SEL-787 Relay
Transformer Protection Relay

Instruction Manual

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SCHWEITZER ENGINEERING LABORATORIES, INC.

PM787-01

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Preface

Manual Overview

The SEL-787 Transformer Protection Relay Instruction Manual describes common aspects of transformer relay application and use. It includes the necessary information to install, set, test, and operate the relay.

An overview of each manual section and topics follows:

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

Section 1: Introduction and Specifications. Describes the basic features and functions of the SEL-787; lists the relay specifications.

Section 2: Installation. Describes how to mount and wire the SEL-787; illustrates wiring connections for various applications.

Section 3: PC Software. Describes the features, installation methods, and types of help available with the ACSELERATOR QuickSet SEL-5030 Software.

Section 4: Protection and Logic Functions. Describes the operating characteristic of each protection element, using logic diagrams and text, and explains how to calculate element settings; describes contact output logic, automation, and report settings.

Section 5: Metering and Monitoring. Describes the operation of each metering function; describes the monitoring functions.

Section 6: Settings. Describes how to view, enter, and record settings for protection, control, communications, logic, and monitoring.

Section 7: Communications. Describes how to connect the SEL-787 to a PC for communication; shows serial port pinouts; lists and defines serial port commands. Describes the communications port interfaces and protocols supported by the relay for serial and Ethernet.

Section 8: Front-Panel Operations. Explains the features and use of the front panel, including front-panel command menu, default displays, and automatic messages.

Section 9: Analyzing Events. Describes front-panel LED operation, trip-type front-panel messages, event summary data, standard event reports, and Sequential Events Recorder (SER) report.

Section 10: Testing and Troubleshooting. Describes protection element test procedures, relay self-test, and relay troubleshooting.

Appendix A: Firmware, ICD, and Manual Versions. Lists the current relay firmware version and details differences between the current and previous versions. Provides a record of changes made to the manual since the initial release.

Appendix B: Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in flash memory.

Appendix C: SEL Communications Processors. Provides examples of how to use the SEL-787 with SEL communications processors for total substation automation solutions.

Appendix D: DNP3 Communications. Describes the DNP3 protocol support provided by the SEL-787.

Appendix E: Modbus Communications. Describes the Modbus protocol support provided by the SEL-787.

Appendix F: IEC 61850 Communications. Describes IEC 61850 implementation in the SEL-787.

Appendix G: DeviceNet Communications. Describes the use of DeviceNet (data-link and application protocol) over CAN (controller area network).

Appendix H: MIRRORED BITS Communications. Describes how SEL protective relays and other devices can directly exchange information quietly, securely, and with minimum cost.

Appendix I: Synchrophasors. Describes the Phasor Measurement Control Unit (PMCU), and accessing Synchrophasor data via ASCII Command (**MET PM**) and IEEE C37.118 Protocol.

Appendix J: Relay Word Bits. Lists and describes the Relay Word bits (outputs of protection and control elements).

Appendix K: Analog Quantities. Lists and describes the Analog Quantities (outputs of analog elements).

Appendix L: Protection Application Examples. Describes transformer winding and CT connection compensation settings examples.

SEL-787 Relay Command Summary. Briefly describes the serial port commands that are fully described in *Section 7: Communications*.

Safety Information

Dangers, Warnings, and Cautions

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

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

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

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

Safety Symbols

The following symbols are often marked on SEL products.

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

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with 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.
⚠CAUTION To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.	**⚠ATTENTION** Pour assurer la sécurité et le bon fonctionnement, il faut vérifier les classements d’équipement ainsi que les instructions d’installation et d’opération avant la mise en service ou l’entretien de l’équipement. Il faut vérifier l’intégrité de toute connexion de conducteur de protection avant de réaliser d’autres actions. L’utilisateur est responsable d’assurer l’installation, l’opération et l’utilisation de l’équipement pour la fonction prévue et de la manière indiquée dans ce manuel. Une mauvaise utilisation pourrait diminuer toute protection de sécurité fournie par l'équipement.
For use in Pollution Degree 2 environment.	Pour utilisation dans un environnement de Degré de Pollution 2.
Ambient air temperature shall not exceed 50°C (122°F).	La température ambiante de l'air ne doit pas dépasser 50°C (122°F).
For use on a flat surface of a Type 1 enclosure.	Pour utilisation sur une surface plane d'un boîtier de Type 1.
Terminal Ratings Wire Material Use 75°C (167°F) copper conductors only. Tightening Torque Terminal Block: 0.9–1.4 Nm (8–12 in-lb) Compression Plug: 0.5–1.0 Nm (4.4–8.8 in-lb) Compression Plug Mounting Ear Screw: 0.18–0.25 Nm (1.6–2.2 in-lb)	Spécifications des bornes Type de filage Utiliser seulement conducteurs en cuivre 75°C (167°F). Couple de serrage Bornier : 0,9–1,4 Nm (8–12 livres-pouce) Fiche à compression : 0,5–1,0 Nm (4,4–8,8 livres-pouce) Vis à oreille de montage de la fiche à compression : 0,18–0,25 Nm (1,6–2,2 livres-pouce)

Hazardous Locations Safety Marks

⚠WARNING – EXPLOSION HAZARD Open circuit before removing cover.	⚠AVERTISSEMENT – DANGER D'EXPLOSION Ouvrir le circuit avant de déposer le couvercle.
⚠WARNING – EXPLOSION HAZARD Substitution of components may impair suitability for Class I, Division 2.	⚠AVERTISSEMENT – DANGER D'EXPLOSION La substitution de composants peut détériorer la conformité à Classe I, Division 2.
Ambient air temperature shall not exceed –20°C ≤ Ta ≤ +50°C.	La température de l'air ambiant ne doit pas dépasser –20°C ≤ Ta ≤ +50°C.

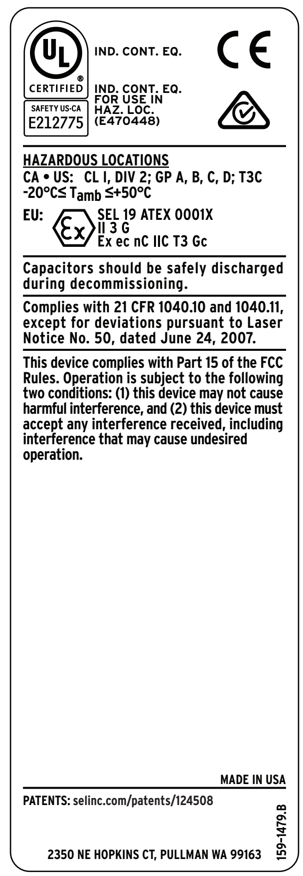
Hazardous Locations Approvals

The SEL-787 is UL certified for hazardous locations to Canadian and U.S. standards. In North America, the relay is approved for Hazardous Locations Class I, Division 2, Groups A, B, C, and D, and temperature class T3C in the maximum surrounding air temperature of 50°C.

The SEL-787 shall be installed in an indoor or outdoor (extended) locked enclosure that provides a degree of protection to personnel against access to hazardous parts. In either environment, the relay shall be protected from direct sunlight, precipitation, and full wind pressure.

To comply with the requirements of the European ATEX standard for hazardous location, the SEL-787 shall be installed in an ATEX-certified enclosure with a tool-removable door or cover that provides a degree of protection not less than IP54, in accordance with EN 60079-7. The enclosure shall be limited to the surrounding air temperature range of –20°C ≤ Ta ≤ +50°C. The enclosure should be certified to these requirements or be tested for compliance as part of the complete assembly. The enclosure must be marked "WARNING—Do not open when a explosive atmosphere is present."

The figure shows the compliance label that is located on the left side of the device.



Product Compliance Label for the SEL-787

Other Safety Marks

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING 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 This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING To install an option card, the relay must be de-energized and then re-energized. When re-energized, the relay will reboot. Therefore, de-energize the protected equipment before installing the option card to prevent damage to the equipment.	⚠AVERTISSEMENT Pour installer une carte à option, le relais doit être éteint et ensuite rallumé. Quand il est rallumé, le relais redémarrera. Donc, il faut éteindre l'équipement protégé avant d'installer la carte à option pour empêcher des dégats à l'équipement.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠WARNING Overtightening the mounting nuts may permanently damage the relay chassis.	⚠AVERTISSEMENT Une pression excessive sur les écroux de montage peut endommager de façon permanente le chassis du relais
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION Looking into optical connections, fiber ends, or bulkhead connections can result in hazardous radiation exposure.	⚠ATTENTION Regarder vers les connecteurs optiques, les extrémités des fibres oules connecteurs de cloison peut entraîner une exposition à des rayonnements dangereux.

Other Safety Marks

⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.

General Information

Typographic Conventions

There are three ways to communicate with the SEL-787:

➤ Using a command line interface on a PC terminal emulation window.

➤ Using the front-panel menus and pushbuttons.

➤ Using QuickSet.

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

Example	Description
STATUS	Commands typed at a command line interface on a PC.
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC dialog boxes and menu selections. The > character indicates submenus.
ENABLE	Relay front- or rear-panel labels and pushbuttons.
`Main > Meters`	Relay front-panel LCD menus and relay responses. The > character indicates submenus.

Trademarks

All brand or product names appearing in this document are the trademark or registered trademark of their respective holders. No SEL trademarks may be used without written permission.

SEL trademarks appearing in this manual are shown in the following table.

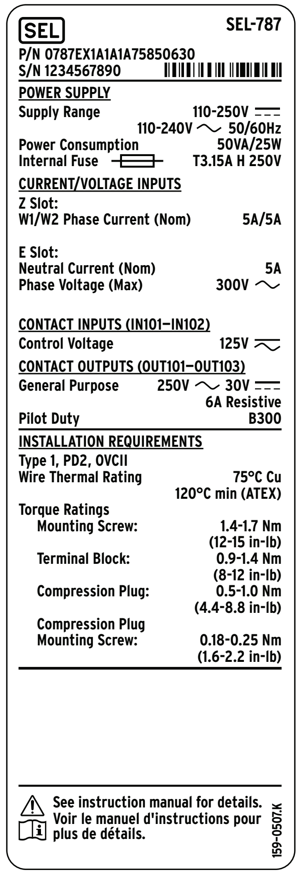
ACSELERATOR Architect®	SEL-2407®
ACSELERATOR QuickSet®	SELOGIC®
ACSELERATOR Report Server®	SYNCHROWAVE®
MIRRORED BITS®	

Examples

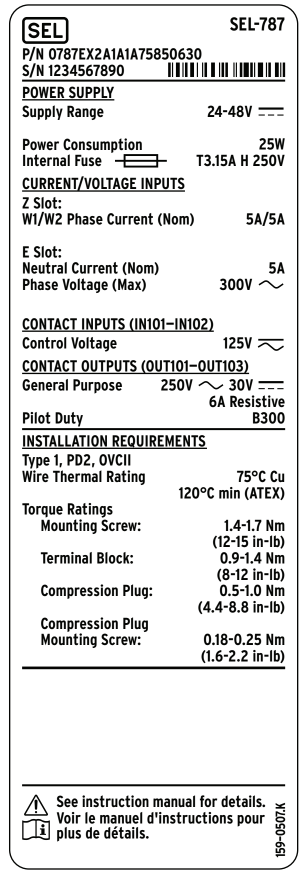
This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-787. These examples are for demonstration purposes only; the firmware identification information or settings values included in these examples may not necessarily match those in the current version of your SEL-787.

Product Labels

The two labels shown below are the product labels for the high-voltage and low-voltage power supply options. The label is located on the left side panel of the product. The label shows the serial number, model number, and the ratings of the product.



