bit	Definition	Primary Application
	87LC	C-phase differential trip output	
	87L2	Negative-sequence differential trip output	
	87LG	Zero-sequence differential trip output	
	*	Reserved for future use	Alarming
	CHXAL	Status of Channel X	
61	87LOPA	A-phase differential current enable level detector	Testing, Control
	87LAE	A-phase differential calculation enable	
	R87LA	A-phase restraint region detection output	
	CTAA	A-phase CT alarm level detector	Alarming
	*	Reserved for future use	
	TRIP87	Line current differential trip logic output asserted	Tripping
	*	Reserved for future use	
	*	Reserved for future use	
62	87LOPB	B-phase differential current enable level detector	Testing, Control
	87LBE	B-phase differential calculation enable	
	R87LB	B-phase restraint region detection output	
	CTAB	B-phase CT alarm level detector	Alarming
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
63	87LOPC	C-phase differential current enable level detector	Testing, Control
	87LCE	C-phase differential calculation enable	
	R87LC	C-phase restraint region detection output	
	CTAC	C-phase CT alarm level detector	Alarming
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
64	87LOP2	Negative-sequence current enable level detector	Testing, Control
	87L2E	Negative-sequence differential calculation enable	
	R87L2	Negative-sequence restraint region detection output	
	B87L2	Extended 87L2 block	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
65	87LOPG	Zero-sequence current enable level detector	Testing, Control
	87LGE	Zero-sequence differential calculation enable	
	R87LG	Zero-sequence restraint region detection output	

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 7 of 8)

Row	Bit	Definition	Primary Application
	B87LG	Extended 87LG block	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
66	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	RDTX	Differential Channel X receive direct trip	Tripping
	TDTX	Differential Channel X transmit direct trip	
	TESTX	Differential Channel X in test mode	Testing
	3POX	Differential Channel X receive three pole open	
67	R4X	Received Channel X bit 4	Control
	R3X	Received Channel X bit 3	
	R2X	Received Channel X bit 2	
	R1X	Received Channel X bit 1	
	T4X	Transmitted Channel X bit 4	
	T3X	Transmitted Channel X bit 3	
	T2X	Transmitted Channel X bit 2	
	T1X	Transmitted Channel X bit 1	
68	*	Reserved for future use	
69	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	DBADX	One-way delay on Channel X exceeds 10 ms	Alarming, Testing
	AVAX	Channel X unavailability exceeds 10 packets lost in last 10,000	
	RBADX	Channel X dropout exceeds one second	
	ROKX	Channel X instantaneous receive status	
70	50LA	Local A-phase overcurrent element output	Testing
	50RA	Remote A-phase overcurrent element output	
	50LB	Local B-phase overcurrent element output	
	50RB	Remote B-phase overcurrent element output	
	50LC	Local C-phase overcurrent element output	
	50RC	Remote C-phase overcurrent element output	
	50L2	Local 3I2 overcurrent element output	
	50R2	Remote 3I2 overcurrent element output	

Table 3.7 Relay Word Bit Definitions for the SEL-387L (Sheet 8 of 8)

Row	Bit	Definition	Primary Application
71	50LG	Local 3I0 overcurrent element output	
	50RG	Remote 3I0 overcurrent element output	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
	*	Reserved for future use	
72	*	Reserved for future use	
73	*	Reserved for future use	

This page intentionally left blank

Section 4
User Interface

Overview

The relay user interface includes metering, current differential channel communication, configuration and monitoring, serial port commands, and front-panel commands.

Instantaneous Metering

The relay provides accurate metering of the following:

- Local and remote phase currents (magnitude and angle): IA, IB, IC
- Local and remote sequence currents (magnitude and angle): I1, 3I2, 3I0
- Power system frequency
- DC battery voltage (between 20–300 Vdc)

Reported metering data depends on the relay application and the status of the communications channel at the time of measurement, as shown in *Table 4.1*.

Table 4.1 Reported Data for Different Data Availability

Case	Values Displayed
Relays are communicating properly	Local, Remote, Vector Sum, and Alpha Plane values, referenced to local positive-sequence current, I1
Leader/follower application	Local and Remote values only, referenced to local positive-sequence current, I1. (Vector Sum and Alpha Plane values are hidden.)
No 87 communication	Local currents only

Figure 4.1 shows the instantaneous metering quantities in the SEL-387L Relay for the case where the relays are communicating properly.

```
=>MET <Enter>

FEEDER 2                          Date: 2003/12/17    Time: 08:33:28.587
PALOUSE

Local              A         B         C        3I0       3I2       I1
I MAG (A Sec)    1.089     1.092     1.090      0.005     0.004     1.091
I ANG (DEG)      -0.20   -120.00    120.10    -127.40    -80.90      0.00

Remote             A         B         C        3I0       3I2       I1
I MAG (A Sec)    1.090     1.086     1.093      0.003     0.013     1.090
I ANG (DEG)     179.60     59.90    -59.80     21.90    118.50    180.00

Vector Sum         A         B         C        3I0       3I2       I1
I MAG (A Sec)    0.004     0.006     0.003      0.003     0.009     0.001
I ANG (DEG)     100.80   -102.30    -20.30    -97.80    125.60      0.00

Alpha Plane        A         B         C        3I0       3I2       I1
RADIUS           1.000     0.990     1.000      0.000     0.000     1.000
ANG (DEG)       179.90    180.00    179.90       0.00      0.00    179.90

FREQ (Hz)      59.98               VDC (V)       125.2

=>
```

Figure 4.1 Instantaneous Metering (Local and Remote)

`Local` current values in *Figure 4.1* are the current values measured from the CTs at the local relay. `Remote` current values are the current values measured at the remote relay, received by the local relay via the communications channel. `Vector Sum` is the vector sum of the total current entering the protected line. `Alpha Plane` measurements report the ratio of the remote to the local currents.

Serial Port Communications and Commands

NOTE: If the relay is ordered with DNP3, the port settings are available, in which case *Table 4.2* shows the default values.

Serial port commands allow you to configure, interrogate, and control the relay. The command structure is arranged in four access levels (1, B, 2, and C), each level protected by a separate password. In Level B, the user has access to all Level 1 commands, plus commands to control the circuit breaker and relay. In Level 2, the user has access to Level 1 and Level B commands, plus commands to change settings. In Level C, the user has access to all commands. Use Level C only under direction of the SEL factory or to change the default CAL level password. *Table 4.2* shows the fixed settings for each port.

A list of commands available from the CAL level is available from SEL upon request.

Table 4.2 Fixed Settings for Each Serial Port

Port F, 1	Port 2	Port 3
Baud Rate = 9600	Baud Rate = 19200	Baud Rate = 19200
Data Bits = 8	Data Bits = 8	Data Bits = 8
Parity = N	Parity = N	Parity = N
Stop Bits = 1	Stop Bits = 1	Stop Bits = 1
DTA = N	DTA = N	DTA = N
T_OUT = 15	T_OUT = 15	T_OUT = 15
AUTO = N	AUTO = N	AUTO = N
RTSCTS = N (Port F only)	RTSCTS = N	RTSCTS = N
FASTOP = N	FASTOP = Y	FASTOP = N

To change port settings, use the **SET P** command or the front-panel **SET** pushbutton. The **SET P** command is only available in relays ordered with the DNP protocol. For a summary of all the serial port ASCII commands that the SEL-387L supports, see the *SEL-387L Relay Command Summary* at the end of this section.

Front-Panel Operation

Pushbuttons

Figure 4.2 shows the front-panel pushbuttons. Most of these pushbuttons have dual functions (primary/secondary). Labels on the top row, **METER** and **EVENTS**, for example, indicate the primary functions for these pushbuttons. Labels on the bottom row, **CANCEL** and **SELECT**, for example, indicate the secondary functions (see *Table 4.3* for a summary of pushbutton functions). Pushing any pushbutton for the first time selects a primary function, **METER**, for example. After you select a primary function, all pushbuttons operate on their secondary functions. For example, after you press the **METER** pushbutton, the pushbuttons with the primary functions **SET** and **CNTRL** now operate on the secondary functions of up/down arrows to scroll through the front-panel metering screens.

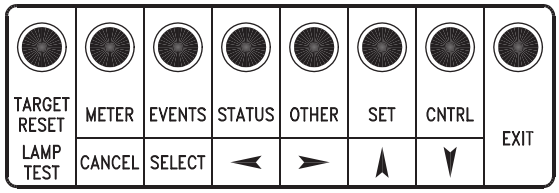


Figure 4.2 Front-Panel Pushbuttons, Showing Secondary and Primary Functions

If you press the **EXIT** pushbutton while operating on the secondary functions, the relay leaves the secondary level and activates primary functions of the pushbuttons. If there is no front-panel activity for 15 minutes, the pushbuttons revert to their primary functions, and the LCD display shows the default values. Some front-panel commands are password protected. To enter Access Level B and Access Level 2 passwords from the front panel (if required), use the **left/right** arrow pushbuttons to underscore a password digit position. Then use the **up/down** arrow pushbutton to change the digit. After selecting the correct Access Level B or Access Level 2 password, press the **SELECT** pushbutton. *Table 4.3* describes the functions of the front-panel pushbuttons from left to right.

Table 4.3 Functions of the Front-Panel Pushbuttons

Pushbutton	Description
TARGET RESET	Resets latched targets and illuminates all LEDs (except the enable LED) for approximately one second.
METER	Displays either differential values or instantaneous values (INST). Differential values include: local phase currents (IAL, IBL, and ICL) local zero-sequence current (3I0L) local negative-sequence current (3I2L) local positive-sequence current (I1L) remote values (IAX, IBX, and ICX; 3I0X, 3I2X, and I1X), total current (ΣIA, ΣIB, ΣIC, Σ3I0, Σ3I2, ΣI1), and alpha-plane ratios (αIA, αIB, αIC, α3I0, α3I2, αI1) Instantaneous values (INST) include: local phase currents (IA, IB, and IC) local ground current (IG) local positive- (I1), negative- (3I2), and zero-sequence (3I0) current local frequency (FRQ) and battery voltage (VDC)
EVENTS	Displays data from the event summary including event number, date, time, event type, difference currents (87IA, 87IB, 87IC, 87IG , and 873I2), local currents (IA, IB, IC, IG, and 3I2), frequency (FREQ), and targets (A, B, C, G).
STATUS	Displays internal temperature and the results of several self-tests.
OTHER	Allows setting of time and date; access to the **TAR** command and to the LCD SCROLL LOCK.
SET	Allows access to the **SET** menu, from which you can set or show relay addressing (TA_X, and RA_X), passwords settings, or port settings. The **PORT** menu is displayed only if DNP was ordered.
CNTRL	See *Local Control on page 4.5*.
EXIT	If you are operating in secondary functions, and press the EXIT pushbutton, you will leave the secondary function level and activate primary functions.

Target LEDs

Table 4.4 Target LEDs (Sheet 1 of 2)

LED Label	Definition
EN	Relay Enabled
TRIP	Indication that a trip occurred
52 OPEN LOC	Local breaker is open
52 OPEN REM	Remote breaker is open
T1	Input T1 is asserted
T2	Input T2 is asserted
ADDR ERR	The local and remote channel address settings are not complimentary
TEST	87L test mode is activated via the TST command
A	A-phase involved in the fault
B	B-phase involved in the fault
C	C-phase involved in the fault
G	Ground involved in the fault
R1	Output R1 is closed
R2	Output R2 is closed

Table 4.4 Target LEDs (Sheet 2 of 2)

LED Label	Definition
87DIS	87L protection in the local relay is disabled either because input 87DIS is asserted or because bit R3X is asserted (R3X is controlled by the remote relay).
87CH FAIL	87L communications channel problem

Alphanumeric Display

The alphanumeric display contains several rotating screens that show relay information. Displayed information includes the following:

- local and remote current values
- breaker status
- communications channel status
- indication when the relay is in follower mode

The local relay displays remote currents only if properly communicating with another SEL-387L or an SEL-311L. If the relays are not properly communicating, the relay displays local currents only. When current values exceed 10 A, the display automatically adjusts the decimal point from two decimal values to one decimal value. Both local and remote current values are in secondary amperes. *Figure 4.3* shows three default screens.

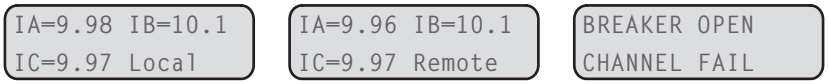


Figure 4.3 Three Different LCD Screens Showing Local and Remote Current Values and Breaker and Channel Status

Local Control

The next screen prompts you to press the **CNTRL** pushbutton to activate local control functions.

Figure 4.4 SEL-387L LCD Showing the CNTRL Pushbutton Prompt

Use Local Control to trip or close the circuit breaker(s). Use the MANUAL TRIP function to assert Relay Word bit TRIP. In turn, Relay Word bit TRIP asserts the four output contacts **TRIP1**, **TRIP2**, **TRIP3**, and **TRIP4**. Because the MANUAL TRIP function asserts Relay Word bit TRIP, the trip outputs all latch. If the circuit breaker opens correctly, the output contacts reset nine cycles later. Otherwise, use the **TARGET RESET** pushbutton to unlatch the output contacts. *Figure 4.5* shows the sequence for using the MANUAL TRIP command after pressing the **CNTRL** pushbutton.

Figure 4.5 Sequence to Trip the Circuit Breaker With the Front-Panel MANUAL TRIP Command

Use the MANUAL CLOSE function to assert Relay Word bit CLOSE. In turn, Relay Word bit CLOSE asserts the four output contacts **CLOSE1**, **CLOSE2**, **CLOSE3**, and **CLOSE4** for no longer than one second. After pressing the **CNTRL**

pushbutton, the first display shown in *Figure 4.6* appears. Press the right arrow ➤ and follow the actions depicted in *Figure 4.6* to close the circuit breaker with the CLOSE command.

Figure 4.6 Sequence to Close the Circuit Breaker With the Front-Panel MANUAL CLOSE Command

The next screen (*Figure 4.7*) shows the breaker status and the 87L communications channel if the channel is in a trouble state.

Figure 4.7 Breaker Status and Channel Status Indication

The following screen (*Figure 4.8*) appears when the relay is in the follower mode or when Input **87 DIS** asserts. When Input **87 DIS** asserts, the SEL-387L disables differential protection and displays 87L BLOCKED on the LCD.