(High-Voltage Supply)



(Low-Voltage Supply)

LED Emitter

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

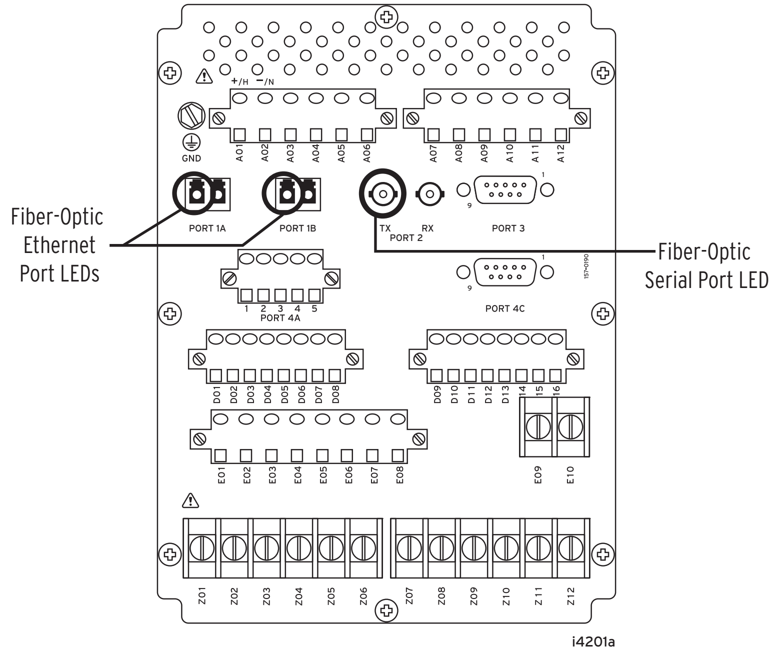
⚠CAUTION
Looking into optical connections, fiber ends, or bulkhead connections can result in hazardous radiation exposure.

The following table shows LED information specific to the SEL-787 (see *Figure 2.9* for the location of fiber-optic Ethernet PORT 1 [or 1A, 1B] and PORT 2, the ports using these LEDs, on the relay).

SEL-787 LED Information

Item	Fiber-Optic Ethernet Port 1 (1A, 1B)	Port 2
Mode	Multimode	Multimode
Wavelength	1300 nm	820 nm
Source	LED	LED
Connector type	LC	ST
Typical Output power	–15.7 dBm	–16 dBm

The following figure shows the LED location specific to the SEL-787 (see *Figure 2.9* for the complete rear-panel drawing).



SEL-787 LED Locations

LED Safety Warnings and Precautions

- Do not look into the end of an optical cable connected to an optical output.
- Do not look into the fiber ports/connectors.
- Do not perform any procedures or adjustments that are not described in this manual.
- During installation, maintenance, or testing of the optical ports, only use test equipment classified as Class 1 laser products.
- Incorporated components such as transceivers and laser/LED emitters are not user serviceable. Units must be returned to SEL for repair or replacement.

Environmental Conditions and Voltage Information

The following table lists important environmental and voltage information.

Condition	Range/Description
Indoor/outdoor use	Indoor
Altitude[a]	To 2000 m
Temperature	
IEC Performance Rating (per IEC/EN 60068-2-1 and IEC/EN 60068-2-2)	–40° to +85°C
Relative humidity	5% to 95%
Main supply voltage fluctuations	To ±10% of nominal voltage

Condition	Range/Description
Overvoltage	Category II
Pollution	Degree 2
Atmospheric pressure	80 to 110 kPa

[a] Consult the factory for derating specifications for higher altitude applications.

Wire Sizes and Insulation

For wiring connections, use 105°C-rated wiring. Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes. Refer to the application note *Wiring SEL-2400, SEL-2200, and SEL-700 Series Devices* (AN2014-08) for wiring and termination guidance. Strip the wires 8 mm (0.31 in) for installation and termination.

Connection Type	Wire Size		Insulation Voltage
	Minimum	Maximum	
Grounding (Earthing)	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min
Current	16 AWG (1.30 mm^2)	12 AWG (3.30 mm^2)	300 V min
Potential (Voltage)	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min
Contact I/O	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min
RTD[a]	28 AWG (0.08 mm^2)	16 AWG (1.30 mm^2)	300 V min
Other	18 AWG (0.80 mm^2)	14 AWG (2.10 mm^2)	300 V min

[a] See Table 2.13 for typical maximum RTD lead lengths.

Instructions for Cleaning and Decontamination

Use a mild soap or detergent solution and a damp cloth to carefully clean the SEL-787 chassis when necessary. Avoid using abrasive materials, polishing compounds, and harsh chemical solvents (such as xylene or acetone) on any surface of the relay.

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 U.S.A.
Phone: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

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Section 1
Introduction and Specifications

Overview

The SEL-787 Transformer Protection Relay is designed to provide current differential and overcurrent protection to two-winding transformers, buses, generators, etc. The basic relay provides current differential and instantaneous and inverse time-overcurrent protection. Voltage-based and RTD-based protection are available as options. All relay models provide monitoring functions.

This manual contains the information needed to install, set, test, operate, and maintain any SEL-787. You need not review the entire manual to perform specific tasks.

Features

Standard Protection Features

- Phase Instantaneous Overcurrent (50P)
- Ground (Residual) Instantaneous Overcurrent (50G)
- Negative-Sequence Overcurrent (50Q)
- Phase Time Overcurrent (51P)
- Ground (Residual) Time Overcurrent (51G)
- Negative-Sequence Time Overcurrent (51Q)
- Current Differential (87)
- Breaker Failure Protection

Optional Protection Features

- Voltage-Based Protection
  - Undervoltage (27)
  - Overvoltage (59)
  - Negative-Sequence Overvoltage (59Q)
  - Directional Power (32)
  - Loss of Potential (60LOP)
  - Frequency (81)
  - Volts/Hertz (24)
- Neutral Current-Based Protection
  - Neutral Instantaneous Overcurrent (50N)
  - Neutral Time Overcurrent (51N)
  - Restricted Earth Fault (REF)

- RTD-Based Protection: As many as ten (10) RTDs may be monitored when an internal RTD card is used, or as many as twelve (12) when an external SEL-2600 RTD Module with the ST option (SEL-2812 compatible) is used. There are separate Trip and Warn settings for each RTD.

Monitoring Features

- Event summaries that contain relay ID, date and time, trip cause, and current/voltage magnitudes
- Event reports including filtered and raw analog data
- Sequential Events Record (SER)
- Compatibility with SEL-3010 Event Messenger
- Transformer Through-Fault Event Monitor
- Load Profile Report
- A complete suite of accurate metering functions

Communications and Control

- EIA-232, front-panel port
- EIA-232, EIA-485, Ethernet (single/dual copper or fiber-optic), and SEL-2812 compatible ST fiber-optic rear-panel port
- IRIG-B time-code input
- Modbus RTU slave, Modbus TCP/IP, DNP3 serial or LAN/WAN, Ethernet FTP, Telnet, SNTP, MIRRORED BITS, IEC 61850, DeviceNet, and Synchrophasors with IEEE C37.118 Protocol
- SEL ASCII, Compressed ASCII, Fast Meter, Fast Operate, Fast SER, Fast Message Protocols, and Event Messenger Protocol
- Programmable Boolean and math operators, logic functions, and analog compare

Models, Options, and Accessories

Models

Complete ordering information is not provided in this instruction manual. See the latest SEL-787 Model Option Table at selinc.com, under Support > Product Literature, Ordering Information (Model Option Tables). Options and accessories are listed below.

SEL-787 Base Unit

- Front panel with large LCD display
  - Four programmable pushbuttons with eight LEDs
  - Eight target LEDs (six programmable)
  - Operator control interface
  - EIA-232 port
- Processor and communications card (Slot **B**)
  - EIA-232 serial port with IRIG-B time code input
  - Multimode (ST) fiber-optic serial port (SEL-2812 compatible)

- EIA-485 serial port with external IRIG-B time code input (terminals B01, B02)
- Six ac current inputs card (Slot Z)
- Power supply card with two digital inputs and three digital outputs (Slot A)
- Three expansion slots for optional cards (Slots C, D, E)
- Protocols
  - Modbus RTU
  - SEL ASCII and Compressed ASCII
  - SEL Fast Meter, Fast Operate, Fast SER, Fast Message
  - Ymodem File Transfer
  - SEL MIRRORED BITS
  - Event Messenger
  - Synchrophasors with C37.118

Options

- Neutral AC Current Option (1 A or 5 A neutral)
- Voltage Option
  - Four-wire wye
  - Open-delta
  - Single phase connected
- Input/Output (I/O) Option
  - Additional digital I/O
  - Additional analog I/O
  - 10 RTD inputs
- Communications Options (Protocol/Ports)
  - EIA-485/EIA-232/Ethernet ports (single/dual copper or fiber-optic)
  - Modbus TCP/IP
  - DeviceNet (**Note:** This option has been discontinued and is no longer available as of September 25, 2017.)
  - IEC 61850 Communications
  - DNP3 serial and LAN/WAN
  - Simple Network Time Protocol (SNTP)

Accessories

Contact your Technical Service Center or the SEL factory for additional detail and ordering information for the following accessories:

- External RTD protection
  - SEL-2600 RTD Module (with ST option only)
  - A simplex 62.5/125 µm fiber-optic cable with ST connector for connecting the external RTD module to the SEL-787
- SEL-2505 Remote I/O module (with SEL-2812 compatible ST fiber-optic port) for connection to relay fiber-optic serial Port 2, or use SEL-2505 with EIA-232 (DB-9) serial port to connect to EIA-232 Port 3 on the relay
- SEL-787 Configurable Labels

- Rack-Mounting Kits
  - For one relay
  - For two relays
  - For one relay and a test switch
- Wall-Mounting Kits
- Bezels for Retrofit
- Replacement Rear Connector Kit
- Relay Wire Termination Kits—See *Application Note AN2014-08: Wiring SEL-2400, SEL-2200, and SEL-700 Series Devices*

For all SEL-787 mounting accessories for competitor products' replacement, including adapter plates, visit selinc.com/applications/mountingselector.

Applications

Refer to *Section 2: Installation* for various applications and their related connection diagrams. The following is a list of possible application scenarios:

- Two-winding transformer protection with current differential and overcurrent elements and through-fault monitor
- Two-winding transformer protection with current differential and overcurrent elements and through-fault monitor with optional restricted earth fault protection (REF) and neutral-overcurrent protection
- Two-winding transformer protection with current differential and overcurrent elements and through-fault monitor with optional voltage elements, power elements, and frequency elements
- Two-winding transformer protection with current differential and overcurrent elements and through-fault monitor with optional internal or external RTD inputs module

Getting Started

IMPORTANT: Upon relay initial power up or Port 1 setting changes or Logic setting changes, the user may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled, as soon as the **ENABLED** LED comes ON (about 5–10 seconds from power up).

Understanding basic relay operation principles and methods will help you use the SEL-787 effectively. This section presents the fundamental knowledge you need to operate the SEL-787, organized by task. These tasks help you become familiar with the relay and include the following:

- *Powering the Relay*
- *Establishing Communication*
- *Checking the Relay Status*
- *Setting the Date and Time*

Perform these tasks to gain a fundamental understanding of relay operation.

Powering the Relay

Power the SEL-787 with 110–240 Vac, 110–250 Vdc or 24/48 Vdc, depending on the part number.

- ➤ Observe proper polarity, as indicated by the **+/H** (terminal **A01**) and the **–/N** (terminal **A02**) on the power connections.
- ➤ Connect the ground lead; see *Grounding (Earthing) Connections on page 2.19*.
- ➤ Once connected to power, the relay does an internal self-check and the **ENABLED** LED illuminates.

Establishing Communication

The SEL-787 base model has two EIA-232 serial communications ports. The following steps require PC terminal emulation software and an SEL Cable C234A (or equivalent) to connect the SEL-787 to the PC. See *Section 7: Communications* for further information on serial communications connections and the required cable pinout.

Step 1. Connect the PC and the SEL-787 using the serial communications cable.

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

Step 3. Start the PC terminal emulation program.

Step 4. Set the PC terminal emulation program to the communications port settings listed in the Default Value column of *Table 1.1*. Also, set the terminal program to emulate either VT100 or VT52 terminals.

Step 5. Press the **<Enter>** key on the PC keyboard to check the communications link.

You will see the = prompt at the left side of the computer screen.

If you do not see the = prompt, check the cable connections, and confirm that the settings in the terminal emulation program are the default values in *Table 1.1*.

Table 1.1 SEL-787 Serial Port Settings

Description	Setting Label	Default Value
SPEED	SPEED	9600
DATA BITS	BITS	8
PARITY	PARITY	N
STOP BITS	STOP	1
PORT TIMEOUT	T_OUT	5
HWDR HAND-SHAKING	RTSCTS	N

Step 6. Type **QUIT <Enter>** to view the relay response header.