Figure 4.8 Mode of Operation Indication

The final screen (*Figure 4.9*) indicates whether the supervisory control is enabled or disabled. (See *Figure 3.2* for supervisory control description.)

Figure 4.9 Supervisory Control Indication

Event Reports

An event shows selected data of the power system at a specific time. Events include instances such as a relay trip, an abnormal situation in the power system that triggers a relay element, or an event capture command.

Information from relay event reports and SER data is very valuable if you are responsible for outage analysis, outage management, or relay settings coordination.

The SEL-387L stores at least 40 standard 15-cycle event reports in nonvolatile memory. If more than 40 reports are triggered, the latest event report overwrites the oldest event report. The relay triggers (generates) a standard event report when any of the following occur:

- The relay issues a trip output (see *Figure 3.2* for more information)
- The relay issues a close output (see *Figure 3.4* for more information)

- **TRI** (Trigger Event Reports) serial port command executes
- Output contacts pulse via the serial port **PUL** command or front-panel PUL (Pulse output contact) command

Event Report Formations

The SEL-387L provides you the ability to select specific information from a number of different event report formats. Use one of the following commands to specify format:

- **HISTORY** (**HIS <Enter>**)
- **SUMMARY** (**SUM <Enter>**)
- **EVENT** (**EVE <Enter>**)
- **Compressed EVENT** (**CEV <Enter>**)

HISTORY Command

Enter the **HISTORY** command to see a list of as many as 40 previous events in reverse chronological order. *Figure 4.10* shows the relay response to the **HIS** command. The report shows the relay name (FEEDER 2) and terminal name (PALOUSE), the date (2003/12/22) and time (14:66:36.618) when the **HIS** command was entered, the event number (#), date and time of the event, event type (see *Table 4.7*), maximum current of the event currents, frequency, and the targets that asserted during the fault. The EVENT field includes a T if Relay Word bit TRIP asserted.

```
=>>HIS <Enter>

FEEDER 2                          Date: 2003/12/22    Time: 14:66:36.618
PALOUSE

#     DATE       TIME         EVENT   CURR  FREQ  TARGETS
1     2003/12/22 13:56:06.257 BG T    10.98 60.00 B G
2     2003/12/22 13:40:13.398 ABG T    1.00 60.00 A B G
3     2003/12/22 13:39:55.745 TRIG     1.00 60.00

=>>
```

Figure 4.10 Relay Response to the HIS Command

SUMMARY Command

For more event report detail, use the **SUMMARY** (**SUM <Enter>**) command, as shown in *Figure 4.11*. In addition to information available from the history report, the summary report shows remote current values during the fault and local prefault current values. Prefault current magnitudes and phase angles are selected from the first cycle of the event report. Fault data are sampled one and one-quarter cycles after the event report is triggered. Communications channel status and the status of the six communications bits (Received Bits R1–R4 and Transmit Bits T1 and T2) also appear in this report. If, for example, Communications Bit T1 had been asserted, the report would indicate T1:1. Close time appears when the relay issues a close output. Each time an event is triggered, the relay sends the summary report to all serial ports that have AUTO = Y. (Port settings become available only with the DNP ordering option. Without DNP, all ports have automessaging turned off. See *Table 4.2* for more information.)

```
=>>SUM <Enter>

FEEDER 2                          Date: 2003/12/22    Time: 17:29:30.830
PALOUSE

Event: AG T                                    Trip Time: 17:29:30.830
#: 00008  Freq:  59.99                        Close Time: --:--:--.---
Targets: A G

                    Local                          Remote
PreFault:     IA     IB     IC    3I2       IA     IB     IC    3I2
MAG(A sec)    1.74   1.73   1.73   0.01   1.74   1.74   1.74   0.01
ANG(DEG)    173.3   53.6  -66.4   94.0   -6.6 -126.5  113.8  -78.0
Fault:
MAG(A sec)    1.73   1.74   1.74   0.01   1.74   1.74   1.74   3.46
ANG(DEG)    173.1   53.4  -66.6   56.0  173.4 -126.6  113.5  173.0

87L Channel Status: OK          R1:0 R2:0 R3:0 R4:0    T1:0 T2:0

                           Local
PreFault:     IA     IB     IC     IG    3I2
MAG(A sec)    1.69   1.70   1.70   0.00   0.00
ANG(DEG)      0.00-119.95 120.08-168.56-168.56
Fault:
MAG(A sec)    1.69   1.70   1.69   0.01   0.01
ANG(DEG)     -0.17-120.03 119.97-105.13-105.13

=>>
```

Figure 4.11 Relay Response to the SUM Command

EVENT Command

NOTE: Raw event reports display one extra cycle of data at the beginning of the report. Each report contains four cycles of data that precede the event report triggering point. The event report consists of three sections (analog section, digital section, and event summary) followed by relay identification and addresses.

Use the **EVE** command to retrieve line current differential reports. See the *SEL-387L Relay Command Summary* at the end of this section for complete command format).

Analog Section of the Event Report

Because the user can retrieve analog and digital information separately from the relay, the event report format contains analog and digital information in two separate sections. *Figure 4.12* shows the format for the analog section of the 1/4-cycle event report (the 1/16-cycle report is similar). If no data are available from the channel, then the `Local`, `Remote`, and `Total` currents display `***.**` (first two rows of cycle [2] in *Figure 4.12*). When the relay is in follower mode, 87L protection is disabled and the relay cannot calculate total current. In this case, the `Total` current displays `***.**` (last two rows of cycle [2] in *Figure 4.12*).

```
FEEDER 2                          Date: 2004/04/12              Time: 08:54:29.577
PALOUSE

FID=SEL-387L-R100-V0-Z001001-D20040412                    CID=F0FF

             Terminal and Total Currents (Amps Sec)
          Local                   Remote                  Total          Freq Vdc
    IA      IB      IC      IA      IB      IC      IA      IB      IC
[1]
  -3.12  -17.23   18.45   -3.56  -17.78   18.89   -3.90  -17.01   18.12 59.9 124
  16.12  -10.23   -0.45   16.56  -10.67   -0.78   16.89  -10.90   -0.01 59.9 124
   1.12   18.23  -19.34    1.45   18.56  -19.67    1.78   18.89  -19.90 59.9 124
 -17.12   18.23    0.34  -17.45   18.56    9.67  -17.78   18.89    9.90 59.9 123
[2]
 ***.**  ***.**  ***.**  ***.**  ***.**  ***.**  ***.**  ***.**  ***.** 59.9 124
 ***.**  ***.**  ***.**  ***.**  ***.**  ***.**  ***.**  ***.**  ***.** 59.9 123
   1.12   18.23  -19.34    1.45   18.56  -19.67  ***.**  ***.**  ***.** 59.9 122
 -17.12   18.23    0.34  -17.45   18.56    9.67  ***.**  ***.**  ***.** 59.9 124
[3]
```

Figure 4.12 Format for the Analog Section of the Event Report With [1], [2], and [3] Indicating Cycle Numbers in the Event Report

Table 4.5 lists and defines the headings of the analog section of the event report.

Table 4.5 Standard Event Report Definitions

Heading	Definition
Local IA	Local A-phase current (measured at local terminal)
Local IB	Local B-phase current (measured at local terminal)
Local IC	Local C-phase current (measured at local terminal)
Remote IA	Remote A-phase current (received from remote terminal)
Remote IB	Remote B-phase current (received from remote terminal)
Remote IC	Remote C-phase current (received from remote terminal)
Total IA	Total A-phase current (sum of local and remote currents)
Total IB	Total B-phase current (sum of local and remote currents)
Total IC	Total C-phase current (sum of local and remote currents)
Freq	Power system frequency
Vdc	Battery voltage

Digital Section of the Event Report

Figure 4.13 shows the format for the digital section of the event report. *Table 4.6* shows the 87L protection event report Relay Word bit definitions.

```
87L Protection and Contact I/O Elements

            BB                              T  Outputs          8  Inputs
87L    Rstr  88 R    RT   R 3   RB LB LT R  TRIP CLOSE R1 R2 7  5  D
             77      DD D O P O          8T                   AA 2CTITT
ABCG2L ABCG2 G2 1234 TT D K O C 12 12 12 7R 1234 1234  12 12 LL ALRS12
[1]
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
[2]
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
...... ..... .. .... .. . . . . .. .. .. .. .... ....  .. .. .. ......
```

Figure 4.13 Format for the Digital Section of the Event Report With [1] and [2] Indicating the Cycle Number in the Event Report

Table 4.6 87L Protection Event Report Relay Word Bit Definitions
(Sheet 1 of 2)

Relay Word Bit	Symbol	Definition
87LA, 87LB, 87LC, 87LG, 87L2, 87LL	*	87LA, 87LB, 87LC, 87LG, 87L2, 87L asserted
Rstr A, Rstr B, Rstr C, Rstr G, Rstr 2	*	R87LA, R87LB, R87LC, R87LG, R87L2 asserted
B87G, B872	*	B87LG, B87L2 asserted
R1, R2, R3, R4	X	Receive bit 1, 2, 3, or 4 on channel X asserted
RDT, TDT, DD, ROKX, 3PO	*	RDTX, TDTX, DD, ROKX, 3PO asserted
OC	o	OC asserted (**OPEN** command)
CC	c	CC asserted (**CLOSE** command)

Table 4.6 87L Protection Event Report Relay Word Bit Definitions (Sheet 2 of 2)

Relay Word Bit	Symbol	Definition
RB1, RB2	*	Remote bit RB1 or RB2 asserted (supervisory control)
LB1, LB2	*	Local bit LB1 or LB2 asserted (local control)
LT1, LT2	*	Latch bit LT1 or LT2 asserted (supervisory control)
TR87	*	TRIP87 asserted
TR	*	TRIP asserted
TRIP1, TRIP2, TRIP3, TRIP4	*	Output **TRIP1**, **TRIP2**, **TRIP3**, **TRIP4** asserted
CLOSE1, CLOSE2, CLOSE3, CLOSE4	*	Output **CLOSE1**, **CLOSE2**, **CLOSE3**, **CLOSE4** asserted
R1_1, R1_2	*	R1_1, R1_2 asserted
R2_1, R2_2	*	R2_1, R2_2 asserted
87AL, AL	*	**87ALRM**, **ALARM** asserted
52A, CL, TR, DIS, T1, T2	*	Input **52A**, **CLOSE**, **TRIP**, **87 DIS**, **T1**, **T2** asserted

Event Summary Section of the Event Report

Figure 4.14 depicts the event summary section of the event report and shows event type, targets, and the relay currents. Each time the relay generates a standard event report, it also sends a corresponding event summary (*Figure 4.14*) to all serial ports with port setting of AUTO = Y. (Port settings become available only with the DNP ordering option.) The summary in *Figure 4.14* shows the event, targets, and the A-phase, B-phase, C-phase, zero-sequence, and negative-sequence (Q) currents recorded at the local relay.

```
Event: BG T  Frequency:  60.00
Targets: B G
Currents (A Sec), ABCGQ:    1.00  10.98   1.00   9.98   9.98
```

Figure 4.14 Format for the Event Summary Section of the Event Report

Event Type. The Event field shows the event type. *Table 4.7* shows the possible event types and corresponding descriptions.

Table 4.7 Event Types and Corresponding Descriptions

Event	Type	Description
AG, BC, ABC, etc.	Shows phase involvement	Appends T if TRIP asserted
TRIG	Execution of **TRIGGER** command	
PULSE	Execution of **PULSE** command	
TRIP, TRIP87	Assertion of Relay Word bit TRIP or Relay Word bit TRIP87	Relay could not determine phase involvement, so just TRIP or TRIP87 is displayed
CLOSE	Assertion of Relay Word bit CLOSE	

Clearing Standard Event Report Buffer

The **HIS C** command clears the event summaries and corresponding standard event reports from nonvolatile memory.

Compressed ASCII Event Reports

The SEL-387L provides Compressed ASCII event reports to facilitate event report storage and display. The compressed report contains more information than the regular report, and is in a format that directly imports into spreadsheet or database programs and is validated with a checksum. Use the **CEV** (15 cycles, 4 samples per cycle, Compressed ASCII format) command or the **CEV L** (15 cycles, 16 samples per cycle, Compressed ASCII format) command to display Compressed ASCII event reports. The SEL-2032, the SEL-2030, or the SEL-2020 Communications Processor and the SEL-5601-2 SYNCHROWAVE® Event Software take advantage of the Compressed ASCII format.

Sequential Events Recorder (SER) Report

In addition to the event reports, the SEL-387L also provides Sequential Events Recorder (SER) reports. The relay adds date- and time-stamped lines in the Sequential Events Recorder report for a change of state of predefined conditions. The relay stores the latest 512 lines of the SER report in nonvolatile memory. If the report exceeds 512 lines, newer rows overwrite the oldest rows in the report.

SER Triggering

The relay triggers (generates) an entry in the SER report for a change of state of any of the following elements:

IN52A, INTRIP, INCLOS, IN87DI, INT1, INT2, TRIP1, TRIP2, CLOSE1, CLOSE2, R1_1, R2_1, 87ALRM, TRIP, CLOSE, DBADX, TRIP3, TRIP4, CLOSE3, CLOSE4, R1_2, R2_2, 87LA, 87LB, 87LC, 87L2, 87LG, TRIP87, OC, CC, CF, R1X, R2X, R3X, R4X, RB1, RB2, LB1, LB2, LT1, LT2, TSOK, TIRIG

If an element changes state, the relay time-tags the changes in the SER. The relay adds a message to the SER to indicate the relay turned on or settings change conditions: `Relay newly powered up` or `Relay settings changed`. Each entry in the SER includes SER row number, date, time, element name, and element state.

Retrieving SER Reports

The relay saves the latest 512 rows of the SER in nonvolatile memory. Row 1 is the most recently triggered row, and Row 512 is the oldest. View the SER report by date or SER row number as outlined in the *SEL-387L Relay Command Summary*. *Figure 4.15* shows an example of an SER report.

```
FEEDER 2                          Date: 2004/04/12              Time: 08:54:29.577
PALOUSE

FID=SEL-387L-R100-V0-Z001001-D20040412                    CID=F0FF

#     DATE        TIME           ELEMENT           STATE

5     2003/12/23  13:28:13.921   IN52A           Asserted
4     2003/12/23  13:28:15.213   IN52A           Deasserted
3     2003/12/23  13:28:19.287   INTRIP          Asserted
2     2003/12/23  13:28:19.287   TRIP            Asserted
1     2003/12/23  13:28:20.304   INTRIP          Deasserted

=>>
```

Figure 4.15 Example SER Report

SEL-387L Relay Command Summary

Command	Access Level	Description
2AC	1	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 2 password in order to enter Access Level 2. The prompt is: =>>.
ACC	0	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 1 password to enter Access Level 1. The Access Level 1 commands primarily allow the user to look at information (e.g., metering), not change it. The prompt is: =>.
BAC	1	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts for entry of the Access Level B password. The prompt is: ==>.
CAL	2	Go to Access Level C. Should only be used under direction of SEL factory or to change the default password.
CAS	0	Compressed ASCII configuration data.
CEV [*n* S*x* L*y* L R C]	1	Compressed event report (parameters in [ ] are optional)
where: ***n***		event number (1–40, defaults to 1).
S*x*		*x* samples per cycle (4 or 16); defaults to 4. If S*x* parameter is present, it overrides the L parameter.
L*y*		*y* cycles event report length (1–15), defaults to 15 if not specified, unfiltered reports are one cycle longer.
L		16 samples per cycle; overridden by the S*x* parameter, if present.
R		specifies raw (unfiltered) data; defaults to 16 samples per cycle unless overridden by the S*x* parameter. Defaults to 16 cycles in length unless overridden with the L*y* parameter.
C		specifies 16 samples per cycle, 15-cycle length.
CHIS	1	Compressed history.
CLO	B	Assert Relay Word bits CLOSE1–CLOSE4.
COM	1	Show a communications summary report.
COM C	1	Clear the communications summary report.
COM L	1	Show a communications summary report and history of up to 256 entries.
COM L *d1*	1	Show a communications summary report for events occurring on date *d1*.
COM L *d1 d2*	1	Show a communications summary report for events occurring between dates *d1* and *d2*. Date Format is YY/MM/DD or YYYY/MM/DD.
COM L *m n*	1	Show a communications summary report for events *n*–*m*.
COM L *n*	1	Show a communications summary for latest *n* events.
COM X	2	Show a communication log summary for Channel X.
COM X C	2	Clear a communication log summary for Channel X.

Command	Access Level	Description

CON *n*	2	Control Remote bit RB*n* (Remote Bit *n*; *n* = 1 or 2). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following:
		SRB *n* set Remote Bit *n* (assert RB*n*).
		CRB *n* clear Remote Bit *n* (deassert RB*n*).
		PRB *n* pulse Remote Bit *n* (assert RB*n* for 1/4 cycle). To enable supervisory control, pulse RB1. To disable supervisory control, pulse RB2.
		For example, to assert Remote Bit 1 (which enables supervisory control), type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01; SRB 1 <Enter>`
		To deassert Remote Bit 1, type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01: CRB 1 <Enter>`
		To pulse Remote Bit 1, type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01: PRB 1 <Enter>`

CST	1	Compressed status report.
CSU	1	Compressed event summary.
DAT	1	Set/show relay date.
DAT y/m/d	1	Set the date.
DNP	1	Set/show DNP map (available only with DNP option; refer to *Appendix B: Distributed Network Protocol* for DNP point mapping).
EVE *n*	1	Show event report number *n* with 1/4-cycle resolution.
EVE A	1	Specify that only the analog section of the event is displayed.
EVE *n* C	1	Show event report *n* in Compressed ASCII format for use with SEL-5601-2 SYNCHROWAVE® Event Software.
EVE C/CEV	1	Display the report in Compressed ASCII format.
EVE D	1	Specify that only the digital section of the event is displayed.
EVE L *n*	1	Show event report number *n* with 1/16-cycle resolution.
EVE R	1	Specify the unfiltered (raw) event report. Defaults to 16 samples per cycle unless overridden with the S*x* parameter.
EVE R *n*	1	Show raw event report number *n* with 1/16-cycle resolution.
EVE S*x*	1	Display *x* samples per cycle (4 or 16); defaults to 4 if not listed.
HIS *n*	1	Show brief summary of the *n* latest event reports.
HIS C	1	Clear the brief summary and corresponding event reports.
IRI	1	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
L_D	2	Load new firmware.
MET *k*	1	Display instantaneous metering data (currents and alpha plane) for local and remote terminals. Enter *k* for repeat count.
OPE	B	Assert Relay Word bits TRIP1–TRIP4 (Close TRIP outputs, see *Figure 3.2*).
PAS 1	2	Change Access Level 1 password (default password: OTTER).
PAS 2	2	Change Access Level 2 password (default password: TAIL).
PAS B	2	Change Access Level B password (default password: EDITH).

Command	Access Level	Description
PAS C	C	Change Access Level C password (default password: CLARKE).
PUL *n k*	B	Pulse Output Contact *n* for *k* (1–30) seconds. Parameter *n* must be specified; *k* defaults to 1 if not specified. Valid options are TRIP1–TRIP4 and CLOSE1–CLOSE4.
QUI	1	Quit. Returns to Access Level 0. Terminates SEL Distributed Port Switch Protocol (LMD) connection (available in all access levels).
SER *d1*	1	Show rows in the Sequential Events Recorder (SER) event report from date *d1*.
SER *d1 d2*	1	Show rows in the Sequential Events Recorder (SER) event report from date *d1* to date *d2*. Uses the date format of year, month, day (YMD).
SER *n*	1	Show the latest *n* rows in the Sequential Events Recorder (SER) event report.
SER *m n*	1	Show rows *m* through *n* in the Sequential Events Recorder (SER) event report.
SER C	1	Clear the Sequential Events Recorder (SER).
SET	2	Change Relay Identification, Terminal Identification, and relay communication addresses.
SET P *n*	2	Change Port *n* settings (available only with DNP option).
SHO	1	Show Relay Identification, Terminal Identification, and relay communication addresses.
SHO P *n*	1	Show Port *n* settings (*n* = F, 1, 2, 3) (available only with DNP option).
STA	1	Show relay self-test status.
STA C	2	Reset self-test warnings/failures and reboots relay.
SUM	1	Show newest event summary.
SUM A	1	Acknowledge oldest event summary.
SUM A N	1	Display or acknowledge event summary number “N.”
SUM N	1	View oldest unacknowledged event report.
TAR *n k*	1	Display Relay Word row. If *n* = 0–73, display row *n*. If *n* is an element name (e.g., 87LA) display the row containing element *n*. Enter *k* for repeat count.
TAR R	1	Reset the front-panel tripping targets.
TIM	1	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 *[time]*	1	Trigger an event report. Enter time to trigger an event at an exact specified time, in 24-hour format.
TST X	2	Test the differential communication channel.
VER	1	Display version and configuration information.

This page intentionally left blank

Section 5

Testing and Troubleshooting

Overview

This section provides guidelines for determining and establishing test routines for the SEL-387L Relay. It includes discussions on testing philosophies, methods, and tools. This section also contains relay self-tests and troubleshooting procedures, which are shown at the end of the section.

Testing Philosophy

Protective relay testing can be divided into three categories:

- acceptance
- commissioning
- maintenance

The categories are differentiated by when they take place in the life cycle of the relay, as well as by the test complexity.

The paragraphs below describe when to perform each type of test, 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 for use in a utility system.

Goals:

- Ensure that the relay meets published critical performance specifications such as operating speed and element accuracy.
- Ensure that the relay meets the requirements of the intended application.
- Gain familiarity with relay 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 or protection scheme logic.

Commissioning Testing

⚠WARNING
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

When: When installing a new protection system.

Goals:

- ➤ Ensure that all system ac, dc, and communications connections are correct.
- ➤ Ensure that the relay functions as intended.
- ➤ Ensure that all auxiliary equipment operates as intended.

What to test: Commissioning tests should verify all connected inputs and outputs, polarity and phase rotation of ac connections, correct operation of the 87L channel, and correct operation 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.

Maintenance Testing

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

Goals:

- ➤ Ensure that the relay is measuring ac quantities accurately.
- ➤ Ensure that scheme logic and protection elements are functioning correctly.
- ➤ 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 reduce utility 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 data, you can determine whether the relay protection elements are operating properly. Using the event report input and output data and the SER information, you can determine whether the relay is asserting outputs at the correct times and that auxiliary equipment is operating properly.

Because SEL relays are microprocessor-based, the relay operating characteristics do not change over time. It is not necessary to verify operating characteristics as part of maintenance checks. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

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

Testing Methods and Tools

Test Features Provided by the Relay

The following features assist you during relay testing.

Table 5.1 Commands for Relay Testing

Command	Description
MET command	The **MET** command shows local and remote currents (referenced to the local I1 positive-sequence current), the vector sum, and the vector ratio in the alpha plane. Use this information, with load applied to the protected line, to validate ac current connections at all terminals.
TST command	Use the **TST** command to display the status of the communications channel. Use the **TST X** command to place the channel in a loopback or end-to-end test mode. Note that in loopback mode the received current is the same as the local current. This condition can result in relay operation. Disable trip outputs before testing.
EVENT command	Use the **EVENT** (**EVE**) command (available at the serial ports) to view 15-cycle event reports that the relay generates when it trips. Each report contains current information, relay element states, and input/output contact information.
SER command	Use the **SER** command (available at the serial ports) to view time-tagged changes in selected relay elements.
TARGET command	Use the **TARGET** (**TAR**) command (available at the serial ports and front panel) to view the state of relay control inputs, relay outputs, and relay elements individually during a test.
PULSE command	Use the **PULSE** (**PUL**) command to test the contact output circuits. The **PULSE** command is available at the serial ports and the front panel.

Low-Level Test Interface

The SEL-387L has a low-level test interface between the calibrated input module and the separately calibrated processing module. You can test the relay in either of two ways:

- by using secondary injection testing
- by applying low-magnitude ac voltage signals to the low-level test interface

Access the test interface by removing the relay front panel.

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

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

Figure 5.1 shows the low-level interface connections and signal scaling factors. 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-4000 Relay Test System. Never apply voltage signals greater than 9 V peak-to-peak to the low-level test interface.

You can test the input module two different ways:

1. Measure the outputs from the input module with an accurate voltmeter (measure signal pin to GND pin), and compare the readings to accurate instruments in the relay input circuits.
2. Replace the ribbon cable, press the front-panel **METER** pushbutton, and compare the relay readings to other accurate instruments in the relay input circuits.

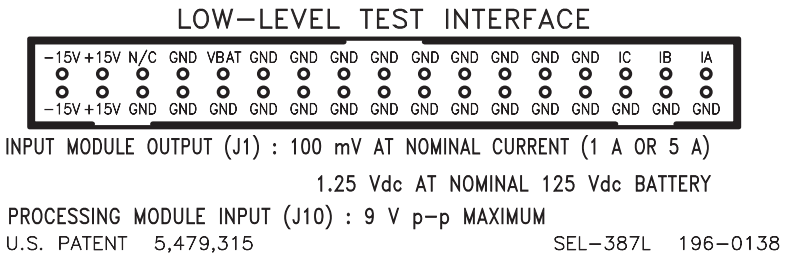


Figure 5.1 Low-Level Test Interface

Current Differential Communications Channel Configuration, Monitoring, and Testing

Our factory configures the line current differential communications channel as an IEEE C37.94 compliant multimode fiber (850 nm), 1300 nm multimode or single-mode direct fiber, or 1550 nm single-mode direct fiber, per your ordering option. The 1300 nm and 1550 nm fiber-optic interfaces are preconfigured at the factory for back-to-back operation.

Phase Rotation

⚠DANGER
Never disconnect the CTs when primary current is flowing. Open circuiting a CT when primary current flows will cause high voltage spikes on the CT secondary terminals that can result in injury or death.

If, during testing, you measure negative-sequence current only and very little positive-sequence and zero-sequence current, your power system may be operating on an ACB phase rotation. The SEL-387L is configured at the factory for an ABC phase rotation. If your power system operates on an ACB phase rotation, simply interchange, with the same polarity, B-phase and C-phase CT connections on the relay terminals. If the remote end of the feeder also operates on an ACB phase rotation, be sure to change B-phase and C-phase CT connections on both the relays.

87L Channel Monitors and Channel Problem Indicators

The relay indicates a problem with the 87L channel in several ways. Front-panel LED **87CH FAIL** illuminates when the relay detects a communication problem. LED **ADDR ERR** illuminates when the transmit and/or receive addresses are incorrect. Rear-panel **TX/RX** LEDs illuminate when the relay transmits and receives valid 87L packets from another SEL-387L/SEL-311L Relay. In addition, several Relay Word bits indicate channel health and can help you determine the cause of channel problems. Collectively, the Relay Word bits, LEDs, and channel monitor report form the channel monitor. *Table 5.2* describes the Relay Word bits and LEDs.

Table 5.2 Relay Word Bits and LEDs

Indicator	Description
AVAX	The availability monitor counts lost packets to detect channel degradation or failure. A packet is lost if it is not received, is received out of order, is corrupted, or contains an incorrect address. When more than 10 packets of the previous 10,000 (ten thousand) packets are lost, Relay Word bit AVAX asserts and illuminates front-panel LED **87CH FAIL**. After 87L communications are restored, the **87CH FAIL** LED may remain illuminated for 15 seconds, the time necessary to receive 10,000 good packets.
RBADX	The continuous dropout monitor detects a total loss of 87L communications for longer than two seconds. If the relay receives no valid packets for longer than two seconds, Relay Word bit RBADX asserts, the rear-panel Output Contact **87FAIL** closes, and front-panel LED **87CH FAIL** illuminates. Contact **87FAIL** also closes if power is removed from the relay or if a relay self-test fails.
DBAD	Relay Word bit DBAD asserts when the calculated one-way delay of the channel has exceeded 24 milliseconds. DBAD appears in the SER report when the bit asserts and deasserts.
ROKX	ROKX asserts if both of the previous two received packets contain no errors. Assertion of this bit is an instantaneous, unfiltered indication of channel health. The relay uses ROKX to produce the other Relay Word bits described above. ROKX can also be useful for testing by using the **TAR ROKX** command.
87LPE	87LPE asserts when 87L protection is enabled. The relay monitors the channel and determines if enough information is available from the remote relay to perform 87L protection. When the relay cannot perform 87L protection, Relay Word bit 87LPE deasserts and front-panel LED **87CH FAIL** illuminates.
Rear-Panel **TX/RX** LED	Two rear-panel LEDs help in troubleshooting installation problems. The **RX** LED illuminates when the channel is enabled and receives valid packets from another SEL-387L. The **RX** LED extinguishes if the channel is disabled, if there are sufficient data errors to prevent the relay from recognizing the packet boundaries, or if the receive data are entirely absent. The **TX** LED illuminates when the channel transmits valid packets.
Front-Panel **ADDR ERR** LED	This LED illuminates when the transmit address in the local relay does not match the receive address in the remote relay, and when the local receive address does not match the remote transmit address.