You will see a computer screen display similar to *Figure 1.1*. If you see jumbled characters, change the terminal emulation type in the PC terminal emulation program.

```
=>QUIT <Enter>=>QUIT <Enter>
Transformer xyz          Date: 03/10/2008  Time: 10:31:43
Station 1           Time Source: Internal
```

Figure 1.1 Response Header

Step 7. Type **ACC <Enter>** and the appropriate password (see *Table 7.28* for factory-default passwords) to go to Access Level 1.

Checking the Relay Status

Use the **STA** serial port command to view the SEL-787 operational status. Analog channel dc offset and monitored component status are listed in the status report depicted in *Figure 1.2*.

```
=>>STA <Enter>

SEL-787                                  Date: 06/28/2011   Time: 11:00:07.626
TRNSFRMR RELAY                           Time Source: Internal

Serial Num = 12345678910111
FID = SEL-787-R206-V0-Z003001-D20110610                 CID = C351
PART NUM = 0787EX1B0X9X7585063X

SELF TESTS (W=Warn)
  FPGA  GPSB  HMI   RAM   ROM   CR_RAM  NON_VOL  CLOCK  CID_FILE  +0.9V  +1.2V
  OK    OK    OK    OK    OK    OK      OK       OK     OK        0.90   1.20

  +1.5V  +1.8V  +2.5V  +3.3V  +3.75V  +5.0V  -1.25V  -5.0V   BATT
  1.49   1.81   2.51   3.33   3.74    4.96   -1.25   -4.96   3.02

Option Cards
  CARD_C  CARD_D  CARD_E  CURRENT
  OK      OK      OK      OK

Offsets
  IAW1  IBW1  ICW1  IAW2  IBW2  ICW2   IN    VA    VB    VC
  0     0     0     0     0     0     0     0     0     0

  Relay Enabled

=>>
```

Figure 1.2 STA Command Response—No DeviceNet Communications Card or EIA-232/EIA-485 Communications Card

If a communications card with the DeviceNet protocol is present, the status report depicted in *Figure 1.3* applies. If a communications card with Modbus RTU protocol is present, the status report depicted in *Figure 1.2* applies.

```
=>>STA <Enter>

SEL-787                                   Date: 06/28/2011   Time: 10:59:30.907
TRNSFRMR RELAY                            Time Source: Internal

Serial Num = 12345678910111
FID = SEL-787-R206-V0-Z003001-D20110610                CID = C351
PART NUM = 0787EX1BA39X7585063X

SELF TESTS (W=Warn)
  FPGA  GPSB  HMI   RAM   ROM   CR_RAM  NON_VOL  CLOCK  CID_FILE  +0.9V  +1.2V
  OK    OK    OK    OK    OK    OK      OK       OK     OK        0.90   1.21

  +1.5V  +1.8V  +2.5V  +3.3V  +3.75V  +5.0V  -1.25V  -5.0V   BATT
  1.49   1.81   2.51   3.33   3.74    4.96   -1.25   -4.96   3.02

Option Cards
  CARD_C  CARD_D  CARD_E  CURRENT
  OK      OK      OK      OK

DeviceNet
  DN_MAC_ID     ASA      DN_RATE   DN_STATUS
  3          1a28 35b3h  AUTO      0000 0000

Offsets
  IAW1  IBW1  ICW1  IAW2  IBW2  ICW2   IN    VA    VB    VC
  0     0     0     0     0     0     0     0     0     0

  Relay Enabled

=>>
```

Figure 1.3 STA Command Response—With DeviceNet Communications Card

Table 7.39 provides the definition of each status report designator and *Table 10.8* shows all the self-tests performed by the relay. The beginning of the status report printout (see *Figure 1.2*) contains the relay serial number, firmware identification string (FID), and checksum string (CID). These strings uniquely identify the relay and the version of the operating firmware.

Setting the Date and Time

DAT (Date Command)

Viewing the Date

Type **DAT <Enter>** at the prompt to view the date stored in the SEL-787. If the date stored in the relay is February 28, 2008, and the DATE_F setting is MDY, the relay will reply:

```
2/28/2008
```

If the DATE_F setting is YMD, the relay will reply:

```
2008/2/28
```

If the DATE_F setting is DMY, the relay will reply:

```
28/2/2008
```

Changing the Date

Type **DAT** followed by the correct date at the prompt to change the date stored in the relay. For example, to change the date to May 2, 2008 (DATE_F = MDY), enter the following at the action prompt:

```
DAT 5/2/08
```

You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

TIM (Time Command)

Viewing the Time

Enter **TIM** at the prompt to view the time stored in the SEL-787. The relay will reply with the stored time:

```
13:52:44
```

This time is 1:52 p.m. (and 44 seconds).

Changing the Time

Enter **TIM** followed by the correct time at the action prompt to change the time stored in the relay. For example, to change the time to 6:32 a.m., enter the following at the prompt:

```
TIM 6:32:00
```

You can separate the hours, minutes, and seconds parameters with spaces, commas, slashes, colons, and semicolons.

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

49 CFR 15B, Class A

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.

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

CE Mark

RCM Mark

Hazardous Locations

UL Certified for Hazardous Locations to U.S. and Canadian standards CL 1, DIV 2; GP A, B, C, D; T3C, maximum surrounding air temperature of 50°C (File E470448)

EU

SEL 19 ATEX 0001X
II 3 G
Ex ec nC IIC T3 Gc

EN 60079-0:2012 + A11:2013, EN 60079-7:2015, EN 60079-15:2010, EN 60079-11:2012

Note: Where so marked, ATEX and UL Hazardous Locations Certification tests are applicable to rated supply specifications only and do not apply to the absolute operating ranges, continuous thermal, or short circuit duration specifications.

General

AC Current Input

Phase and Neutral Currents

I_{NOM} = 1 A or 5 A secondary depending on model

I_{NOM} = 5 A

Continuous Rating:	3 • I_{NOM} @ 85°C 4 • I_{NOM} @ 55°C
A/D Measurement Limit:	216 A peak (150 A rms symmetrical)
1-Second Thermal:	500 A
Burden (Per Phase):	<0.1 VA @ 5 A

I_{NOM} = 1 A

Continuous Rating:	3 • INOM @ 85°C 4 • INOM @ 55°C
A/D Measurement Limit:	43 A peak (30 A rms symmetrical)
1-Second Thermal:	100 A
Burden (Per Phase):	<0.01 VA @ 1 A
Measurement Category:	II

AC Voltage Inputs

VNOM (L-L secondary) Range:	100–250 V (if DELTA_Y := DELTA) 100–440 V (if DELTA_Y := WYE)
Rated Continuous Voltage:	300 Vac
10-Second Thermal:	600 Vac

	Burden	Input Impedance (Per Phase)	Input Impedance (Phase-to-Phase)
Vphase	0.008 VA @ 120 Vac	2 MΩ	4 MΩ

Power Supply

Relay Start-Up Time:	Approximately 5–10 seconds (after power is applied until the **ENABLED** LED turns on)

High-Voltage Supply

Rated Supply Voltage:	110–240 Vac, 50/60 Hz 110–250 Vdc
Input Voltage Range (Design Range):	85–264 Vac 85–300 Vdc
Power Consumption:	<50 VA (ac) <25 W (dc)
Interruptions:	50 ms @ 125 Vac/Vdc 100 ms @ 250 Vac/Vdc

Low-Voltage Supply

Rated Supply Voltage:	24–48 Vdc
Input Voltage Range (Design Range):	19.2–60.0 Vdc
Power Consumption:	<25 W (dc)
Interruptions:	10 ms @ 24 Vdc 50 ms @ 48 Vdc

Fuse Ratings

LV Power Supply Fuse

Rating:	3.15 A
Maximum Rated Voltage:	300 Vdc, 250 Vac
Breaking Capacity:	1500 A at 250 Vac
Type:	Time-lag T

HV Power Supply Fuse

Rating:	3.15 A
Maximum Rated Voltage:	300 Vdc, 250 Vac
Breaking Capacity:	1500 A at 250 Vac
Type:	Time-lag T
Heater Fuses F2, F3:	5 A, 125 V slow blow 125 Vdc/50 A break rating

Output Contacts

General

The relay supports Form A, B, and C outputs.

Dielectric Test Voltage:	2500 Vac
Impulse Withstand Voltage (U_{IMP}):	5000 V
Mechanical Durability:	100,000 no-load operations

Standard Contacts

Pickup/Dropout Time:	≤8 ms (coil energization to contact closure)

DC Output Ratings

Rated Operational Voltage:	250 Vdc
Rated Voltage Range:	19.2–275 Vdc
Rated Insulation Voltage:	300 Vdc
Make:	30 A @ 250 Vdc per IEEE C37.90
Continuous Carry:	6 A @ 70°C 4 A @ 85°C
1-Second Thermal:	50 A
Contact Protection:	360 Vdc, 115 J MOV protection across open contacts

Breaking Capacity (10,000 Operations) per IEC 60255-0-20:1974:

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

Cyclic (2.5 Cycles/Second) per IEC 60255-0-20:1974:

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

AC Output Ratings

Maximum Operational Voltage (U_e) Rating: 240 Vac

Insulation Voltage (U_i) Rating (excluding EN 61010-1): 300 Vac

1-Second Thermal: 50 A

Contact Rating Designation: B300

B300 (5 A Thermal Current, 300 Vac Max)			
	Maximum Current		Max VA
Voltage	120 Vac	240 Vac	—
Make	30 A	15 A	3600
Break	3 A	1.5 A	360
PF <0.35, 50–60 Hz			

Utilization Category: AC-15

AC-15		
Operational Voltage (Ue)	120 Vac	240 Vac
Operational Current (Ie)	3 A	1.5 A
Make Current	30 A	15 A
Break Current	3 A	1.5 A
Electromagnetic loads >72 VA, PF <0.3, 50–60 Hz		

Voltage Protection Across Open Contacts: 270 Vac, 115 J

Fast Hybrid (High-Speed, High-Current Interrupting)

DC Output Ratings

Rated Operational Voltage: 250 Vdc

Rated Voltage Range: 19.2–275 Vdc

Rated Insulation Voltage: 300 Vdc

Make: 30 A @ 250 Vdc per IEEE C37.90

Carry: 6 A @ 70°C
4 A @ 85°C

1-Second Thermal: 50 A

Open State Leakage Current: <500 µA

MOV Protection (maximum voltage): 250 Vac/330 Vdc

Pickup Time: <50 µs, resistive load

Dropout Time: <8 ms, resistive load

Breaking Capacity (10,000 Operations) per IEC 60255-0-20:1974:

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

Cyclic Capacity (4 Cycles in 1 Second, Followed by 2 Minutes Idle for Thermal Dissipation) per IEC 60255-0-20:1974:

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

AC Output Ratings

See *AC Output Ratings* for *Standard Contacts*.