87L COM Report

The 87L Channel Monitor creates a detailed report containing all of the previous 256 channel problems. Retrieve the entire report through use of the **COM L** command. Filter both the summary report and the extended report by selecting start and stop dates, or start and stop records.

For example, the command:

```
=>>COM L 01/06/15 01/06/17 <Enter>
```

displays and summarizes all problems encountered on and between June 15, 2001, and June 17, 2001 (date format is YY/MM/DD). Use the **COM C** command to clear the COM report.

Loopback, End-to-End, and Back-to-Back Testing With the TST Command

The **TST** command temporarily modifies the channel configuration. Upon exiting test mode, the channel returns to normal mode of operation. The **TST** command enables short term or long term internal or external loopback tests, end-to-end tests, or back-to-back tests.

After entering the **TST** command (*Figure 5.2*), the relay warns that protection and tripping are still enabled. Cut out the 87L trip contacts to avoid misoperations. All applied faults and load current appear as internal faults when the communications channel is looped back. All channel monitor functions remain operational during test mode. This allows you to monitor the channel for errors during the test.

```
=>>TST X <Enter>
Entering Test Mode on Channel X.

WARNING!!!  Tripping is enabled in test mode.  !!!WARNING
Press Ctrl X now to abort. Type "TST X C" to end test mode.

  Disable 87L Communications: Yes or No (Y, N)           ? N <Enter>
  Enable Loop-Back: Internal, External or None (I,E,N)   ? E <Enter>
  Timing Source: Internal or External (I,E)              ? I <Enter>
  Test Mode Duration: 1 - 30 min. or Infinite (1-30,INF) ? 30 <Enter>

Are you sure (Y/N) ? Y <Enter>
Test Mode Enabled on Channel X.
Channel X: Test Mode
=>>
```

Figure 5.2 TST Command to Test the Communications Channel

The **TST** command presents several options. The first option enables loopback operation. Choose either internal or external loopback operation to disable receive address checking. Select internal loopback to test the internal SEL-387L hardware without external connections. Internal loopback connects the SEL-387L transmitter to the receiver. While in internal loopback, the relay does not transmit 87L data. Select external loopback to loop the channel anywhere outside the SEL-387L. Loop the channel back at the SEL-387L connector, at the multiplexer, anywhere in the network, or at the far end. Select **None** to perform end-to-end or back-to-back tests.

⚠WARNING
The relay is disabled for Test Mode Duration. Be aware that the relay is enabled immediately after the timer expires so that current injection at this time may cause relay operation.

If you select external or no loopback, the relay prompts for the channel timing source. Select internal timing if the channel is looped before it reaches the communications equipment. Select external timing if the channel is looped after it reaches the communications equipment.

Entering **Y** at the `Disable 87L Communications: Yes or No (Y, N)` prompt (*Figure 5.2*) disables communications between the relays. This setting effectively disables the SEL-387L, and illuminates LEDs **TEST**, **CH FAIL**, and **87DIS** for the duration of temporary test configuration.

Select the duration of the temporary test configuration from 1 to 30 minutes. Enter a duration to prevent accidentally leaving the relay in test mode after the test. After the duration timer expires, the relay reconfigures itself for normal operation. For tests longer than 30 minutes, enter **INF** and be certain to end the test mode with the **TST C** command after testing is complete. There is no need to execute the **TST** command in the other relay.

Testing Alpha-Plane 87L Elements

Test alpha-plane 87L elements for operation speed and security, and for element accuracy. To test for operation speed and security, you can apply prefault load current and then switch to an internal or external fault. Because the SEL-387L often trips in less than one cycle, transient effects in the fault

currents impact operation speed. In some instances, it may be necessary to test using Comtrade files from an EMTP simulation or a real time simulator. The operate speeds depicted in *Figure 1.2* and *Figure 1.3* are from fault inception to closure of high-speed Output Contacts **TRIP3** and **TRIP4**. The tests used symmetrical fault currents only, so they can be easily reproduced.

SEL-387L Relay 87L Element Test Procedure

Purpose: Test the accuracy of phase elements and negative-sequence 87L elements. Use an identical procedure to test the ground 87L element.

Required Equipment:

- Two SEL-387L relays with established 87L communications interface
- Three-phase secondary injection test equipment, or low-level test equipment such as the SEL-AMS Adaptive Multichannel Source
- PC with terminal emulation software
- SEL Cable SEL-C234A

Test Setup:

Step 1. Connect three-phase secondary injection current sources or low-level test sources to the relays.

Step 2. Connect the PC to the relays with an SEL-C234A cable, and establish communications.

The relays are ready when the **EN** (enable) LED is illuminated.

Test Phase 87L Element Accuracy: *Figure 5.3* graphically depicts the approach to testing 87LOPA, 87LOPB, 87LOPC, and phase restraint element R87LA.

To test the operate element, perform the following steps:

Step 1. Apply a low current internal three-phase fault at the local relay (with zero current applied to the remote relay)

Step 2. Increase the current at the local relay until the relay trips.

To test R87LA, the restraint element, perform the following steps:

Step 1. Apply currents at the local relay while applying no current to the remote relay.

This simulates a weak-infeed internal fault, deasserts restraint element R87LA, and causes both relays to trip.

Step 2. Increase the magnitude of the currents at the remote relay until the restraint bit R87LA asserts.

Step 3. Continue to increase the magnitude of the remote currents until restraint bit R87LA deasserts.

Step 4. Repeat with various phase angles applied between local and remote currents.

Step 5. Finally, apply an internal fault with equal current at each relay.

Step 6. Change the angle of the current on the remote relay until you obtain a solid assertion of restraint element R87LA in the local relay.

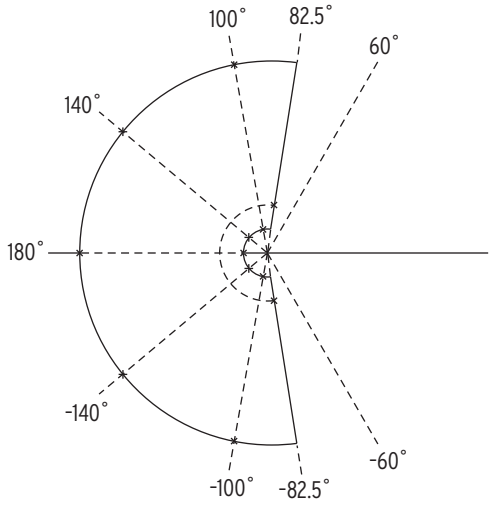


Figure 5.3 Alpha-Plane Element Accuracy Test Points

Phase elements 87LOPB and 87LOPC, and phase restraint elements 87LRB and 87LRC, are identical to the A-phase elements.

Test Procedures

The following procedures assume I_{NOM} = 5 A. If I_{NOM} = 1 A, divide the values by five and adjust the applied currents accordingly.

Phase 87L Element Test. (Operate Region)

Step 1. To test operate region operation, apply the currents listed in *Table 5.3*.

Table 5.3 Current Values for Local and Remote Relays

Local Relay	Remote Relay
IA = 2.5 A ∠0.00°	IA = 2.5 A ∠0.00°
IB = 2.5 A ∠–120°	IB = 2.5 A ∠–120°
IC = 2.5 A ∠120°	IC = 2.5 A ∠120°

Step 2. In the local relay, use the **TAR 87LOPA 10000** command to display the 87LOPA Relay Word bit 10,000 times, or press the **OTHER** front-panel pushbutton and select the TAR command to display Relay Word row 61.

Step 3. Ensure that bit 87LOPA is deasserted.

Step 4. Increase the magnitudes of currents IA, IB, and IC (not the angles) in the local relay until element 87LOPA asserts, and record the current.

Step 5. Ensure that this current is within the range indicated below. (While still applying this current, you can use **TAR 87LOPB 10000** and **TAR 87LOPCA 10000** to verify that the B-phase and C-phase elements also tripped).

3.4 A < _____ < 3.6 A

Phase 87L Element Test. (Restraint Region)

When the complex ratio is in the restraint region, Relay Word bits R87L*n* (*n* = A, B, C) assert.

Step 1. To test restraint region operation, apply the currents listed in *Table 5.4*.

Table 5.4 Current Values for Local and Remote Relays

Local Relay	Remote Relay
IA = 2.33 A ∠0.00°	IA = 0 A ∠180°
IB = 2.33 A ∠–120°	IB = 0 A ∠60°
IC = 2.33 A ∠120°	IC = 0 A ∠–60°

Step 2. In the local relay, use the **TAR R87LA 10000** command to display the R87LA Relay Word bit 10,000 times, or use the **OTHER** front-panel pushbutton and select the TAR command to display Relay Word row 61.

Step 3. Increase the balanced three-phase remote currents until Relay Word bit R87LA asserts solidly, and record the current in *Table 5.5*.

Step 4. While applying this current, change the angle of all three phases (A-phase listed in *Table 5.5*).

Step 5. Ensure that all current values are within the range indicated. (Use **TAR R87LB 10000** or **TAR R87LC 10000** to verify operation of B-phase and C-phase elements, if required).

Table 5.5 Phase Restraint Element Pickup Test Results (Inner Radius)

Remote IA Current Angle	Remote Current at Which R87LA Asserts		
	Min.	Actual	Max.
180	0.377		0.400
140	0.377		0.400
100	0.377		0.400
60	No Assertion		No Assertion
0	No Assertion		No Assertion
–60	No Assertion		No Assertion
–100	0.377		0.400
–140	0.377		0.400

Step 6. Apply the currents shown in *Table 5.6*.

Table 5.6 Current Values for Local and Remote Relays

Local Relay	Remote Relay
IA = 2.33 A ∠0.00°	IA = 13 A ∠180°[a]
IB = 2.33 A ∠–120°	IB = 13 A ∠60°[a]
IC = 2.33 A ∠120°	IC = 13 A ∠–60°[a]

[a] The SEL-387L is rated to withstand 3 • I_{NOM} indefinitely.

Step 7. In the local relay, use the **TAR R87LA 10000** command to display the R87LA Relay Word bit 10,000 times, or press the front-panel **OTHER** pushbutton and select the TAR command to display Relay Word row 61.

Step 8. Ensure that bit R87LA is asserted.

Step 9. Increase the balanced three-phase remote currents until the R87LA bit is no longer asserted solidly (until it begins to deassert).

Step 10. Record the remote A-phase current required to begin deassertion of R87LA in *Table 5.7*.

Step 11. Repeat current application for the remaining values in *Table 5.7*.

Step 12. Ensure that all current values are within the range indicated.

Table 5.7 Phase Restraint Element Dropout Test Results (Outer Radius)

Remote Current Angle	Remote Current at Which R87LA Deasserts		
	Min.	Actual	Max.
180	13.58		14.42
140	13.58		14.42
100	13.58		14.42
–100	13.58		14.42
–140	13.58		14.42

Step 13. Apply the currents shown in *Table 5.8*.

Table 5.8 Current Values for Local and Remote Relays

Local Relay	Remote Relay
IA = 5 A ∠0.00°	IA = 5 A ∠0.00°
IB = 5 A ∠–120°	IB = 5 A ∠–120°
IC = 5 A ∠120°	IC = 5 A ∠120°

Step 14. In the local relay, use the **TAR R87LA 10000** command to display the R87LA Relay Word bit 10,000 times, or press the **OTHER** front-panel pushbutton and then select the TAR command to display Relay Word row 61.

Step 15. Ensure that bit R87LA is deasserted.

Step 16. Increase the angles of the balanced three-phase remote currents until Relay Word bit R87LA is asserted solidly.

Step 17. Record the angle of IA required to obtain solid assertion of R87LA. (Use **TAR R87LB 10000** or **TAR R87LC 10000** to verify operation of B-phase and C-phase elements, if required).

Step 18. Ensure that the angle is within the following range:

$$80° < \_\_\_\_\_ < 85°$$

Step 19. Return the angles to the values listed in *Table 5.7*.

Step 20. Decrease the angle of the remote IA from zero (more negative) until Relay Word bit R87LA is asserted solidly.

Step 21. Record the angle of IA required to obtain solid assertion of R87LA.

Step 22. Ensure that the angle is within the following range:

$$-85° < \_\_\_\_\_ < -80°$$

Step 23. Stop applying current, and reset the relays.

Negative-Sequence 87L Element Tests. Ground operate element 87LOPG and ground restraint element R87L2 are not tested here, but you can test these elements with an identical procedure.

Step 1. Apply the currents shown in *Table 5.9*.

Table 5.9 Current Values for Local and Remote Relays

Local Relay	Remote Relay
IA = 0.75 A ∠0.00°	IA = 0.75 A ∠0.00°
IB = 0.75 A ∠–120°	IB = 0.75 A ∠–120°
IC = 0.75 A ∠120°	IC = 0.75 A ∠120°

Step 2. Increase IA in the remote relay (at 0 degrees) until 87LOP2 asserts.

Step 3. Record the remote A-phase current that causes 87LOP2 to assert.

Step 4. Ensure that this current is within the range indicated.

$$1.19 \text{ A} < \_\_\_\_\_ < 1.31 \text{ A}$$

Step 5. Return the remote relay A-phase current to 0.75 A, and repeat *Step 1* through *Step 4* with the B- and C-phase currents if you choose. Expect similar results.

Step 6. Apply the following currents:

Local Relay: IA = 2.33 A ∠0.00°

Remote Relay: IA = 0 A ∠180°

Step 7. In the local relay, use the **TAR R87L2 10000** command to display the R87L2 Relay Word bit 10,000 times, or press the front-panel **OTHER** pushbutton and then select the TAR command to display Relay Word row 64.

Step 8. Ensure that bit R87L2 is deasserted.

Step 9. Increase the remote A-phase current at 180 degrees until the R87L2 bit asserts solidly.

Step 10. Record the remote A-phase current required to obtain solid assertion of R87L2 in *Table 5.10*.

Step 11. Ensure that this current is within the range indicated.

Table 5.10 Negative-Sequence Restraint Element Pickup Test Results (Inner Radius)

Remote Current Angle	Remote Current at Which R87L2 Asserts		
	Min.	Actual	Max.
180	0.377		0.400
140	0.377		0.400
100	0.377		0.400
60	No Assertion		No Assertion
0	No Assertion		No Assertion
–60	No Assertion		No Assertion
–100	0.377		0.400
–140	0.377		0.400

Step 12. Apply the following currents:

Local Relay: IA = 2.33 A ∠0.00°

Remote Relay: IA = 13 A ∠0.00° (The SEL-387L is rated to withstand 3 • I_{NOM} indefinitely.)

Step 13. In the local relay, use the **TAR R87L2 10000** command to display the R87L2 Relay Word bit 10,000 times, or press the front-panel **OTHER** pushbutton and select the TAR command to display Relay Word row 64.

Step 14. Ensure that bit R87L2 is asserted.

Step 15. Increase the remote A-phase current at 180 degrees until the R87L2 bit is no longer asserted solidly (until it begins to deassert).

Step 16. Record the remote A-phase current required to begin deassertion of R87L2 in *Table 5.11*.

Step 17. Ensure that this current is within the range indicated.

Step 18. Repeat *Step 12* through *Step 17* for each remote current angle shown in *Table 5.11*.

Table 5.11 Negative-Sequence Restraint Element Dropout Test Results (Outer Radius)

Remote Current Angle	Remote Current at Which R87L2 Deasserts		
	Min.	Actual	Max.
180	13.58		14.42
140	13.58		14.42
100	13.58		14.42
–100	13.58		14.42
–140	13.58		14.42

Step 19. Apply the following currents:

Local Relay: IA = 5 A ∠0.00°

Remote Relay: IA = 5 A ∠0.00°

Step 20. In the local relay, use the **TAR R87L2 10000** command to display the R87L2 Relay Word bit 10,000 times, or press the **OTHER** front-panel pushbutton and then select the TAR command to display Relay Word row 64.

Step 21. Ensure that bit R87L2 is deasserted.

Step 22. Increase the angle on the remote IA from zero until Relay Word bit R87L2 is asserted solidly.

Step 23. Record the angle of IA required to obtain solid assertion of R87L2.

Step 24. Ensure that the angle is within the following range:

$$80° < \_\_\_\_\_ < 85°$$

Step 25. Decrease the angle on the remote IA from zero (more negative) until Relay Word bit R87L2 is asserted solidly.

Step 26. Record the angle of IA required to obtain solid assertion of R87LA.

Step 27. Ensure that this angle is within the following range:

$$-85° < \_\_\_\_\_ < -80°$$

Step 28. Stop applying current, and reset the relays.

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 5.12*):

Protection Disabled: The relay disables overcurrent elements and trip/close logic. All output contacts are de-energized. The **EN** front-panel LED is extinguished.

ALARM Output: Because the **ALARM** output contact is a b contact (normally closed), it closes for an alarm condition or if the relay is de-energized.

87FAIL Output: The **87FAIL** output contact signals that the relay has not received valid 87L packets for 2 seconds by going to the de-energized state. As with the **ALARM** contact, this output is form B.

Line Current Differential Protection Disabled: The relay disables 87L protection and de-energizes the alarms and close outputs. Relay Word bit 87LPE deasserts, and Relay Word bit 87HWAL asserts.

STATUS Reports: The relay generates automatic STATUS reports at the serial port for warnings and failures.

Failure Messages: The relay displays failure messages on the relay LCD.

For certain failures, the relay automatically restarts as many as three times within 24 hours. A “Diagnostic restart” entry is recorded in the Sequential Events Recorder (SER), but the automatic restart may occur before Relay Word bits ALARM and 87HWAL are recorded in the SER and before front-panel failure messages are displayed.

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

Table 5.12 Relay Self-Tests (Sheet 1 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
IA, IB, IC,	Warning	30 mV	No	Pulsed	Measures the dc offset at each of the input channels every 10 seconds.
Master Offset	Warning	20 mV	No	Pulsed	Measures the dc offset at the A/D every 10 seconds.
	Failure	30 mV	Yes	Latched	
+5 V PS	Warning	+4.80 V +5.20 V	No	Pulsed	Measures the +5 V power supply every 10 seconds.
	Failure	+4.65 V +5.40 V	Yes	Latched	
±5 V REG	Warning	+4.75 V +5.20 V –4.75 V –5.25 V	No	Pulsed	Measures the regulated 5 V power supply every 10 seconds.
	Failure	+4.50 V +5.40 V –4.50 V –5.50 V	Yes	Latched	
±12 V PS	Warning	+11.50 V +12.50 V	No	Pulsed	Measures the 12 V power supply every 10 seconds.
	Failure	+11.20 V +14.00 V	Yes	Latched	
±15 V PS	Warning	+14.40 V +15.60 V	No	Pulsed	Measures the 15 V power supply every 10 seconds.
	Failure	+14.00 V +16.00 V	Yes	Latched	
TEMP	Warning	–40° C +85° C	No		Measures the temperature at the A/D voltage reference every 10 seconds.
RAM	Failure		Yes	Latched	Performs a read/write test on system RAM every 60 seconds.
ROM	Failure	checksum	Yes	Latched	Performs a checksum test on the relay program memory every 10 seconds.
A/D	Failure		Yes	Latched	Validates proper number of conversions each 1/4 cycle.
CR_RAM	Failure	checksum	Yes	Latched	Performs a checksum test on the active copy of the relay settings every 10 seconds.
EEPROM	Failure	checksum	Yes	Latched	Performs a checksum test on the non-volatile copy of the relay settings every 10 seconds.
87L RAM	Failure		87L only disabled	87HWAL asserted; **ALARM** pulsed	Periodically performs a read/write test at each RAM location.
87L ROM	Failure	checksum	87L only disabled	87HWAL asserted; **ALARM** pulsed	Performs a checksum test on program storage ROM.
CHAN X	Failure		Determined by 87LPE	None	See *87L Channel Monitors and Channel Problem Indicators on page 5.4*.
FPGA	Failure		87L only disabled	87HWAL asserted; **ALARM** pulsed	Ensures that FPGA configures properly.

Table 5.12 Relay Self-Tests (Sheet 2 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
BOARD	Failure		87L only disabled	87HWAL asserted; **ALARM** pulsed	Checks each processing interval to ensure that dedicated 87L hardware responds and that the watchdog timer has not expired.
The following self-tests are performed by dedicated circuitry in the microprocessor and the SEL-387L main board. Failures in these tests shut down the microprocessor and are not shown in the STATUS report.					
Microprocessor Crystal	Failure		Yes	Latched	The relay monitors the microprocessor crystal. If the crystal fails, the relay displays `CLOCK STOPPED` on the LCD display. The test runs continuously.
Microprocessor	Failure		Yes	Latched	The microprocessor examines each program instruction, memory access, and interrupt. The relay displays `CPU Failure` on the LCD upon detection of an invalid instruction, memory access, or spurious interrupt. The test runs continuously.

Relay Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the relay. After you finish the inspection, proceed to the *Troubleshooting Procedure*.

Step 1. Measure and record the power supply voltage at the power input terminals.

Step 2. Check to see that the power is on. Do not turn the relay off.

Step 3. Measure and record the voltage at all control inputs.

Step 4. Measure and record the state of all output relays.

Troubleshooting Procedure

All Front-Panel LEDs Dark

1. Input power not present or fuse is blown.
2. Self-test failure.

Cannot See Characters on Relay LCD Screen

1. Relay is de-energized. Check to see if the **ALARM** contact is closed.
2. LCD contrast is out of adjustment. Use the steps below to adjust the contrast.
   a. Remove the relay front panel by removing the six front-panel screws.
   b. Press any front-panel button. The relay should turn on the LCD backlighting.
   c. Locate the contrast adjustment potentiometer adjacent to the serial port connector.

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. Ensure that the communications device is connected to the relay.
2. Verify relay or communications device transmission rate setting and other communications parameters. Check for a cabling error.
3. Relay serial port may have received an XOFF, halting communications. Type **<Ctrl+Q>** to send relay an XON and restart communications.
4. Relay may be set to LMD protocol (available with the DNP ordering option), for which you must have an address to turn on the serial port. View the port setting, by using the front-panel **SET** pushbutton, to see if the port is set to LMD and to see the address.

NOTE: Fixed port transmission rates are: Port F = Port 1 = 9600 baud, and Port 2 = Port 3 = 19200 baud.

Relay Does Not Respond to Faults

1. Verify that the **87CHFAIL** front-panel LED is extinguished.
2. Verify that the test source is set properly.
3. Use the **MET** command to verify that test connections are correct.
4. Ensure that the analog input cable between transformer secondary and main board is neither loose nor defective.
5. Inspect the relay self-test status with the **STA** command or with the front-panel **STATUS** pushbutton.

87CHFAIL LED Is Illuminated

The **87CHFAIL** LED illuminates when the relay detects a problem with the 87L communications channel. The following steps isolate the problem to either the transmit or receive direction on that channel. Further isolation of the problem may then be possible based on the channel interface type. The **87CHFAIL** LED can take as long as 15 seconds to extinguish after resolution of the problem.

1. Determine if there is a channel delay problem.
   a. Inspect Relay Word bit DBADX by typing **TAR DBADX 10000**, or press the front-panel **OTHER** pushbutton and select the TAR command to display Relay Word row 69. DBADX asserts if half the round trip channel delay on the 87L Channel exceeds 24 ms.
   b. Rectify the excessive channel delay.

2. Determine if there is a transmit or receive problem.
    a. Inspect Relay Word bits AVAX and RBADX by typing **TAR RBADX 10000**, or press the front-panel **OTHER** pushbutton and select the TAR command to display Relay Word row 69. If either bit is asserted, then that channel has a problem in the receive direction. If neither bit is asserted, proceed to *Step 2.l*.
    b. If the **RX** LED is illuminated, the local relay is receiving valid packets from the remote relay. If the **RX** LED is not illuminated, proceed to *Step 2.h*.
    c. Use the **SHO** command to verify that the address parameters are correct in remote and local relays.
    d. Use the **SET** command to change incorrect addresses. The Last Error field in the report generated by the **COM X** command indicates Address Error if the address settings in both relays are not correct. The **ADDR ERR** front-panel LED also illuminates if the RX address is wrong.
    e. If the addresses are correct (as verified by the **COM X** command), issue the **COM X C** command.
    f. Wait a few minutes and issue the **COM X** commands again. If the report logs new errors, then the communications link is probably unreliable or noisy. However, this logging of new errors may also be caused by a back-to-back connection with a multimode fiber interface.
    g. Use the **TST** command to change one relay to internal timing.

       If the problem persists, the communications link is probably noisy or unreliable.
    h. If the **RX** LED is extinguished, the local relay is not receiving valid packets from the remote relay.
    i. Swap the transmit and receive fibers at the rear panel of the relay.
    j. If this does not rectify the problem, verify with an optical power meter that received power is more than –58 dBm for a 1300 nm or 1550 nm fiber interface, and more than –32 dBm for an IEEE Standard C37.94 interface.
    k. For all interface types, verify that the rear-panel **TX** LED is illuminated on the remote relay.

       If the remote relay **TX** LED is illuminated, and the local relay **RX** LED is extinguished, the transmit data that leave the remote relay do not arrive at the local relay.
    l. If AVAX, RBADX, and DBADX are all deasserted, then there is a receive problem in the remote relay. Repeat *Step 2* for the remote relay.
3. If the problem persists, contact the factory for assistance.

Relay Calibration

The SEL-387L is factory-calibrated. If you suspect that the relay is out of calibration, please contact the factory.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 USA
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

NOTE: The hardware of SEL-387L Relays with R300-series firmware differs from the hardware of SEL-387L Relays with R100-series firmware. R300-series firmware revisions cannot be loaded on to SEL-387L Relays shipped with R100-series firmware. R100-series firmware is not compatible with R300-series hardware.

To find the firmware revision number in your relay, use the serial port **STATUS** command to view the status report. The status report displays the Firmware Identification (FID) label:

FID=SEL-387L-Rxxx-Vx-Z001001-Dxxxxxxxx

You can also view the FID label from the front panel by pressing the **STATUS** pushbutton. After pressing the **STATUS** pushbutton, use the left and right arrow keys to view the complete number.

In the FID label, the firmware revision number follows the R, and the date code follows the D.

For example,

FID=SEL-387L-R100-V0-Z001001-D20040412

is firmware revision number 100, date code April 12, 2004.