Optoisolated Control Inputs

When Used With DC Control Signals

250 V: ON for 200–312.5 Vdc
OFF below 150 Vdc

220 V: ON for 176–275 Vdc
OFF below 132 Vdc

125 V: ON for 100–156.2 Vdc
OFF below 75 Vdc

110 V: ON for 88–137.5 Vdc
OFF below 66 Vdc

48 V: ON for 38.4–60 Vdc
OFF below 28.8 Vdc

24 V: ON for 15–30 Vdc
OFF for <5 Vdc

When Used With AC Control Signals

250 V: ON for 170.6–312.5 Vac
OFF below 106 Vac

220 V: ON for 150.2–275 Vac
OFF below 93.3 Vac

125 V: ON for 85–156.2 Vac
OFF below 53 Vac

110 V: ON for 75.1–137.5 Vac
OFF below 46.6 Vac

48 V: ON for 32.8–60 Vac
OFF below 20.3 Vac

24 V: ON for 14–30 Vac
OFF below 5 Vac

Current draw at nominal dc voltage: 2 mA (at 220–250 V)
4 mA (at 48–125 V)
10 mA (at 24 V)

Rated Impulse Withstand Voltage (U_{imp}): 4000 V

Analog Output (Optional)

	1A0	4A0
Current:	4–20 mA	±20 mA
Voltage:	—	±10 V
Load at 1 mA:	—	0–15 kΩ
Load at 20 mA:	0–300 Ω	0–750 Ω
Load at 10 V:	—	>2000 Ω
Refresh Rate:	100 ms	100 ms
% Error, Full Scale, at 25°C:	<±1%	<±0.55%
Select From:	Analog quantities available in the relay	

Analog Inputs (Optional)

Maximum Input Range: ±20 mA
±10 V
Operational range set by user

Input Impedance: 200 Ω (current mode)
>10 kΩ (voltage mode)

Accuracy at 25°C:

With user calibration: 0.05% of full scale (current mode)
0.025% of full scale (voltage mode)

Without user calibration: Better than 0.5% of full scale at 25°C

Accuracy Variation With Temperature: ±0.015% per °C of full-scale (±20 mA or ±10 V)

Frequency and Phase Rotation

System Frequency: 50, 60 Hz

Phase Rotation: ABC, ACB

Frequency Tracking: 20–70 Hz (requires ac voltage inputs option)

Time-Code Input

Format:	Demodulated IRIG-B
On (1) State:	V_{ih} ≥2.2 V
Off (0) State:	V_{il} ≤0.8 V
Input Impedance:	2 kΩ

Synchronization Accuracy:

Internal Clock:	±1 µs
Synchrophasor Reports (e.g., MET PM):	±10 µs
All Other Reports:	±5 ms

Simple Network Time Protocol (SNTP) Accuracy

Internal Clock:	±5 ms
Unsynchronized Clock Drift Relay Powered:	2 minutes per year, typically

Communications Ports

Standard EIA-232 (2 ports)

Location:	Front Panel Rear Panel
Data Speed:	300–38400 bps

EIA-485 Port (optional)

Location:	Rear Panel
Data Speed:	300–19200 bps

Ethernet Port (optional)

Single/Dual 10/100BASE-T copper (RJ45 connector)
Single/Dual 100BASE-FX (LC connector)

Standard Multimode Fiber-Optic Port

Location:	Front Panel
Data Speed:	300–38400 bps

Fiber-Optic Ports Characteristics

Port 1 (or 1A, 1B) Ethernet

Wavelength:	1300 nm
Optical Connector Type:	LC
Fiber Type:	Multimode
Link Budget:	16.1 dB
Typical TX Power:	–15.7 dBm
RX Min. Sensitivity:	–31.8 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~6.4 km
Data Rate:	100 Mbps
Typical Fiber Attenuation:	–2 dB/km

Port 2 Serial (SEL-2812 compatible)

Wavelength:	820 nm
Optical Connector Type:	ST
Fiber Type:	Multimode
Link Budget:	8 dB
Typical TX Power:	–16 dBm
RX Min. Sensitivity:	–24 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~1 km
Data Rate:	5 Mbps
Typical Fiber Attenuation:	–4 dB/km

Optional Communications Cards

Option 1:	EIA-232 or EIA-485 communications card
Option 2:	DeviceNet communications card

Communications Protocols

SEL, Modbus, DNP, FTP, TCP/IP, Telnet, SNTP, IEC 61850, MIRRORED BITS, EVMSG, C37.118 (synchrophasors), and DeviceNet. See *Table 7.3* for details.

Operating Temperature

IEC Performance Rating:	–40° to +85°C (–40° to +185°F) (per IEC/EN 60068-2-1 & 60068-2-2)

NOTE: Not applicable to UL applications.

NOTE: LCD contrast is impaired for temperatures below –20°C and above +70°C

DeviceNet Communications Card Rating:	+60°C (140°F) maximum

Operating Environment

Pollution Degree:	2
Overvoltage Category:	II
Atmospheric Pressure:	80–110 kPa
Relative Humidity:	5%–95%, noncondensing
Maximum Altitude:	2000 m

Dimensions

144.0 mm (5.67 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in)

Weight

2.7 kg (6.0 lb)

Relay Mounting Screws (#8–32) Tightening Torque

Minimum:	1.4 Nm (12 in-lb)
Maximum:	1.7 Nm (15 in-lb)

Terminal Connections

Terminal Block

Screw Size:	#6
Ring Terminal Width:	0.310 in maximum

Terminal Block Tightening Torque

Minimum:	0.9 Nm (8 in-lb)
Maximum:	1.4 Nm (12 in-lb)

Compression Plug Tightening Torque

Minimum:	0.5 Nm (4.4 in-lb)
Maximum:	1.0 Nm (8.8 in-lb)

Compression Plug Mounting Ear Screw Tightening Torque

Minimum:	0.18 Nm (1.6 in-lb)
Maximum:	0.25 Nm (2.2 in-lb)

Product Standards

Electromagnetic Compatibility:	IEC 60255-26:2013 IEC 60255-27:2013 UL 508 CSA C22.2 No. 14-05

Type Tests

Environmental Tests

Enclosure Protection:	IEC 60529:2001 + CRDG:2003 IP65 enclosed in panel IP50-rated terminal dust protection assembly (SEL Part #915900170). The 10°C temperature derating applies to the temperature specifications of the relay.
Vibration Resistance:	IEC 60255-21-1:1998 IEC 60255-27:2013, Section 10.6.2.1 Endurance: Class 2 Response: Class 2

Shock Resistance:	IEC 60255-21-2:1998 IEC 60255-27:2013, Section 10.6.2.2 IEC 60255-27:2013, Section 10.6.2.3 Withstand: Class 1 Response: Class 2 Bump: Class 1
Seismic (Quake Response):	IEC 60255-21-3:1993 IEC 60255-27:2013, Section 10.6.2.4 Response: Class 2
Cold:	IEC 60068-2-1:2007 IEC 60255-27:2013, Section 10.6.1.2 IEC 60255-27:2013, Section 10.6.1.4 –40°C, 16 hours
Dry Heat:	IEC 60068-2-2:2007 IEC 60255-27:2013, Section 10.6.1.1 IEC 60255-27:2013, Section 10.6.1.3 85°C, 16 hours
Damp Heat, Steady State:	IEC 60068-2-78:2001 IEC 60255-27:2013, Section 10.6.1.5 Severity Level: 93% relative humidity minimum 40°C, 10 days
Damp Heat, Cyclic:	IEC 60068-2-30:2001 IEC 60255-27:2013, Section 10.6.1.6 Test Db; Variant 2; 25°–55°C, 6 cycles, 95% relative humidity minimum
Change of Temperature:	IEC 60068-2-14:2009 IEC 60255-1:2010, Section 6.12.3.5 –40° to +85°C, ramp rate 1°C/min, 5 cycles

Dielectric Strength and Impulse Tests

Dielectric (HiPot):	IEC 60255-27:2013, Section 10.6.4.3 IEEE C37.90-2005 1.0 kVac on analog outputs, Ethernet ports 2.0 kVac on analog inputs, IRIG 2.5 kVac on contact I/O 3.6 kVdc on power supply, IN and VN terminals
Impulse:	IEC 60255-27:2013, Section 10.6.4.2 Severity Level: 0.5 J, 5 kV on power supply, contact I/O, ac current, and voltage inputs 0.5 J, 530 V on analog outputs IEEE C37.90:2005 Severity Level: 0.5 J, 5 kV 0.5 J, 530 V on analog outputs

RFI and Interference Tests

EMC Immunity

Electrostatic Discharge Immunity:	IEC 61000-4-2:2008 IEC 60255-26:2013, Section 7.2.3 IEEE C37.90.3:2001 Severity Level 4 8 kV contact discharge 15 kV air discharge
Radiated RF Immunity:	IEC 61000-4-3:2010 IEC 60255-26:2013, Section 7.2.4 10 V/m IEEE C37.90.2-2004 20 V/m
Fast Transient, Burst Immunity:	IEC 61000-4-4:2012 IEC 60255-26:2013, Section 7.2.5 4 kV @ 5.0 kH 2 kV @ 5.0 kHz for comm. ports
Surge Immunity:	IEC 61000-4-5:2005 IEC 60255-26:2013, Section 7.2.7 2 kV line-to-line 4 kV line-to-earth
Surge Withstand Capability Immunity:	IEC 61000-4-18:2010 IEC 60255-26:2013, Section 7.2.6 2.5 kV common mode 1 kV differential mode 1 kV common mode on comm. ports IEEE C37.90.1-2002 2.5 kV oscillatory 4 kV fast transient
Conducted RF Immunity:	IEC 61000-4-6:2008 IEC 60255-26:2013, Section 7.2.8 10 Vrms
Magnetic Field Immunity:	IEC 61000-4-8:2009 IEC 60225-26:2013, Section 7.2.10 Severity Level: 1000 A/m for 3 seconds 100 A/m for 1 minute; 50/60 Hz IEC 61000-4-9:2001 Severity Level: 1000 A/m IEC 61000-4-10:2001 Severity Level: 100 A/m (100 kHz and 1 MHz)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999 IEC 61000-4-29:2000 IEC 60255-26:2013, Section 7.2.11 IEC 60255-26:2013, Section 7.2.12 IEC 60255-26:2013, Section 7.2.13

EMC Emissions

Conducted Emissions:	IEC 60255-26:2013 Class A FCC 47 CFR Part 15.107 Class A ICES-003 Issue 6 EN 55011:2009 + A1:2010 Class A EN 55022:2010 + AC:2011 Class A EN 55032:2012 + AC:2013 Class A CISPR 11:2009 + A1:2010 Class A CISPR 22:2008 Class A CISPR 32:2015 Class A
Radiated Emissions:	IEC 60255-26:2013 Class A FCC 47 CFR Part 15.109 Class A ICES-003 Issue 6 EN 55011:2009 + A1:2010 Class A EN 55022:2010 + AC:2011 Class A EN 55032:2012 + AC:2013 Class A CISPR 11:2009 + A1:2010 Class A CISPR 22:2008 Class A CISPR 32:2015 Class A

Processing Specifications and Oscillography

AC Voltage and Current Inputs:	16 samples per power system cycle
Frequency Tracking Range:	20–70 Hz (requires ac voltage inputs option)
Digital Filtering:	One-cycle cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.
Protection and Control Processing:	Processing interval is 4 times per power system cycle (except for math variables and analog quantities, which are processed every 100 ms). The 51 elements are processed 2 times per power system cycle.

Oscillography

Length:	15 or 64 cycles
Sampling Rate:	16 samples per cycle unfiltered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII
Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy:	±5 ms

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (with respect to time source):	±5 ms

Relay Elements

Instantaneous/Definite-Time Overcurrent (50P, 50G, 50N, 50Q)

Pickup Setting Range, A secondary:	
5 A models:	0.50–96.00 A, 0.01 A steps
1 A models:	0.10–19.20 A, 0.01 A steps
Accuracy:	±5% of setting plus ±0.02 • I_{NOM} A secondary (Steady State pickup)
Time Delay:	0.00–5.00 seconds, 0.01-second steps, ±0.5% plus ±0.25 cyc
Pickup/Dropout Time:	<1.5 cyc

Inverse Time Overcurrent (51P, 51G, 51N, 51Q)

Pickup Setting Range, A secondary:	
5 A models:	0.50–16.00 A, 0.01 A steps
1 A models:	0.10–3.20 A, 0.01 A steps
Accuracy:	±5% of setting plus ±0.02 • I_{NOM} A secondary (Steady State pickup)
Time Dial:	
US:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Accuracy:	±1.5 cycles plus ±4% between 2 and 30 multiples of pickup (within rated range of current)

Differential (87)

Unrestrained Pickup Range:	1.0–20.0 in per unit of TAP
Restrained Pickup Range:	0.10–1.00 in per unit of TAP
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Unrestrained Element	
Pickup Time:	0.8/1.0/1.9 cycles (Min/Typ/Max)
Restrained Element (with harmonic blocking)	
Pickup Time:	1.5/1.6/2.2 cycles (Min/Typ/Max)
Restrained Element (with harmonic restraint)	
Pickup Time:	2.62/2.72/2.86 cycles (Min/Typ/Max)

Harmonics

Pickup Range (% of fundamental):	5%–100%
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Time Delay Accuracy:	±0.5% of setting or ±0.25 cycle

Restricted Earth Fault (REF)