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History (Sheet 1 of 2)

Firmware Part/Revision No.	Description of Firmware	Manual Date Code
SEL-387L-R301-V0-Z002001-D20150810	➤ Added Relay Word bits TIRIG and TSOK. ➤ Added Relay Word bits TIRIG and TSOK to the Sequential Events Recorder (SER). ➤ Changed temperature diagnostics behavior so that extreme temperatures generate a diagnostic warning but do not disable the relay. ➤ Reduced the required access level for VER command from 2AC to ACC. ➤ Added *[time]* parameter to TRI command. ➤ Revised relay so that password characters are not echoed as they are entered. ➤ Increased the maximum number of allowed password characters from 6 to 12. ➤ Modified the PAS command to no longer display passwords. ➤ Added one minute lockout time after three failed password attempts. ➤ Improved RAM self-tests to restart relay as many as 3 times in 24 hours.	20150810
SEL-387L-R300-V0-Z002001-D20150630	➤ Firmware version R300 did not production release.	NA
SEL-387L-R103-V0-Z001001-D20100609	➤ Allows conformal coating option in the part number.	20100609

Table A.1 Firmware Revision History (Sheet 2 of 2)

Firmware Part/Revision No.	Description of Firmware	Manual Date Code
SEL-387L-R102-V0-Z001001-D20050512	➤ Corrected issue where the relay may intermittently respond with asterisks (*****) for current differential metering on the front-panel HMI and in the Fast Meter response when Fast Meter is used on Port 3.	20050512
SEL-387L-R101-V0-Z001001-D20041116	➤ Close 87FAIL contact for communications failure. (The 87FAIL contact would open under this condition in the previous firmware version.)	20041116
SEL-387L-R100-V0-Z001001-D20040412	➤ Initial release.	20040412

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.2 lists the instruction manual date codes and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.2 Instruction Manual Revision History (Sheet 1 of 3)

Date Code	Summary of Revisions
20250127	Preface ➤ Removed reference to CD-ROM information.
20221103	Section 1 ➤ Added UKCA Mark in *Specifications*.
20211203	Section 1 ➤ Updated *Type Tests* in *Specifications*.
20191107	Section 1 ➤ Updated Specifications.
20190809	Section 4 ➤ Updated *Compressed ASCII Event Reports* in *Standard 15-, 30-, or 60-Cycle Event Reports.* ➤ Removed *Figure 4.15: Internal Fault*. SEL-387L Relay Command Summary ➤ Updated **EVE *n* C**. Appendix D ➤ Added *Appendix D: PC Software*.
20170804	Section 1 ➤ Updated *Specifications*.
20160122	Section 1 ➤ Updated *Specifications*. Section 3 ➤ Updated *Table 3.7: Relay Word Bit Definitions for the SEL-387L.* Section 4 ➤ Updated *Table 4.4: Target LEDs*.
20150810	Section 2 ➤ Added description of TIRIG and TSOK Relay Word bits.

Table A.2 Instruction Manual Revision History (Sheet 2 of 3)

Date Code	Summary of Revisions
	Section 3 ➤ Added TIRIG and TSOK Relay Word bits to *Table 3.6: SEL-387L Relay Word Bits* and *Table 3.7: Relay Word Bit Definitions for the SEL-387L.* Section 4 ➤ Added TIRIG and TSOK to the list of elements monitored by the sequential events recorder (SER). SEL-387L Relay Command Summary ➤ Removed *xxxxxx* parameter from **PAS** command as it is no longer supported. ➤ Added *[time]* parameter to **TRI** command. ➤ Reduced required access level for **VER** command from 2AC to ACC. Section 5 ➤ Added description of number of times the relay automatically restarts after a diagnostic failure and the message that is displayed in the SER. Appendix A ➤ Added note to clarify firmware versions that are supported by specific hardware. ➤ Updated for firmware version R301.
20150126	Preface ➤ Added *Safety Information*. Section 1 ➤ Updated *Specifications*.
20111027	Section 2 ➤ Removed mention of specific modems. ➤ Added description of how to connect SEL-387L to SEL-311L. ➤ Added discussion of maximum allowable 87L channel delay. Section 3 ➤ Corrected description of disturbance detector. ➤ Added *Table 3.6: SEL-387L Relay Word Bits* and *Table 3.7: Relay Word Bit Definitions for the SEL-387L.*
20100609	Appendix A ➤ Updated for firmware version R103.
20091028	Sections 1 and 2 ➤ Clarified that IEEE C37.94 fiber-optic interfaces can be used to directly connect an SEL-311L to an SEL-387L, but not to directly connect an SEL-387L to another SEL-387L. Section 4 and Command Summary ➤ Added CAL setting.
20050512	Sections 2 and 5 ➤ Added information for connecting to an ACB system (see *Phase Rotation on page 2.4* and *Phase Rotation on page 5.4*). Appendix A ➤ Updated for firmware version R102.
20041116	Section 2 ➤ Corrected *Figure 2.3: Typical Current Transformer, DC, and Communications Connections* by changing 87ALRM to 87FAIL. Appendix A ➤ Updated for firmware version R101.
20040628	Reverse of Cover ➤ Added MIRRORED BITS® to list of SEL copyright terms. Section 1 ➤ Updated information in Overview. ➤ Changed caption for Figure 1.4 to Relay Identification and Communication Addressing. ➤ Changed abbreviation of Distributed Network Protocol from DNP 3.0 to DNP3.

Table A.2 Instruction Manual Revision History (Sheet 3 of 3)

Date Code	Summary of Revisions
	Section 4 ➤ Updated information in Serial Port Communications and Commands including adding note about port settings available with DNP3, and changing the title of Table 4.2 to Fixed Settings for Each Serial Port. ➤ Updated information in Event Reports. Command Summary ➤ Updated information. Section 5 ➤ Updated information in Testing Methods and Tools and Relay Troubleshooting. Appendix A ➤ Updated Firmware and Manual Versions tables. Appendix B ➤ Changed abbreviation of Distributed Network Protocol from DNP 3.0 to DNP3.
20040412	➤ Initial release.

Appendix B
Distributed Network Protocol

Overview

If the relay order includes the DNP3 Level 2 Slave protocol option, all port settings become available, including DNP point remapping. DNP3 Level 2 Slave includes access to metering data, protection elements (Relay Word), contact I/O, targets, Sequential Events Recorder, relay summary event reports, and time synchronization.

Configuration

To configure a port for DNP, set the port PROTO setting to DNP. Although DNP may be selected on any of the available ports, DNP may not be enabled on more than one port at a time. *Table B.1* shows the information necessary to configure a port for DNP operation.

Table B.1 Information Necessary to Configure a Port for DNP Operation (Sheet 1 of 2)

Name	Description	Range	Default
SPEED	Transmission rate	300–19200 bps	[a]
DNPADR	DNP address	0–65534	0
ECLASS	Class for event data	0–3	2
TIMERQ	Minutes for request interval	0–32767	0
DECPLM	Miscellaneous data scaling decimal places	0–3	2
STIMEO	Seconds to select/operate time-out	0.0–30	1
DRETRY	Data-link retries	0–15	3
DTIMEO	Seconds to data-link time-out	0–5	1
MINDLY	Minimum seconds from DCD to TX	0.00–1	0.05
MAXDLY	Maximum seconds from DCD to TX	0.00–1	0.1
PREDLY	Settle time from RTS ON to TX	OFF, 0.00–30 sec	0
PSTDLY	Settle time from TX to RTS OFF	0.00–30 sec	0
ANADB	Analog reporting dead-band counts	0–32767	100
UNSOL	Enable unsolicited reporting	Y, N	N
PUNSOL	Enable unsolicited reporting when the relay turns on	Y, N	N
REPADR	DNP address to which to report	0–65534	0
NUMEVE	Number of events on which the relay transmits	1–200	10

Table B.1 Information Necessary to Configure a Port for DNP Operation (Sheet 2 of 2)

Name	Description	Range	Default
AGEEVE	Seconds until oldest event to TX on	0.0–60	2
UTIMEO	Seconds to event message confirm time-out	1–50	2

[a] Port F = Port 1 = 9600; Port 2 = Port 3 = 19200. Port settings are ordinarily fixed, but become available when you order the DNP option.

The RTS signal may be used to control an external transceiver. The relay uses the CTS signal as a DCD input, indicating when the medium is in use. Transmissions are only initiated if DCD is deasserted. When DCD drops, the next pending outgoing message may be sent once an idle time is satisfied. For this idle time, the relay selects a random value between the minimum and maximum allowed idle times (i.e., MINDLY and MAXDLY).

In addition, the SEL-387L Relay monitors received data and treats receipt of data as a DCD indication. This allows RTS to be looped back to CTS in cases where the external transceiver does not support DCD. When the SEL-387L transmits a DNP message, it delays transmitting after asserting RTS by at least the time in the PREDLY setting.

After transmitting the last byte of the message, the SEL-387L delays for at least PSTDLY milliseconds before deasserting RTS. If the PSTDLY time delay is in progress (RTS still high) following a transmission and another transmission is initiated, the SEL-387L transmits the message without completing the PSTDLY delay and without any preceding PREDLY delay.

The RTS/CTS handshaking may be completely disabled by setting PREDLY to OFF. In this case, RTS is forced high and CTS is ignored, with only received characters acting as a DCD indication. The timing is the same as above, but PREDLY functions as if it were set to 0, and RTS is not actually deasserted after the PSTDLY time delay expires.

Data-Link Operation

You must make two important decisions about the data-link layer operation. One is how to handle data-link confirmation; the other is how to handle data-link access. If a highly reliable communications link exists, the data-link access can be disabled altogether, which significantly reduces communications overhead. Otherwise, it is necessary to enable confirmation and determine how many retries to allow and what the data-link time-out should be. The noisier the communications channel, the more likely a message will be corrupted. Thus, the number of retries should be set higher on noisy channels. Set the data-link time-out long enough to allow for the worst case response of the master plus transmission time.

When the SEL-387L decides to transmit on the DNP link, it has to wait if the physical connection is in use. The SEL-387L monitors physical connections by using CTS input (treated as a Data Carrier Detect) and monitoring character receipt. Once the physical link goes idle, as indicated by CTS being deasserted and no characters being received, the SEL-387L will wait a configurable amount of time before beginning a transmission. This hold-off time will be a random value between the MINDLY and MAXDLY setting values. The randomness of the hold-off time prevents simultaneous communication of multiple devices waiting to communicate on the network.

Data Access Method

Based on the capabilities of the system, you need to determine the method for retrieving data on the DNP connection. *Table B.2* summarizes the main options, listed from least to most efficient, and includes the corresponding key related settings.

Table B.2 Data Access Methods

Data Retrieval Method	Description	Relevant SEL-387L Settings
Polled Static	The master polls for static (Class 0) data only.	Set ECLASS = 0, Set UNSOL = N.
Polled Report-by-Exception	The master polls frequently for event data and occasionally for static data.	Set ECLASS to a nonzero value, Set UNSOL = N.
Unsolicited Report -by-Exception	The slave devices send unsolicited event data to the master and the master occasionally sends integrity polls for static data.	Set ECLASS to a nonzero value, Set UNSOL = Y, Set NUMEVE and AGEEVE according to how often you want to send messages.
Quiescent	The master never polls and relies on unsolicited reports only.	Set ECLASS to a nonzero value, Set UNSOL = Y, Set NUMEVE and AGEEVE according to how often you want to send messages.

Device Profile

Table B.3 contains the standard DNP3 device profile information. Rather than check boxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table B.3 SEL-387L DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-387L Relay
Highest DNP request level	Level 2
Highest DNP response level	Level 2
Device function	Slave
Notable objects, functions, and/or qualifiers supported	Supports enabling and disabling of unsolicited reports on a class basis
Maximum data-link frame size transmitted/received (octets)	292
Maximum data-link retries	Configurable, range 0–15
Requires data-link layer confirmation	Configurable by setting
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting event data
Data-link confirm time out	Configurable
Complete application fragment time-out	None

Table B.3 SEL-387L DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
Application confirm time-out	Configurable
Complete application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control SELECT/OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch On	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	16 bits
Sends multifragment responses	No

SEL-387L Port settings control all configurable items within the device profile. *Table B.4* shows the object, function code, and qualifier code combinations that the SEL-387L supports.

Table B.4 SEL-387L DNP Object List (Sheet 1 of 3)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
1	0	Binary Input–All Variations	1	0, 1, 6, 7, 8		
1	1	Binary Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
2	0	Binary Input Change–All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3[f]	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28

Table B.4 SEL-387L DNP Object List (Sheet 2 of 3)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
10	0	Binary Output– All Variations	1	0, 1, 6, 7, 8		
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
20	0	Binary Counter– All Variations	1	0, 1, 6, 7, 8		
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
20	6[e]	16-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
22	0	Counter Change Event– All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
30	0	Analog Input– All Variations	1	0, 1, 6, 7, 8		
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
32	0	Analog Change Event– All Variations	1	6, 7, 8		
32	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
40	0	Analog Output Status– All Variations	1	0, 1, 6, 7, 8		
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8

Table B.4 SEL-387L DNP Object List (Sheet 3 of 3)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	1	Time and Date	2	7, 8 index=0	129	07, quantity=1
51	2	Unsynchronized Time and Date CTO				07, quantity=1
52	2	Time Delay, Fine			129	07, quantity=1
60	0	All Classes of Data	1, 20, 21	6		
60	1	Class 0 Data	1	6		
60	2	Class 1 Data	1, 20, 21	6, 7, 8		
60	3	Class 2 Data	1, 20, 21	6, 7, 8		
60	4	Class 3 Data	1, 20, 21	6, 7, 8		
70	1	File Identifier	1, 2	6	129	7, 8
80	1	Internal Indications	2	0, 1 index=7		
No object			13, 14, 23			

[a] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation
[f] Supports request, but response contains no data

Table B.5 is the default object map that the SEL-387L supports.

Table B.5 SEL-387L DNP3 Default Data Map (Sheet 1 of 2)

Object	Indices	Description
01, 02	000–599	Relay Word, where index is divided by 8 to get the row and the remainder is used as a bit index
01, 02	600–1199	Relay Word from the SER, encoded same as inputs 000–599 with 600 added
01, 02	1200–1215	Relay front-panel targets where 1215 is A, 1208 is 87FAIL, 1207 is EN and 1200 is TST
01, 02	1216	Relay disabled
01, 02	1217	Relay diagnostic failure
01, 02	1218	Relay diagnostic warning
01, 02	1219	New relay event available
01, 02	1220	Settings change or relay restart
10, 12	00–01	Remote bits RB1–RB2
10, 12	02	Pulse Open command OC
10, 12	03	Pulse Close command CC

Table B.5 SEL-387L DNP3 Default Data Map (Sheet 2 of 2)

Object	Indices	Description
10, 12	04	Reset front-panel targets
10, 12	05	Read next relay event
10, 12	06	Remote bit pair RB1–RB2
10, 12	07	Open/Close pair OC and CC
30, 32	00, 01	IA magnitude and angle
30, 32	02, 03	IB magnitude and angle
30, 32	04, 05	IC magnitude and angle
30, 32	06, 07	IG magnitude and angle
30, 32	08, 09	I1 magnitude and angle
30, 32	10, 11	3I2 magnitude and angle
30, 32	12	Frequency
30, 32	13	VDC
30, 32	14	Fault type (see *Table 4.7* for definition)
30, 32	15	Fault current
30, 32	16	Fault frequency
30, 32	17–19	Fault time in DNP format (high, middle, and low 16 bits)
30, 32	20, 21	IAX magnitude and angle
30, 32	22, 23	IBX magnitude and angle
30, 32	24, 25	ICX magnitude and angle
30, 32	26, 27	IGX magnitude and angle
30, 32	28, 29	I1X magnitude and angle
30, 32	30, 31	3I2X magnitude and angle
30, 32	32, 33	IAT magnitude and angle
30, 32	34, 35	IBT magnitude and angle
30, 32	36, 37	ICT magnitude and angle
30, 32	38, 39	IGT magnitude and angle
30, 32	40, 41	I1T magnitude and angle
30, 32	42, 43	3I2T magnitude and angle

NOTE: When values to be returned for indices 20–43 of object 30, 32 are invalid, DNP returns 32767.