Pickup Range (per unit of INOM of neutral current input, IN):	0.05–3.00 per unit, 0.01 per-unit steps
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Timing Accuracy:	
Directional Output:	1.5 ±0.25 cyc
ANSI Extremely Inverse TOC Curve (U4 With 0.5 Time Dial):	±5 cycles plus ±5% between 2 and 30 multiples of pickup (within rated range of current)

Undervoltage (27)

Setting Range:	Off, 12.5–300.0 V
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.5 cycle
Time Delay:	0.0–120.0 seconds, 0.1-second steps
Accuracy:	±0.5% of setting or ±0.25 cycle

Overvoltage (59)

Setting Range:	Off, 12.5–300.0 V
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.5 cycle
Time Delay:	0.0–120.0 seconds, 0.1-second steps
Accuracy:	±0.5% of setting or ±0.25 cycle

Negative-Sequence Overvoltage (59Q)

Setting Range:	12.5–200.0 V
Accuracy:	±5% of setting plus ±2 V
Pickup/Dropout Time:	<1.5 cycle
Time Delay:	0.0–120.0 seconds, 0.1-second steps
Accuracy:	±0.5% of setting or ±0.25 cycle

Volts/Hertz (24)

Definite-Time Element	
Pickup Range:	100%–200%
Steady-State Pickup Accuracy:	±1% of set point
Pickup Time:	25 ms @ 60 Hz (Max)
Time-Delay Range:	0.00–400.00 s
Time-Delay Accuracy:	±0.1% of setting or ±4.2 ms @ 60 Hz
Reset Time Range:	0.00–400.00 s
Inverse-Time Element	
Pickup Range:	100%–200%
Steady-State Pickup Accuracy:	±1% of set point
Pickup Time:	25 ms @ 60 Hz (Max)
Curve:	0.5, 1.0, or 2.0
Factor:	0.1–10.0 s
Timing Accuracy:	±4% plus ±25 ms @ 60 Hz, for V/Hz above 1.05 multiples (Curve 0.5 and 1.0) or 1.10 multiples (Curve 2.0) of pickup setting, and for operating times >4 s
Reset Time Range:	0.00–400.00 s
Composite-Time Element	
Combination of definite-time and inverse-time specifications	
User-Definable Curve Element	
Pickup Range:	100%–200%
Steady-State Pickup Accuracy:	±1% of set point
Pickup Time:	25 ms @ 60 Hz (Max)
Reset Time Range:	0.00–400.00 s

Directional Power (32)

Instantaneous/Definite Time, 3 Phase Elements	
Type:	+W, –W, +VAR, –VAR
Pickup Settings Range, VA secondary:	
5 A Model:	1.0–6500.0 VA, 0.1 VA steps
1 A Model:	0.2–1300.0 VA, 0.1 VA steps

Accuracy:	±0.10 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (5 A nominal) ±0.02 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (1 A nominal)
Pickup/Dropout Time:	<10 cycles
Time Delay:	0.0–240.0 seconds, 0.1-second steps
Accuracy:	±0.5% of setting or ±0.25 cycle

Frequency (81) (requires ac voltage option)

Setting Range:	Off, 20.0–70.0 Hz
Accuracy:	±0.01 Hz (V1 > 60 V) with voltage tracking
Pickup/Dropout Time:	<4 cycles
Time Delay:	0.0–240.0 seconds, 0.1-second steps
Accuracy:	±0.5% of setting or ±0.25 cycle

RTD Protection

Setting Range:	Off, 1°–250°C
Accuracy:	±2°C
RTD Open-Circuit Detection:	>250°C
RTD Short-Circuit Detection:	<–50°C
RTD Types:	PT100, NI100, NI120, CU10
RTD Lead Resistance:	25 ohm max. per lead
Update Rate:	<3 s
Noise Immunity on RTD Inputs:	To 1.4 Vac (peak) at 50 Hz or greater frequency
RTD Fault, Trip, and Alarm Time Delay:	Approx. 12 s

Metering Accuracy

Accuracies are specified at 20°C, nominal frequency, ac currents within (0.2–20.0) • I_{NOM} A secondary, and ac voltages within 50–250 V secondary unless otherwise noted.

Phase Currents:	±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with Inom = 1 A)
Three-Phase Average Current:	±2% of reading
Differential Quantities:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
Current Harmonics:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
IG (Residual Current):	±3% of reading, ±2° (±5.0° at 0.2–0.5 A for relays with Inom = 1 A)
IN (Neutral Current):	±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with Inom = 1 A)
3I2 Negative-Sequence Current:	±3% of reading
System Frequency:	±0.01 Hz of reading for frequencies within 20.00–70.00 Hz (V1 > 60 V) with voltage tracking
Line-to-Line Voltages:	±1% of reading, ±1° for voltages within 24–264 V
Three-Phase Average Line-to-Line Voltage:	±1% of reading for voltages within 24–264 V
Line-to-Ground Voltages:	±1% of reading, ±1° for voltages within 24–264 V
Three-Phase Average Line-to-Ground Voltages:	±1% of reading for voltages within 24–264 V
Voltage Harmonics:	±5% of reading plus ±0.5 V
3V2 Negative-Sequence Voltage:	±3% of reading for voltages within 24–264 V
Real Three-Phase Power (kW):	±3% of reading for 0.10 < pf < 1.00
Reactive Three-Phase Power (kVAR):	±3% of reading for 0.00 < pf < 0.90
Apparent Three-Phase Power (kVA):	±3% of reading
Power Factor:	±2% of reading for 0.86 ≤ pf ≤ 1
RTD Temperatures:	±2°C

Section 2
Installation

Overview

The first steps in applying the SEL-787 Transformer Protection Relay are installing and connecting the relay. This section describes common installation features and requirements.

To install and connect the relay safely and effectively, you must be familiar with relay configuration features and options. You should carefully plan relay placement, cable connections, and relay communication.

This section contains drawings of typical ac and dc connections to the SEL-787. Use these drawings as a starting point for planning your particular relay application.

The instructions for using the versatile front-panel custom label option are available on the SEL-787 product page on the SEL website. This allows you to use SELOGIC control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs.

Relay Placement

Proper placement of the SEL-787 helps to ensure years of trouble-free protection. Use the following guidelines for proper physical installation of the SEL-787.

Physical Location

The SEL-787 is EN 61010-1 certified at Installation/Overvoltage Category II and Pollution Degree 2. This allows mounting of the relay in a sheltered indoor environment that does not exceed the temperature and humidity ratings for the relay. The SEL-787 is required to be mounted in an indoor or outdoor (extended) locked enclosure that provides a degree of protection to personnel against access to hazardous parts. In either environment, the relay shall be protected from direct sunlight, precipitation, and full wind pressure.

You can place the relay in extreme temperature and humidity locations. (See *Operating Temperature* and *Operating Environment on page 1.11*.)
For EN 61010-1 certification, the SEL-787 rating is 2000 m (6562 ft) above mean sea level.

To comply with the requirements of the European ATEX standard for hazardous locations, the SEL-787 shall be installed in an ATEX-certified enclosure with a tool-removable door or cover that provides a degree of protection not less than IP54, in accordance with EN 60079-0. The enclosure shall be limited to the surrounding air temperature range of
–20°C ≤ Ta ≤ +50°C. The enclosure should be certified to these requirements or be tested for compliance as part of the complete assembly. The enclosure

must be marked "WARNING—Do not open when an explosive atmosphere is present." In North America, the relay is approved for Hazardous Locations Class I, Division 2, Groups A, B, C, and D, and temperature class T3C with a maximum surrounding air temperature of 50°C.

Relay Mounting

To flush mount the SEL-787 in a panel, cut a rectangular hole with the dimensions shown in *Figure 2.1*. Use the supplied front-panel gasket for protection against dust and water ingress into the panel (IP65).

For extremely dusty environments, use the optional IP50-rated terminal dust-protection assembly (SEL Part #915900170). The 10°C temperature derating applies to the temperature specifications of the relay.

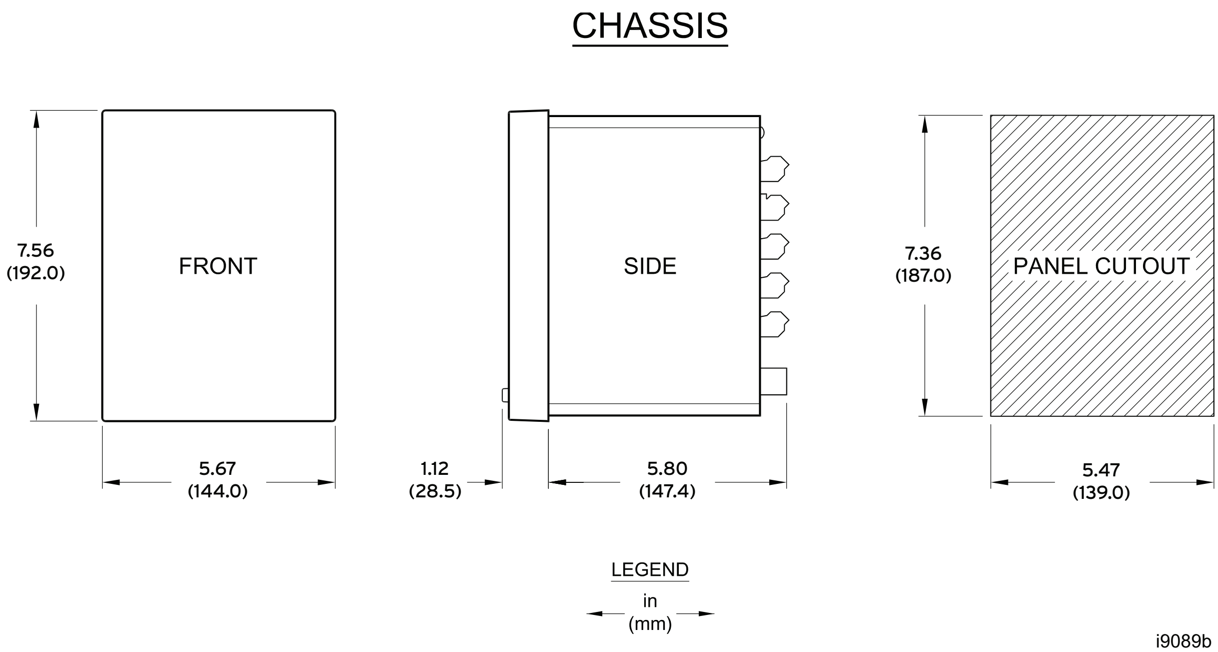


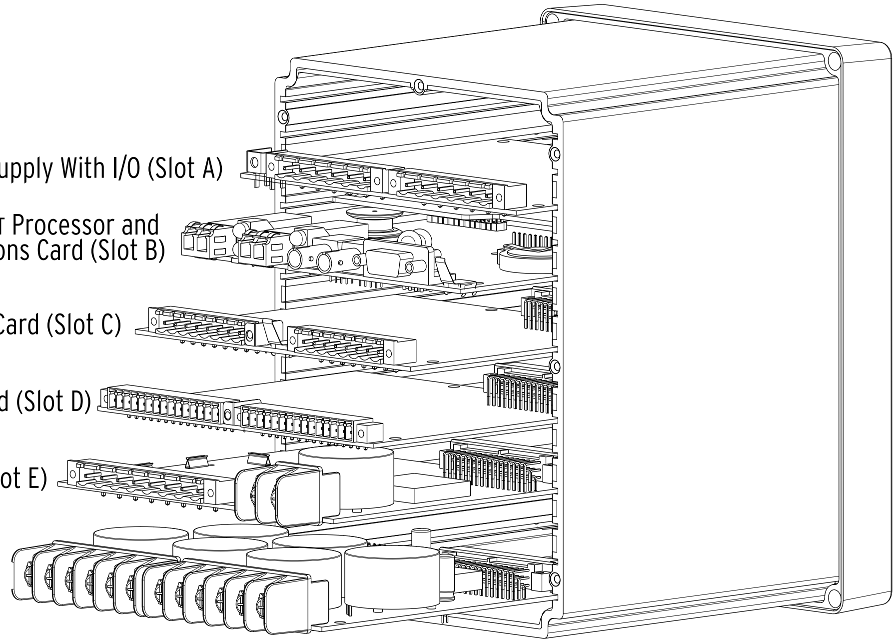
Figure 2.1 Relay Panel-Mount Dimensions

Refer to *Section 1: Introduction and Specifications*, *Models, Options, and Accessories* for information on mounting accessories.

I/O Configuration

Your SEL-787 offers flexibility in tailoring I/O to your specific application. In total, the SEL-787 has six rear-panel slots, labeled as Slots **A**, **B**, **C**, **D**, **E**, and **Z**. Slots **A**, **B**, and **Z** are base unit slots, each associated with a specific function. Optional digital and analog I/O, communications, RTD, and voltage cards are available for the SEL-787. *Figure 2.2* shows the slot allocations for the cards.

Because installations differ substantially, the SEL-787 offers a variety of card configurations to provide options for the many diverse applications. Choose the combination of cards most suited for your application from the following selection.



	Rear-Panel Slot					
	A	B	C	D	E	Z
Software Reference	1 (e.g., OUT101)		3 (e.g., IN301)	4 (e.g., OUT401)	5 (e.g., AI501)	
Description	Power supply and I/O card[a]	CPU/comm. card[b]	Comm. or input/output[c] card	Input/output[c] or RTD card	Input/output[c] or voltage/current card	Current card
Card Type						
SELECT EIA-232/485			●			
SELECT DeviceNet			●			
SELECT 3 DI/4 DO/1 AO (one card per relay)			●	●	●	
SELECT 4 DI/4 DO			●	●	●	
SELECT 4 DI/3 DO (2 Form C, 1 Form B)[d]			●	●	●	
SELECT 8 DI			●	●	●	
SELECT 4 AI/4 AO (one card per relay)			●	●	●	
SELECT 10 RTD				●		
SELECT 1 ACI/3 AVI					●	
SELECT 1 ACI					●	
SELECT 6 ACI						●

[a] Power supply, two inputs, and three outputs.
[b] IRIG-B, EIA-232/485, fiber-optic serial and/or Ethernet ports.
The IRIG-B input option is available on terminals B01, B02 for all models except models with fiber-optic Ethernet port (P1) and dual copper Ethernet port (P1). IRIG-B is also supported via fiber-optic serial port (PORT 2) and rear-panel EIA-232 serial port (PORT 3). You can use only one input at a time.
[c] Digital or analog.
[d] Available in firmware releases R104 or greater and R203 and greater.

Figure 2.2 Slot Allocations for Different Cards

Power Supply Card PSIO/2DI/3DO (Slot A)

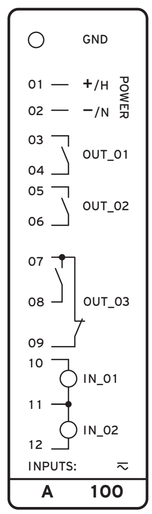
Select appropriate power supply option for the application:

- ➤ High Voltage: 110–250 Vdc, 110–240 Vac, 50/60 Hz
- ➤ Low Voltage: 24–48 Vdc

Select the appropriate digital input voltage option: 125 Vdc/Vac, 24 Vdc/Vac, 48 Vdc/Vac, 110 Vdc/Vac, 220 Vdc/Vac, or 250 Vdc/Vac.

This card is supported in Slot A of the SEL-787 Relay. It has two digital inputs and three digital outputs (two normally open Form A contact outputs and one Form C output). *Table 2.1* shows the terminal designation for the PSIO/2 DI/3 DO card.

Table 2.1 Power Supply Inputs (PSIO/2 DI/3 DO) Card Terminal Designations

Side-Panel Connections Label	Terminal Number	Description
		Ground connection
	A01, A02	Power supply input terminals
	A03, A04	OUT101, driven by OUT101 SELOGIC control equation
	A05, A06	OUT102, driven by OUT102 SELOGIC control equation
	A07, A08, A09	OUT103, driven by OUT103 SELOGIC control equation
	A10, A11	IN101, drives IN101 element
	A12, A11	IN102, drives IN102 element

Communications Ports (Slot B)

Select the communications ports necessary for your application from the base-unit options shown in *Table 2.2*.

Table 2.2 Communications Ports

Port	Location	Feature	Description
F	Front Panel	Standard	Nonisolated EIA-232 serial port
1	Rear Panel	Optional	(Single/Dual) Isolated 10/100BASE-T Ethernet copper port or 100BASE-FX Ethernet port
2	Rear Panel	Standard	Isolated multimode fiber-optic serial port with ST connectors
3	Rear Panel	Standard	Nonisolated EIA-232 or isolated EIA-485 serial port

Port F supports the following protocols:

- ➤ SELBOOT
- ➤ Modbus RTU Slave
- ➤ SEL ASCII and Compressed ASCII
- ➤ SEL Settings File Transfer

- Event Messenger
- C37.118 (Synchrophasor Data)

Port 1 (Ethernet) supports the following protocols:

- Modbus TCP/IP
- DNP3 LAN/WAN
- IEC 61850
- Simple Network Time Protocol (SNTP)
- FTP
- Telnet

Port 2 and **Port 3** support the following protocols:

- Modbus RTU Slave
- SEL ASCII and Compressed ASCII
- SEL Fast Meter
- SEL Fast Operate
- SEL Fast SER
- SEL Fast Message Unsolicited Write
- SEL Settings File Transfer
- SEL MIRRORED BITS (MBA, MBB, MB8A, MB8B, MBTA, MBTB)
- Event Messenger
- DNP3 Slave Level 2
- C37.118 (Synchrophasor Data)

Communications Card (Slot C)

NOTE: After any change, be sure to thoroughly test the settings.

Either the DeviceNet (see *Appendix G: DeviceNet Communications*) or the EIA-232/EIA-485 communications card is supported in Slot **C**. The EIA-232/EIA-485 card provides one serial port with one of the following two serial port interfaces:

- **Port 4A**, an isolated EIA-485 serial port interface
- **Port 4C**, nonisolated EIA-232 serial port interface, supporting the +5 Vdc interface

Select either EIA-232 or EIA-485 functionality using the **Port 4** Setting COMM Interface. *Table 2.3* shows the port number, interface, and type of connector for the two protocols.

Table 2.3 Communication Card Interfaces and Connectors

Port	Interface	Connectors
4A	EIA-485	5-pin Euro
4C	EIA-232	D-sub

The communications card supports all of the following protocols:

- Modbus RTU Slave
- SEL ASCII and Compressed ASCII
- SEL Fast Meter
- SEL Fast Operate
- SEL Fast SER
- SEL Fast Message Unsolicited Write

- ➤ SEL Settings File Transfer
- ➤ SEL MIRRORED BITS (MBA, MBB, MB8A, MB8B, MBTB, MBTA)
- ➤ Event Messenger
- ➤ DNP3 Slave Level 2
- ➤ C37.118 (Synchrophasor Data)

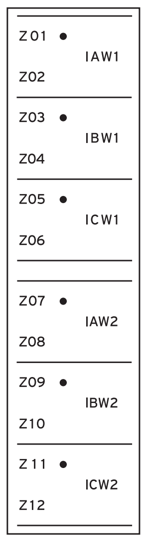
Current Card (6 ACI)

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

Supported in Slot Z only, this card provides Winding 1 and Winding 2 current inputs for three-phase CTs. With this card installed, the SEL-787 samples the currents 16 times per cycle. You can order the following secondary current ratings:

- ➤ 1 A Winding 1, 1 A Winding 2
- ➤ 1 A Winding 1, 5 A Winding 2
- ➤ 5 A Winding 1, 5 A Winding 2

Table 2.4 6 ACI Current Inputs Card Terminal Designations

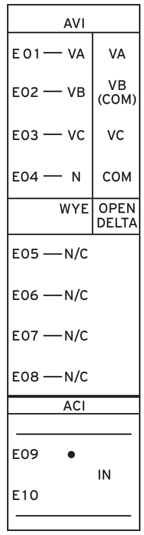
Side-Panel Connections Label	Terminal Number	Description
	Z01, Z02	IAW1, Phase A Winding 1 current input
	Z03, Z04	IBW1, Phase B Winding 1 current input
	Z05, Z06	ICW1, Phase C Winding 1 current input
	Z07, Z08	IAW2, Phase A Winding 2 current input
	Z09, Z10	IBW2, Phase B Winding 2 current input
	Z11, Z12	ICW2, Phase C Winding 2 current input

Current/Voltage Card (1 ACI/3 AVI or 1 ACI)

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

Supported in Slot E only, order this card option when you have either single- or three-phase (wye or delta) PTs and/or neutral ac current input (1 A or 5 A nominal). With this card installed, the SEL-787 samples the voltages and/or current 16 times a cycle—*see Processing Specifications and Oscillography on page 1.12* for more information. The pin connections remain the same for the 1 ACI card, which only supports the neutral current input.

Table 2.5 1 ACI/3 AVI or 1 ACI Current/Voltage Inputs Card Terminal Designations



Side-Panel Connections Label	Terminal Number	Description
	E01	VA, Phase A voltage input
	E02	VB, Phase B voltage input
	E03	VC, Phase C voltage input
	E04	N, Return for VA, VB, VC
	E09, E10	IN1, Neutral current input 1

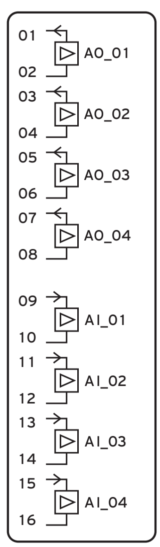
Analog Input/Output Card (4 AI/4 AO)

NOTE: Analog inputs cannot provide loop power. Each analog output is self-powered and has an isolated power supply.

NOTE: Analog outputs are isolated from each other and from the chassis ground.

Supported in any one of the nonbase unit slots (Slot **C**, **D**, or **E**), this card has four analog inputs (AI) and four analog outputs (**AO**). *Table 2.6* shows the terminal designations.

Table 2.6 Four Analog Inputs/Four Analog Outputs (4 AI/4 AO) Card Terminal Designations



Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	AO*x*01, Analog Output number *x*01
	03, 04	AO*x*02, Analog Output number *x*02
	05, 06	AO*x*03, Analog Output number *x*03
	07, 08	AO*x*04, Analog Output number *x*04
	09, 10	AI*x*01, Transducer Input number *x*01
	11, 12	AI*x*02, Transducer Input number *x*02
	13, 14	AI*x*03, Transducer Input number *x*03
	15, 16	AI*x*04, Transducer Input number *x*04

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

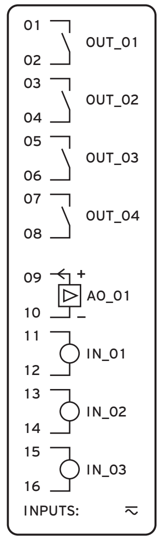
I/O Card (3 DI/4 DO/1 AO)

NOTE: All digital input and digital output connections (including hybrid high-current, high-speed interrupting) are polarity neutral.

NOTE: Analog output is self powered and has an isolated power supply.

Supported in one nonbase unit slot (Slot **C**, **D**, or **E**), this card has three digital inputs, four digital outputs, and one analog output. *Table 2.7* shows the terminal designations.

Table 2.7 I/O (3 DI/4 DO/1 AO) Card Terminal Designations



Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	OUT*x*01, driven by OUT*x*01 SELOGIC control equation
	03, 04	OUT*x*02, driven by OUT*x*02 SELOGIC control equation
	05, 06	OUT*x*03, driven by OUT*x*03 SELOGIC control equation
	07, 08	OUT*x*04, driven by OUT*x*04 SELOGIC control equation
	09, 10	AO*x*01, Analog Output Number 1
	11, 12	IN*x*01, Drives IN*x*01 element
	13, 14	IN*x*02, Drives IN*x*02 element
	15, 16	IN*x*03, Drives IN*x*03 element

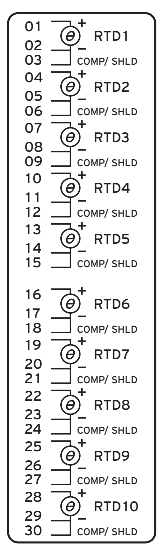
[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

RTD Card (10 RTD)

NOTE: All comp/shield terminals are internally connected to relay chassis and ground.

Supported in Slot **D** only, this card has 10 RTD inputs. *Table 2.8* shows the terminal designations.