Binary Inputs (Objects 1 and 2) are supported as defined by *Table B.5*. Binary inputs 0–599 and 1200–1220 are scanned approximately once per second to generate events. When time is reported with these event objects, it is the time at which the scanner observed the bit change. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. To determine the point index of an element, consult the table containing Relay Word bits. Locate the element of interest in the table and note the row number. From that row number, subtract the row number of the first Relay Word row and multiply that result by 8. This is the index of the right-most element of the Relay Word row of the element in question. Count over to the original element and add the index of the right-most element to get the point index. Binary Inputs 600–1199 (SER RANGE) are derived from the SER and carry the time stamp of actual occurrence. Static reads from these inputs will show the same data as a read from the corresponding index in the RW RANGE group. Only points that are actually in the SER list generate events in the 600–1199 group.

Control Relay Output Block objects (object 12, variation 1) are supported. The control relays correspond to the remote bits and other functions, as shown above. The Trip/Close bits take precedence over the control field. The control field is interpreted as shown in *Table B.6*.

Table B.6 Control Field Elements

Index	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
00–01	Set	Clear	Set	Clear	Pulse	Clear
02–05	Pulse	Do nothing	Pulse	Do nothing	Pulse	Do nothing
06	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1
07	Pulse CC	Pulse OC	Pulse CC	Pulse OC	Pulse CC	Pulse OC

If the Trip bit is set, a Latch Off operation is performed on the specified index. If the Close bit is set, a Latch On operation is performed. The Status field is used exactly as defined; all other fields are ignored. A pulse operation asserts a point for a single processing interval. Qualifier codes of 17h and 28h are supported in both the request and response messages. Only Select (3), Operate (4), Direct Operate (5), and Direct Operate, No Ack (6) function codes are allowed with these objects. Exercise caution with multiple remote bit pulses in a single message (i.e., point count > 1), because this may result in the relay ignoring some of the pulse commands and returning an already active status.

Binary Output status (Object 10 variation 2) is supported. Only the Read function code (1) is allowed on this object. Reads from points 0–15 respond with the online bit set and the state of the requested remote bit. Reads from points 02–05 respond with the online bit set and a state of 0.

Counter objects default to 16-bit counters without flag (object 20, variation 6). Variation 5 is also allowed. Frozen Counters (object 21) are not supported. Event Counters (object 22) are supported with a default variation of 2. Variations 1, 5, and 6 are also allowed. Only the Read function code (1) is allowed on this object. The relay scans counters at a one-second rate and bases the event time stamp on this scan. There are not any counters.

Analog Input objects are supported, as defined by *Table B.6*. The default variation for static objects is 4 and for event objects is 2. All variations of Analog Inputs (30) and Analog Change Events (32) are supported. Frozen analogs (objects 31 and 33) are not supported. When flags are requested, only the online (always set) and the over-range (cannot convert number to desired variation) bits are used. Only the Read function code (1) is allowed on these objects. The values are reported in primary units. The even-numbered analog points in 0–11 and 20–43 (current magnitudes) are scaled according to the DECPLA setting. Analog inputs 12–13, 16, and the odd-numbered points in 0–11 and 20–43 (angles) are scaled by 100. The remaining analogs are not scaled. The relay performs a dead-band check after application of any scaling.

Event class messages are generated whenever an input changes beyond the value given by the ANADB setting. The angles (the odd-numbered points in 0–11 and 20–43) will only generate an event if, in addition to their dead-band check, the corresponding magnitude (the preceding point) contains a value greater than the value given by the ANADB setting. The relay scans analog inputs at approximately a one-second rate, except for analogs 14–19. During a scan, all events generated will use the time of scan initiation. The relay derives analogs 14–19 from the history queue data for the most recently read fault without generating event messages. Analog 14 is a 16-bit composite value, where the upper byte is defined in the following table.

Value	Event Cause
1	**TRIGGER** Command
2	**PULSE** Command
4	Trip Element
8	ER Element

The lower byte is defined as follows:

Value	Fault Type
0	Indeterminate
1	A-phase
2	B-phase
4	C-phase
8	Ground

The lower byte may contain any combination of the above bits (e.g., a 6 means a B-to-C fault and a 9 is an A-to-Ground fault). If Analog 14 is 0, fault information has not been read and the related analogs (15–19) do not contain valid data.

All variations of Analog Output objects (40 and 41) are supported, with variation 2 being the default. Flags with the status objects are always 0. The Control Status field is ignored. All four operate function codes (3, 4, 5, and 6) are supported for object 41. There are not any analog outputs.

Of the Time and Date objects, only object 50, variation 1 and object 52, variation 2 are supported. The Unsynchronized Time and Date CTO object (object 51 variation 1) is only used in conjunction with Binary Input Event Relative Time Objects. Qualifier code 7 is supported for these objects.

Class Objects (60) are supported. Class 0 requests include all static data in their default variations. Class 1, 2, or 3 may be supported, based on your settings. If the supported event class is selected, all unread events are supplied in their default variations.

The only device object that is supported is Internal Indications (80). Only the Write function code (2) is allowed on this object, to clear the RESTART bit.

Relay Summary Event Data

Whenever there are unread relay event summary data (fault data), binary input point 1219 will be set. To load the next available relay event summary, the master should pulse binary output point 5. This loads the event summary analogs (points 12–19) with information from the next oldest relay event summary. Because the summary data are stored in a first-in, first-out manner, loading the next event discards the data from the previous event. The event summary analogs retain this information until the next event is loaded. If no further event summaries are available, attempting to load the next event causes the event type analog (point 14) to be set to 0. *Table B.7* shows the number of DNP event queues for binary inputs, analog inputs, and counters.

Table B.7 Event Queues for Binary Inputs, Analog Inputs, and Counters

Object	Number of Events
Binary inputs	512
Analog inputs	128
Counters	128

Point Remapping

The analog and binary input points (objects 1, 2, 30, and 32) may be re-mapped via the **DNP** command. The map consists of two lists of indices: one for the analogs (30 and 32) and the other for the binaries (1 and 2), corresponding to those listed in the DNP data map. The order in which they occur in the list determines the corresponding value index reported to the DNP master. If a value is not in the list, it is not available to the DNP master. All binaries and analogs may be included in the list, but each can occur only once. The maps are stored in EEPROM and are protected with a checksum. The **DNP** command is only available if DNP has been selected on one of the ports and has the following format:

DNP [*type*]

where *type* can be A (Analog), B (Binary), S (Analog only), T (Binary only) or omitted.

if the **DNP** command is issued without parameters, the relay displays both the analog and binary maps, which have the following format:

```
=>>DNP <STX>
Analogs  =    10 8 17 15 1 26 27 28 29 30 31 32 33 34 35 \
              36 40 41 42 43
Binaries =    Default Map<ETX>
=>>
```

If the **DNP** command is issued with an S parameter, the relay displays only the analog map. Likewise, parameter T causes the relay to display only the binary map. If the map checksum is invalid, the relay will report during a display command that the map is corrupted:

```
=>>DNP T <STX>
Binaries = Map Corrupted<ETX>
=>>
```

If the map is corrupted, DNP responds to all master data requests with an unknown point error. If the **DNP** command is issued with an A or B parameter at level 2 or greater, the relay prompts you to enter indices for the corresponding list, where parameter A specifies the Analog list and parameter B specifies the Binary list. The relay accepts lines of indices until you enter a line without a final continuation character (\). Each line of input accepts a maximum of 80 characters. However, all the points can be remapped, by using multiple lines with continuation characters (\) at the end of the intermediate lines. Entering a single blank line as the first line disables the remapping for that type (i.e., the relay uses the default analog or binary map). The following examples illustrate remapping of analog quantities (DNP A) and binary quantities (DNP B):

```
=>>DNP A <Enter>
Enter the new DNP Analog map
112 113 \<CR>
114 115 116 117 \<CR>
118 119<CR>   [comment: Final entry]
Save Changes (Y/N)? Y <Enter>

=>>DNP B <Enter>
Enter the new DNP Binary map
<CR>           [comment: No change]
Save Changes (Y/N)? Y <Enter>
=>>
```

To change back to the default map after changes are made, type the **DNP A** command, but press the **<Enter>** key instead of entering data:

```
=>>DNP A <Enter>

Enter the new DNP Analog map

<Enter>

Save Changes (Y/N)? Y <Enter>
=>>
```

The **DNP** command reports an error for duplicate entry of an index, use of an invalid index, or for entry of nonnumeric data.

```
xx is referenced more than once, changes not saved

xx is not a valid index, changes not saved
Invalid format, changes not saved
```

This page intentionally left blank

Appendix C

Fast SER Messages, Fast Meter, and Fast Operate Commands

Overview

SEL relays have two separate data streams that share the same serial port. The human data communications with the relay consist of ASCII character commands and reports that are intelligible to humans using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a 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-387L Relay.

Fast Meter, Fast Operate, and Fast SER Messages

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. The relay can also send unsolicited Fast SER messages automatically. If the relay is connected to an SEL communications processor, these messages provide the mechanism that the communications processor uses for substation control and data acquisition (SCADA) or distributed control system (DCS) functions that occur simultaneously with ASCII interaction. For more information on the Fast Meter and Fast Operate generic commands and messages that provide configuration messages, see *Application Guide AG95-10* available on the SEL website. This section summarizes the binary commands and messages and includes our recommendation for using Fast Commands and Compressed ASCII configuration information to communicate with the relay. You need this information to develop or specify the software an external device uses to communicate with the SEL-387L using Fast Messages. To support this type of development, you will also need to contact SEL (see *Technical Support on page 5.18*) for Fast Message protocol details.

Table C.1 Fast Meter Commands

Command (Hex)	Name	Description
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information
A5C1h	Fast Meter configuration block	Defines contents of Fast Meter data message
A5D1h	Fast Meter data message	Sends the Fast Meter block with message length, XY components (X and Y components of IA, IB, IC, Freq, Vbatt, IAX, IBX, ICX, IAT, IBT, and ICT), and digital banks (TAR0–TAR73)
A5B9h	Status bits clear command	Clears the Fast Meter Status byte

Table C.2 Fast Meter Configuration Messages

ASCII Commands	Name	Description
BNA	ASCII names of status bits	Sends the names of the status bits
DNA	ASCII names of digital I/O	Sends the digital I/O names
ID	ASCII FID and TID strings	Sends the firmware ID and TID setting

Table C.3 Fast Operate Commands

Command (Hex)	Name	Description
A5CEh	Fast Operate configuration block	Defines available circuit breaker, remote bits, and associated commands, if setting FASTOP = Y for this port.
A5E0h	Fast Operate remote bit set/clear/pulse	External device sends message to set/clear/pulse a remote bit.
A5E3h	Fast Operate open/close message	External device sends message to perform a fast open/close operation.
A5CDh	Fast Operate reset definition block	Defines Fast Reset message.
A5EDh	Fast Operate reset command	External device sends message to perform a fast reset operation. For this operation the relay must be enabled, and FASTOP = Y.

Table C.4 Fast Message Commands

Command (Hex)	Name	Description
A546h	Fast Message definition block	Defines available Fast Message definitions and configuration information, allows the relay to begin sending unsolicited data to the master, discontinue transferring unsolicited data interrupt transmission to respond to a ping message, then continue with transmission, and message acknowledgment.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum. Most commands are available only in SEL ASCII or Compressed ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports may have fewer characters than conventional SEL ASCII reports, because the compressed reports reduce blanks, tabs, and other white space between data fields to a single comma.

Compressed ASCII Message Format

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX:

```
<STX><MESSAGE LINE 1><CR><LF>
<MESSAGE LINE 2><CR><LF>
o
o
o
<LAST MESSAGE LINE><CR><LF><ETX>
```

Each line in the message consists of one or more data fields, a checksum field, and a <CR><LF>. Commas separate adjacent fields. Each field is either a number or a string. Number fields contain base-10 numbers using the ASCII characters 0–9, plus (+), minus (–), and period (.). String fields begin and end with quote marks (" ") and contain standard ASCII characters. Hexadecimal numbers are contained in string fields. The checksum consists of four ASCII characters that are the hexadecimal representation of the two-byte binary checksum. The checksum value is the sum of the first byte on a line (first byte following <STX>, <CR>, or <CR><LF>) through the comma preceding the checksum. If you request data with a Compressed ASCII command and these data are not available, (in the case of an empty history buffer or invalid event request), the relay responds with the following Compressed ASCII format message:

```
<STX>"No Data Available","0668"<CR><ETX>
```

Table C.5 lists the Compressed ASCII commands and contents of the command responses.

Where:

`"No Data Available"` is a text string field.

`"0668"` is the checksum field, which is a hexadecimal number represented by a character string.

Table C.5 Compressed ASCII Commands

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CEVENT	Event report	1
CHISTORY	List of events	1
CSTATUS	Self-diagnostic status	1
CSUMMARY	Summary of an event report	1
DNAME X	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

Appendix D
PC Software

Overview

NOTE: PC software is updated more frequently than relay firmware. As a result, the descriptions in this section may differ slightly from the software. Select **Help** in the PC software for information.

SEL provides many PC software solutions (applications) that support SEL devices. These software solutions are listed in *Table D.1*.

Visit selinc.com to obtain the latest versions of the software listed in *Table D.1*.