Table 2.8 RTD (10 RTD) Card Terminal Designations



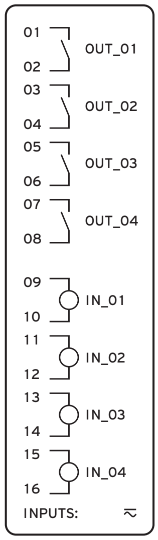
Side-Panel Connections Label	Terminal Number	Description
	01	RTD01 (+)
	02	RTD01 (–)
	03	RTD01 Comp/Shield
	04	RTD02 (+)
	05	RTD02 (–)
	06	RTD02 Comp/Shield
	07	RTD03 (+)
	08	RTD03 (–)
	09	RTD03 Comp/Shield
	•	•
	•	•
	•	•
	28	RTD10 (+)
	29	RTD10 (–)
	30	RTD10 Comp/Shield

I/O Card (4 DI/4 DO)

Supported in any nonbase unit slot (Slot **C**, **D**, or **E**), this card has four digital inputs and four outputs. The four outputs are either all normally open contact outputs or all fast hybrid (high-speed, high-current interrupting) outputs. *Table 2.9* shows the terminal designations.

NOTE: All digital input and digital output connections (including hybrid high-speed, high-current interrupting) are polarity neutral.

Table 2.9 Four Digital Inputs/Four Digital Outputs (4 DI/4 DO) Card Terminal Designations

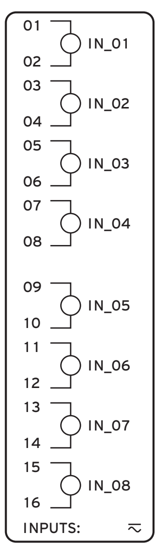
Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	OUT*x*01, driven by OUTx01 SELOGIC control equation
	03, 04	OUT*x*02, driven by OUTx02 SELOGIC control equation
	05, 06	OUT*x*03, driven by OUTx03 SELOGIC control equation
	07, 08	OUT*x*04, driven by OUTx04 SELOGIC control equation
	09, 10	IN*x*01, drives IN*x*01 element
	11, 12	IN*x*02, drives IN*x*02 element
	13, 14	IN*x*03, drives IN*x*03 element
	15, 16	IN*x*04, drives IN*x*04 element

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

I/O Card (8 DI)

Supported in any nonbase unit slot (Slot **C**, **D**, or **E**), this card has eight digital inputs. *Table 2.10* shows the terminal designations.

Table 2.10 Eight Digital Inputs (8 DI) Card Terminal Designations

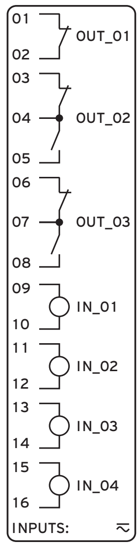
Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	IN*x*01, drives IN*x*01 element
	03, 04	IN*x*02, drives IN*x*02 element
	05, 06	IN*x*03, drives IN*x*03 element
	07, 08	IN*x*04, drives IN*x*04 element
	09, 10	IN*x*05, drives IN*x*05 element
	11, 12	IN*x*06, drives IN*x*06 element
	13, 14	IN*x*07, drives IN*x*07 element
	15, 16	IN*x*08, drives IN*x*08 element

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

I/O Card (4 DI/3 DO)

Supported in any nonbase unit slot (Slot **C** through Slot **E**), this card has four digital inputs, one Form B digital output (normally closed contact output) and two Form C digital output contacts. *Table 2.11* shows the terminal designations.

Table 2.11 Four Digital Inputs, One Form B Digital Output, Two Form C Digital Outputs (4 DI/3 DO) Card Terminal Designations

Side-Panel Connections Label	Terminal Number	Description[a]
	01, 02	OUT*x*01, driven by OUTx01 SELOGIC control equation
	03, 04, 05	OUT*x*02, driven by OUTx02 SELOGIC control equation
	06, 07, 08	OUT*x*03, driven by OUTx03 SELOGIC control equation
	09, 10	IN*x*01, drives IN*x*01 element
	11, 12	IN*x*02, drives IN*x*02 element
	13, 14	IN*x*03, drives IN*x*03 element
	15, 16	IN*x*04, drives IN*x*04 element

[a] x = 3, 4, or 5 if the card is installed in Slot C, D, or E, respectively.

Card Configuration Procedure

Changing card positions or expanding on the initial number of cards requires no card programming; the relay detects the new hardware and updates the software accordingly (you still have to use the **SET** command to program the I/O settings).

The SEL-787 offers flexibility in tailoring I/O to your specific application. The SEL-787 has six rear-panel slots, labeled as Slots **A**, **B**, **C**, **D**, **E**, and **Z**. Slots **A**, **B**, and **Z** are base unit slots, each associated with a specific function. Optional digital/analog I/O cards are available for the SEL-787 in Slots **C**, **D**, and **E**. Optional communications cards are available only for Slot **C**, an RTD card is available only for Slot **D**, and 1 A/5 A CT combinations for voltage/current cards are available only on Slots **E** and **Z**. *Figure 2.2* shows the slot allocations for the cards. Because installations differ substantially, the SEL-787 offers a variety of card configurations that provide options for an array of applications. Choose the combination of cards most suited for your application.

Swapping Optional I/O Boards

When an I/O board is moved from one slot to a different slot, the associated settings for the slot the card is moved from are lost. For example, if a 4 DI/4 DO card is installed in Slot **D**, the SELOGIC control equation settings OUT401–OUT404 are available. If OUT401 = IN101 and 51P1T, and the card is moved to a different slot, then the OUT401 setting is lost. This is true for all the digital and analog I/O cards.

Adding Cards to Slots C, D, E, and Z

The SEL-787 Relay can be upgraded by adding as many as three cards.

Installation

Perform the following steps to install cards in Slots **C**, **D**, **E**, and **Z** of the base unit.

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

Step 1. Save the settings and event report data before installing the new card in the relay.

Step 2. Remove the power supply voltage from terminals **A01+** and **A02–** and remove the ground wire from the green ground screw.

Step 3. Disconnect all the connection plugs.

Step 4. Remove the eight screws on the rear and remove the rear cover.

Step 5. Remove the plastic filler plate covering the slot associated with the card being installed.

Step 6. Insert the card in the correct slot.

Make sure the contact fingers on the printed circuit board are bent at an approximately 130-degree angle relative to the board for proper electromagnetic interference protection.

Step 7. Before reattaching the rear cover, check for and remove any foreign material that may remain inside the SEL-787 case.

Step 8. Carefully reattach the rear cover.

Step 9. Reinstall the eight screws that secure the rear cover to the case.

Step 10. Apply power supply voltage to terminals **A01+** and **A02–**, and reconnect the ground wire to the green ground screw.

Step 11. If the card is in the proper slot, the front panel displays the following:

```
STATUS FAIL
X Card Failure
```

If you *do not* see this message and the **ENABLED** LED is turned on, the card was inserted into the wrong slot. Begin again at *Step 2*.

If you *do* see this message, proceed to *Step 12*.

Step 12. Press the **ESC** pushbutton.

Step 13. Press the **Down Arrow** pushbutton until `STATUS` is highlighted.

Step 14. Press the **ENT** pushbutton.

The front panel displays the following:

```
STATUS
Relay Status
```

Step 15. Press the **ENT** button.

The front panel displays the following:

```
Serial Num
0000000000000000000000000
```

Step 16. Press the **ENT** pushbutton.

The front panel displays the following:

```
Confirm Hardware
Config (Enter)
```

Step 17. Press the **ENT** pushbutton.

The front panel displays the following:

```
Accept New Config?
No Yes
```

Step 18. Select **Yes** and press the **ENT** pushbutton.

The front panel displays the following:

```
Config Accepted
Enter to Reboot
```

Step 19. Press the **ENT** pushbutton.

Step 20. Use the **PARTNO** command from Access Level C to enter the exact part number of the relay after the relay restarts and the **ENABLED** LED turns on to indicate the card was installed correctly.

After reconfiguration, the relay updates the part number, except for the following indicated digits. These digits remain unchanged, i.e., these digits retain the same character as before the reconfiguration. Also, a communications card installed in Slot **C** is reflected as an empty slot in the part number. A regular 4 DI/4 DO card and a hybrid 4 DI/4 DO card have the same device ID. When interchanging these two cards, the part number for the respective slots should be updated manually. Use the **Status** command to view the part number.

```
PART NUM = 0 7 8 7 0 X 1 A 6 X 3 A 1 A 8 5 0 2 0 X
                       ↑ ↑   ↑   ↑   ↑         ↑ ↑
```

Step 21. Update the side-panel drawing with the drawing sticker provided in the option card kit. If necessary, replace the rear panel with the one applicable for the card and attach the terminal-marking label provided with the card to the rear-panel cover. Also, contact SEL for an updated product serial label with the updated part number.

Step 22. Reconnect all of the connection plugs and add any additional wiring/connectors required by the new card.

Slot B CPU Card Replacement

When replacing the Slot **B** card, do the following:

1. Ensure that the card has the latest firmware from the factory.
2. Review the firmware revision history for the changes that were made; note that new settings added, if any, might affect existing settings in the relay or its application.
3. Save all settings and event reports before replacing the card.
4. If the IEC 61850 protocol option was used previously, verify that the IEC 61850 protocol is still operational after the replacement. If not, reenable it. Refer to Protocol Verification *for*

Relays With IEC 61850 Option in *Appendix B: Firmware Upgrade Instructions*, for the verification process.

Perform the following steps to replace the existing CPU board with a new board:

Step 1. Turn off the power to the relay.

Step 2. Use a ground strap between yourself and the relay.

Step 3. Disconnect the terminal blocks and CT/PT wires.

Step 4. Remove the rear panel.

Step 5. Remove the main board from its slot and insert the new board.

Step 6. Attach the rear panel (new if applicable) and reconnect the terminal blocks and CT/PT wires.

Step 7. Apply new side stickers to the relay.

Step 8. Turn on the relay and log in via terminal emulation software.

Step 9. Issue the **STA** command and accept the new configuration.

Step 10. From Access Level 2, type **CAL** to enter Access Level C.

Do not modify any calibration settings other than those listed in this procedure.

The default password for Access Level C is CLARKE.

Step 11. From Access Level C, issue the **SET C** command.

Step 12. Update the serial number and part number to the appropriate values, type **END**, and save the settings.

Step 13. Issue the **STA C** command to reboot the relay.

Step 14. Issue the **STA** command to verify that the serial number and part number of your relay are correct.

Slot A Power Supply Card

If you are replacing the power supply card, change the part number accordingly using the **PARTNO** command from Access Level C. Install new side stickers on the side of the relay.

Analog Input (AI) Voltage/Current Jumper Selection

Figure 2.3 shows the circuit board of an analog I/O board. Jumper *x* determines the nature of Channel *x*. For a current channel, insert Jumper *x* in position 1–2; for a voltage channel, insert Jumper *x* in position 2–3.

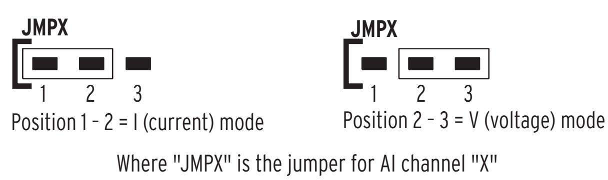


Figure 2.3 Circuit Board of Analog I/O Board, Showing Jumper Selection

Analog Output (AO) Voltage/Current Jumper Selection

NOTE: Analog inputs cannot provide loop power. Each analog output is self-powered and has an isolated power supply.

Figure 2.4 shows the locations of JMP1 through JMP4 on an analog output board. You can select each of the four analog output channels as either a current analog output or a voltage analog output.