Table D.1 SEL Software Solutions

Product Name	Description
SEL Compass®	This application provides an interface for web-based notification of product updates and automatic software updating.
ACSELERATOR QuickSet® SEL-5030 Software	QuickSet is a powerful setting, event analysis, and measurement tool that aids in applying and using the relay. See the *ACSELERATOR QuickSet SEL-5030 Software Instruction Manual* for information about the various QuickSet applications.[a]
ACSELERATOR Architect® SEL-5032 Software	Use this application to design and commission SEL IEDs in IEC 61850 substations, create and map GOOSE messages, utilize predefined reports, create and edit data sets, and read in SCD, ICD, and CID files.
ACSELERATOR TEAM® SEL-5045 Software	The TEAM system provides custom data collection and movement of a wide variety of device information. The system provides tools for device communication, automatic collection of data, and creation of reports, warnings, and alarms. See *ACSELERATOR Team SEL-5045 Software Instruction Manual* for information about the various TEAM applications.
SEL-5601-2 SYNCHROWAVE® Event Software	Converts SEL Compressed ASCII and COMTRADE event report files to oscillography.
Cable Selector SEL-5801 Software	Selects the proper SEL cables for your application.

[a] The SEL-387L does not support the freeform logic described in the QuickSet instruction manual.

This page intentionally left blank

SEL-387L Relay Command Summary

Command	Access Level	Description
2AC	1	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 2 password in order to enter Access Level 2. The prompt is: =>>.
ACC	0	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 1 password to enter Access Level 1. The Access Level 1 commands primarily allow the user to look at information (e.g., metering), not change it. The prompt is: =>.
BAC	1	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts for entry of the Access Level B password. The prompt is: ==>.
CAL	2	Go to Access Level C. Should only be used under direction of SEL factory or to change the default password.
CAS	0	Compressed ASCII configuration data.
CEV [*n* S*x* L*y* L R C]	1	Compressed event report (parameters in [ ] are optional)
where: ***n***		event number (1–40, defaults to 1).
S*x*		*x* samples per cycle (4 or 16); defaults to 4. If S*x* parameter is present, it overrides the L parameter.
L*y*		*y* cycles event report length (1–15), defaults to 15 if not specified, unfiltered reports are one cycle longer.
L		16 samples per cycle; overridden by the S*x* parameter, if present.
R		specifies raw (unfiltered) data; defaults to 16 samples per cycle unless overridden by the S*x* parameter. Defaults to 16 cycles in length unless overridden with the L*y* parameter.
C		specifies 16 samples per cycle, 15-cycle length.
CHIS	1	Compressed history.
CLO	B	Assert Relay Word bits CLOSE1–CLOSE4.
COM	1	Show a communications summary report.
COM C	1	Clear the communications summary report.
COM L	1	Show a communications summary report and history of up to 256 entries.
COM L *d1*	1	Show a communications summary report for events occurring on date *d1*.
COM L *d1 d2*	1	Show a communications summary report for events occurring between dates *d1* and *d2*. Date Format is YY/MM/DD or YYYY/MM/DD.
COM L *m n*	1	Show a communications summary report for events *n*–*m*.
COM L *n*	1	Show a communications summary for latest *n* events.
COM X	2	Show a communication log summary for Channel X.
COM X C	2	Clear a communication log summary for Channel X.

Command	Access Level	Description

CON *n*	2	Control Remote bit RB*n* (Remote Bit *n*; *n* = 1 or 2). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following:
		SRB *n* set Remote Bit *n* (assert RB*n*).
		CRB *n* clear Remote Bit *n* (deassert RB*n*).
		PRB *n* pulse Remote Bit *n* (assert RB*n* for 1/4 cycle). To enable supervisory control, pulse RB1. To disable supervisory control, pulse RB2.
		For example, to assert Remote Bit 1 (which enables supervisory control), type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01; SRB 1 <Enter>`
		To deassert Remote Bit 1, type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01: CRB 1 <Enter>`
		To pulse Remote Bit 1, type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01: PRB 1 <Enter>`

CST	1	Compressed status report.
CSU	1	Compressed event summary.
DAT	1	Set/show relay date.
DAT y/m/d	1	Set the date.
DNP	1	Set/show DNP map (available only with DNP option; refer to *Appendix B: Distributed Network Protocol* for DNP point mapping).
EVE *n*	1	Show event report number *n* with 1/4-cycle resolution.
EVE A	1	Specify that only the analog section of the event is displayed.
EVE *n* C	1	Show event report *n* in Compressed ASCII format for use with SEL-5601-2 SYNCHROWAVE® Event Software.
EVE C/CEV	1	Display the report in Compressed ASCII format.
EVE D	1	Specify that only the digital section of the event is displayed.
EVE L *n*	1	Show event report number *n* with 1/16-cycle resolution.
EVE R	1	Specify the unfiltered (raw) event report. Defaults to 16 samples per cycle unless overridden with the S*x* parameter.
EVE R *n*	1	Show raw event report number *n* with 1/16-cycle resolution.
EVE S*x*	1	Display *x* samples per cycle (4 or 16); defaults to 4 if not listed.
HIS *n*	1	Show brief summary of the *n* latest event reports.
HIS C	1	Clear the brief summary and corresponding event reports.
IRI	1	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
L_D	2	Load new firmware.
MET *k*	1	Display instantaneous metering data (currents and alpha plane) for local and remote terminals. Enter *k* for repeat count.
OPE	B	Assert Relay Word bits TRIP1–TRIP4 (Close TRIP outputs, see *Figure 3.2*).
PAS 1	2	Change Access Level 1 password (default password: OTTER).
PAS 2	2	Change Access Level 2 password (default password: TAIL).
PAS B	2	Change Access Level B password (default password: EDITH).

Command	Access Level	Description
PAS C	C	Change Access Level C password (default password: CLARKE).
PUL *n k*	B	Pulse Output Contact *n* for *k* (1–30) seconds. Parameter *n* must be specified; *k* defaults to 1 if not specified. Valid options are TRIP1–TRIP4 and CLOSE1–CLOSE4.
QUI	1	Quit. Returns to Access Level 0. Terminates SEL Distributed Port Switch Protocol (LMD) connection (available in all access levels).
SER *d1*	1	Show rows in the Sequential Events Recorder (SER) event report from date *d1*.
SER *d1 d2*	1	Show rows in the Sequential Events Recorder (SER) event report from date *d1* to date *d2*. Uses the date format of year, month, day (YMD).
SER *n*	1	Show the latest *n* rows in the Sequential Events Recorder (SER) event report.
SER *m n*	1	Show rows *m* through *n* in the Sequential Events Recorder (SER) event report.
SER C	1	Clear the Sequential Events Recorder (SER).
SET	2	Change Relay Identification, Terminal Identification, and relay communication addresses.
SET P *n*	2	Change Port *n* settings (available only with DNP option).
SHO	1	Show Relay Identification, Terminal Identification, and relay communication addresses.
SHO P *n*	1	Show Port *n* settings (*n* = F, 1, 2, 3) (available only with DNP option).
STA	1	Show relay self-test status.
STA C	2	Reset self-test warnings/failures and reboots relay.
SUM	1	Show newest event summary.
SUM A	1	Acknowledge oldest event summary.
SUM A N	1	Display or acknowledge event summary number “N.”
SUM N	1	View oldest unacknowledged event report.
TAR *n k*	1	Display Relay Word row. If *n* = 0–73, display row *n*. If *n* is an element name (e.g., 87LA) display the row containing element *n*. Enter *k* for repeat count.
TAR R	1	Reset the front-panel tripping targets.
TIM	1	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 *[time]*	1	Trigger an event report. Enter time to trigger an event at an exact specified time, in 24-hour format.
TST X	2	Test the differential communication channel.
VER	1	Display version and configuration information.

This page intentionally left blank

SEL-387L Relay Command Summary

Command	Access Level	Description
2AC	1	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 2 password in order to enter Access Level 2. The prompt is: =>>.
ACC	0	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for entry of the Access Level 1 password to enter Access Level 1. The Access Level 1 commands primarily allow the user to look at information (e.g., metering), not change it. The prompt is: =>.
BAC	1	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts for entry of the Access Level B password. The prompt is: ==>.
CAL	2	Go to Access Level C. Should only be used under direction of SEL factory or to change the default password.
CAS	0	Compressed ASCII configuration data.
CEV [*n* S*x* L*y* L R C]	1	Compressed event report (parameters in [ ] are optional)
where: ***n***		event number (1–40, defaults to 1).
S*x*		*x* samples per cycle (4 or 16); defaults to 4. If S*x* parameter is present, it overrides the L parameter.
L*y*		*y* cycles event report length (1–15), defaults to 15 if not specified, unfiltered reports are one cycle longer.
L		16 samples per cycle; overridden by the S*x* parameter, if present.
R		specifies raw (unfiltered) data; defaults to 16 samples per cycle unless overridden by the S*x* parameter. Defaults to 16 cycles in length unless overridden with the L*y* parameter.
C		specifies 16 samples per cycle, 15-cycle length.
CHIS	1	Compressed history.
CLO	B	Assert Relay Word bits CLOSE1–CLOSE4.
COM	1	Show a communications summary report.
COM C	1	Clear the communications summary report.
COM L	1	Show a communications summary report and history of up to 256 entries.
COM L *d1*	1	Show a communications summary report for events occurring on date *d1*.
COM L *d1 d2*	1	Show a communications summary report for events occurring between dates *d1* and *d2*. Date Format is YY/MM/DD or YYYY/MM/DD.
COM L *m n*	1	Show a communications summary report for events *n*–*m*.
COM L *n*	1	Show a communications summary for latest *n* events.
COM X	2	Show a communication log summary for Channel X.
COM X C	2	Clear a communication log summary for Channel X.

Command	Access Level	Description

CON *n*	2	Control Remote bit RB*n* (Remote Bit *n*; *n* = 1 or 2). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following:
		SRB *n* set Remote Bit *n* (assert RB*n*).
		CRB *n* clear Remote Bit *n* (deassert RB*n*).
		PRB *n* pulse Remote Bit *n* (assert RB*n* for 1/4 cycle). To enable supervisory control, pulse RB1. To disable supervisory control, pulse RB2.
		For example, to assert Remote Bit 1 (which enables supervisory control), type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01; SRB 1 <Enter>`
		To deassert Remote Bit 1, type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01: CRB 1 <Enter>`
		To pulse Remote Bit 1, type the following:
		`=>>CON 1 <Enter>`
		`CONTROL RB01: PRB 1 <Enter>`

CST	1	Compressed status report.
CSU	1	Compressed event summary.
DAT	1	Set/show relay date.
DAT y/m/d	1	Set the date.
DNP	1	Set/show DNP map (available only with DNP option; refer to *Appendix B: Distributed Network Protocol* for DNP point mapping).
EVE *n*	1	Show event report number *n* with 1/4-cycle resolution.
EVE A	1	Specify that only the analog section of the event is displayed.
EVE *n* C	1	Show event report *n* in Compressed ASCII format for use with SEL-5601-2 SYNCHROWAVE® Event Software.
EVE C/CEV	1	Display the report in Compressed ASCII format.
EVE D	1	Specify that only the digital section of the event is displayed.
EVE L *n*	1	Show event report number *n* with 1/16-cycle resolution.
EVE R	1	Specify the unfiltered (raw) event report. Defaults to 16 samples per cycle unless overridden with the S*x* parameter.
EVE R *n*	1	Show raw event report number *n* with 1/16-cycle resolution.
EVE S*x*	1	Display *x* samples per cycle (4 or 16); defaults to 4 if not listed.
HIS *n*	1	Show brief summary of the *n* latest event reports.
HIS C	1	Clear the brief summary and corresponding event reports.
IRI	1	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
L_D	2	Load new firmware.
MET *k*	1	Display instantaneous metering data (currents and alpha plane) for local and remote terminals. Enter *k* for repeat count.
OPE	B	Assert Relay Word bits TRIP1–TRIP4 (Close TRIP outputs, see *Figure 3.2*).
PAS 1	2	Change Access Level 1 password (default password: OTTER).
PAS 2	2	Change Access Level 2 password (default password: TAIL).
PAS B	2	Change Access Level B password (default password: EDITH).

Command	Access Level	Description
PAS C	C	Change Access Level C password (default password: CLARKE).
PUL *n k*	B	Pulse Output Contact *n* for *k* (1–30) seconds. Parameter *n* must be specified; *k* defaults to 1 if not specified. Valid options are TRIP1–TRIP4 and CLOSE1–CLOSE4.
QUI	1	Quit. Returns to Access Level 0. Terminates SEL Distributed Port Switch Protocol (LMD) connection (available in all access levels).
SER *d1*	1	Show rows in the Sequential Events Recorder (SER) event report from date *d1*.
SER *d1 d2*	1	Show rows in the Sequential Events Recorder (SER) event report from date *d1* to date *d2*. Uses the date format of year, month, day (YMD).
SER *n*	1	Show the latest *n* rows in the Sequential Events Recorder (SER) event report.
SER *m n*	1	Show rows *m* through *n* in the Sequential Events Recorder (SER) event report.
SER C	1	Clear the Sequential Events Recorder (SER).
SET	2	Change Relay Identification, Terminal Identification, and relay communication addresses.
SET P *n*	2	Change Port *n* settings (available only with DNP option).
SHO	1	Show Relay Identification, Terminal Identification, and relay communication addresses.
SHO P *n*	1	Show Port *n* settings (*n* = F, 1, 2, 3) (available only with DNP option).
STA	1	Show relay self-test status.
STA C	2	Reset self-test warnings/failures and reboots relay.
SUM	1	Show newest event summary.
SUM A	1	Acknowledge oldest event summary.
SUM A N	1	Display or acknowledge event summary number “N.”
SUM N	1	View oldest unacknowledged event report.
TAR *n k*	1	Display Relay Word row. If *n* = 0–73, display row *n*. If *n* is an element name (e.g., 87LA) display the row containing element *n*. Enter *k* for repeat count.
TAR R	1	Reset the front-panel tripping targets.
TIM	1	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 *[time]*	1	Trigger an event report. Enter time to trigger an event at an exact specified time, in 24-hour format.
TST X	2	Test the differential communication channel.
VER	1	Display version and configuration information.

This page intentionally left blank

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Phone: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com