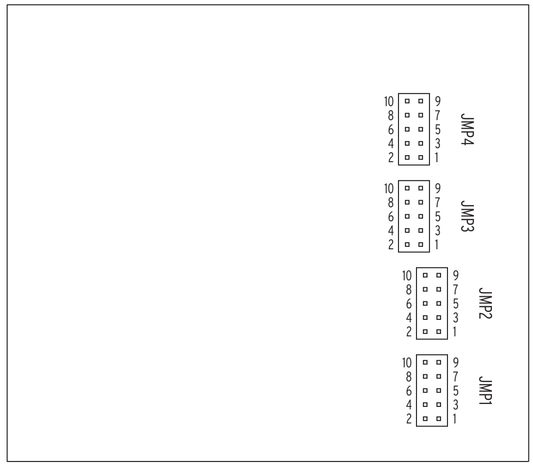


Figure 2.4 JMP1 Through JMP4 Locations on 4 AI/4 AO Board

NOTE: There is no jumper between Pins 5 and 6 for a voltage analog output selection.

You need to insert three jumpers for a current analog output selection and two jumpers for a voltage analog output selection. For a current analog output selection, insert a jumper between Pins 1 and 2, Pins 5 and 6, and Pins 9 and 10. For a voltage analog output selection, insert a jumper between Pins 3 and 4, and Pins 7 and 8. *Figure 2.5* shows JMP4 selected as a current analog output. The current analog output selection is the default setting for JMP1 through JMP4. *Figure 2.6* shows JMP1 selected as a voltage analog output.

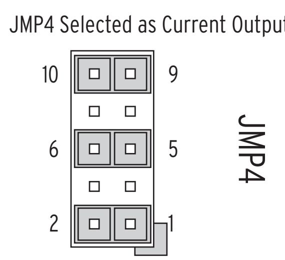


Figure 2.5 Current Output Jumpers

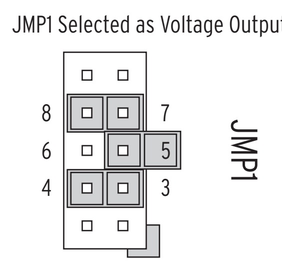


Figure 2.6 Voltage Output Jumpers

Password, Breaker Control, and SELBOOT Jumper Selection

Figure 2.7 shows the major components of the Slot **B** card in the base unit. Notice the three sets of pins labeled A, B, and C.

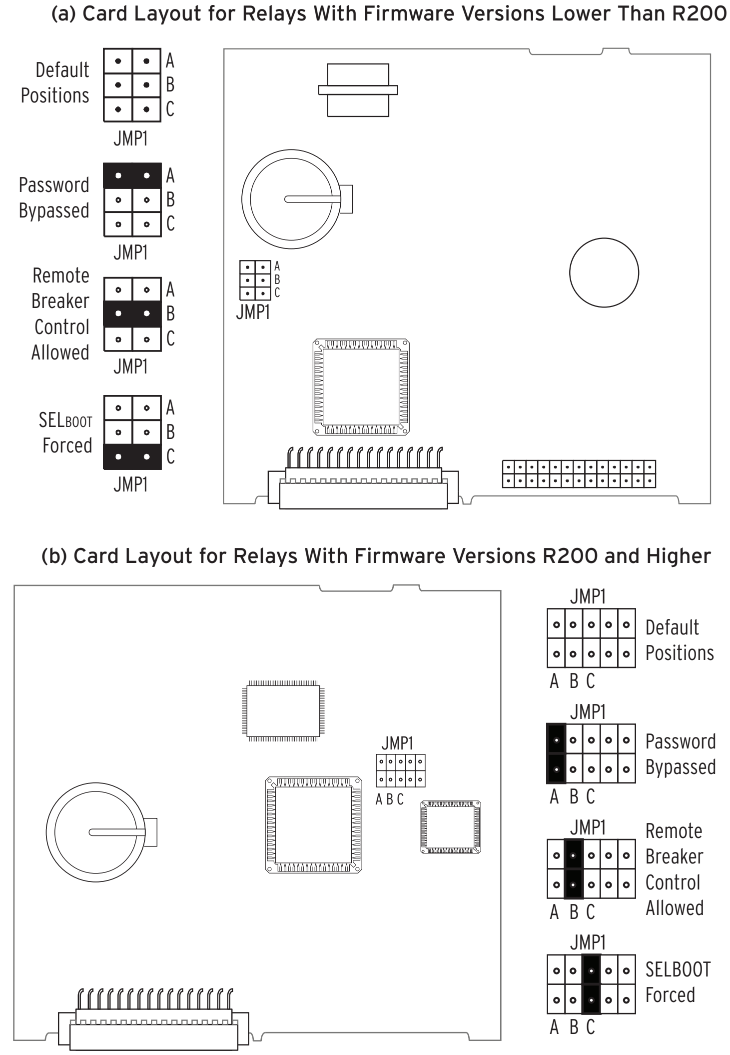


Figure 2.7 Pins for Password Jumper, Breaker Control Jumper, and SELBOOT Jumper

Pins labeled A bypass the password requirement, pins labeled B enable breaker control, and pins labeled C force the relay to the SEL operating system called SELBOOT. In the unlikely event that the SEL-787 experiences an internal failure, communication with the relay may be compromised. Forcing the relay to SELBOOT provides you with a way to downloading new firmware. To force the relay to SELBOOT, place the jumper in Position C, as shown in *Figure 2.7* (SELBOOT Forced). After the relay is forced to SELBOOT, you can only communicate with it via the front-panel port.

To gain access to Level 1 and Level 2 command levels without passwords, position the jumper in position A, as shown in *Figure 2.7* (Password Bypassed). Although you gain access to Level 2 without a password, the alarm contact still closes momentarily when accessing Level 2. See *Table 2.12* for the functions of the three sets of pins and their jumper default positions.

Table 2.12 Jumper Functions and Default Positions

Pins	Jumper Default Position	Description
A	Not bypassed (requires password)	Password bypass
B	Off (breaker control disabled)	Enable breaker control[a]
C	Not bypassed (not forced SELBOOT)	Forced SELBOOT

[a] Jumper position affects breaker control using the OPEN or CLOSE command via the serial port, front panel, or communications protocols. Jumper position does not affect breaker control using remote bits, which are always enabled, or the PULSE command.

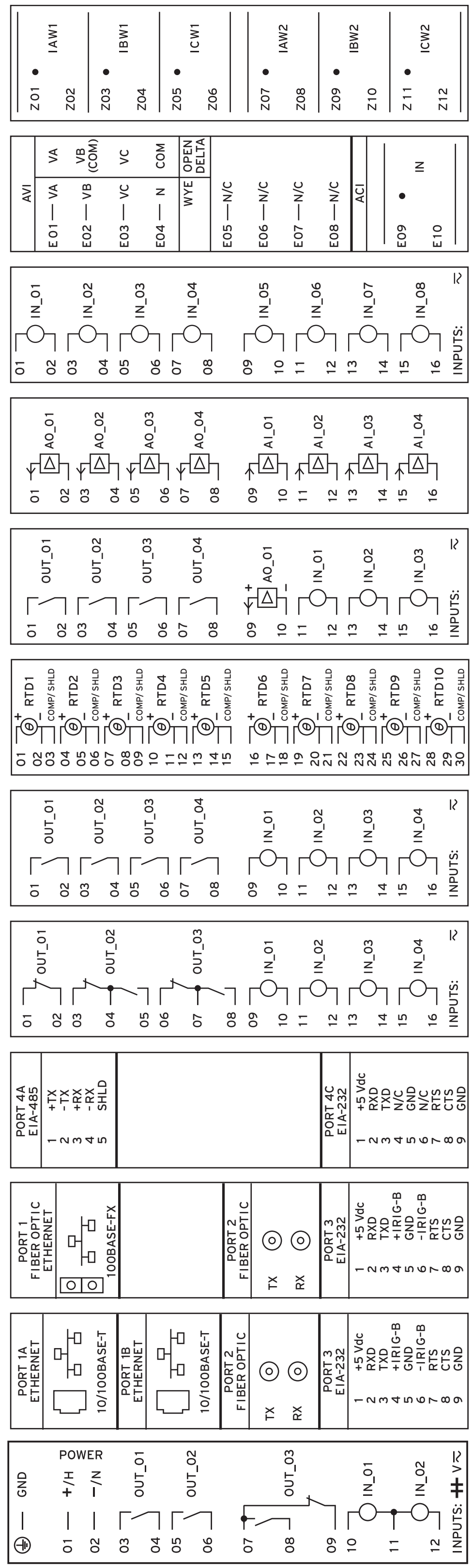
Rear-Panel Connections

NOTE: After any change, be sure to thoroughly test the settings.

NOTE: Analog outputs are isolated from each other and from the chassis ground.

NOTE: All digital input and digital output (including high-speed, high-current hybrid) connections are polarity neutral.

Figure 2.8 shows the rear-panel connections for selected cards. Connections for additional cards are shown in *Figure 2.9* through *Figure 2.11*.



Card 1: Six CT Input Current Card (6 ACI)

Card 2: Three PT /1 CT Input Card (1 ACI/3 AVI)

Card 3: Eight Digital Input Card (8 DI)

Card 4: Four Analog Input/Four Analog Output Card (4 AI/4 AO)

Card 5: Three Digital Input/Four Digital Output/One Analog Output Card (3 DI/4 DO/1 AO)

Card 6: RTD Card (10 RTD)

Card 7: Four Digital Input/Four Digital Output Card (4 DI/4 DO)

Card 8: Four Digital Input/Three Digital Output Card (4 DI/3 DO)

Card 9: Communications Card (EIA-232/EIA-485)

Card 10: Main Board With Single Fiber-Optic Ethernet, Fiber-Optic Serial, and EIA-232 Rear Ports

Card 11: Main Board With Dual Copper Ethernet, Fiber-Optic Serial, and EIA-232 Rear Ports

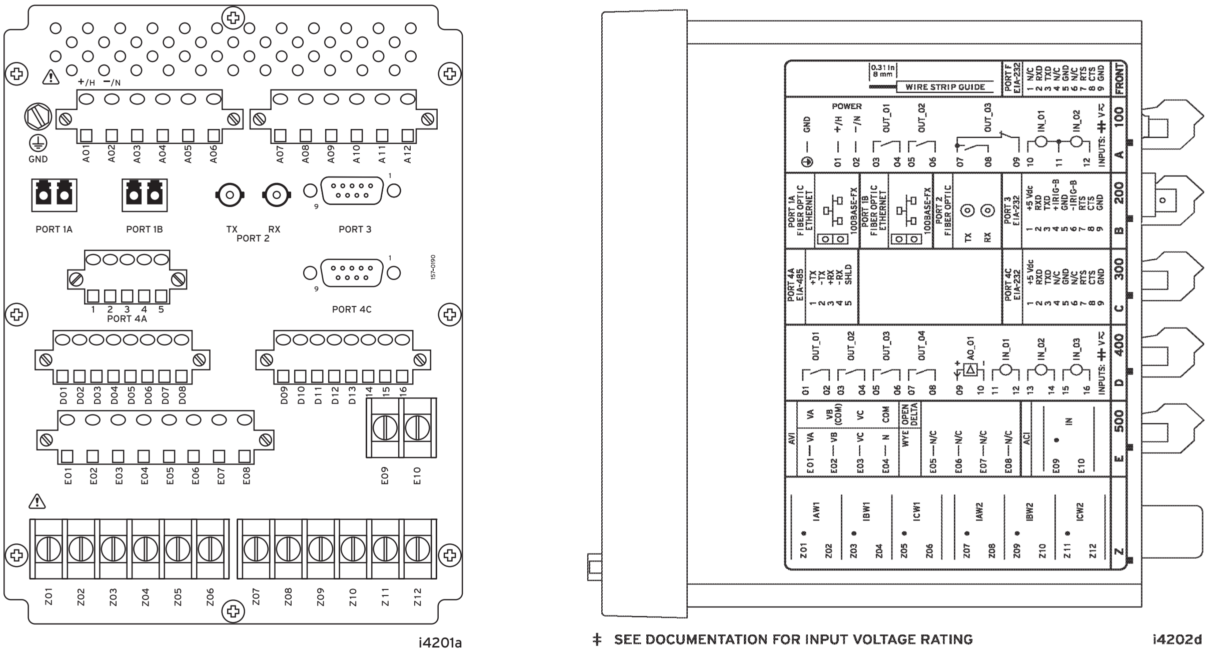
Card 12: Two Digital Input/Three Digital Output Power Supply Card (2 DI/3 DO)

Figure 2.8 Rear-Panel Connections of Selected Cards

Relay Connections

Rear-Panel and Side-Panel Diagrams

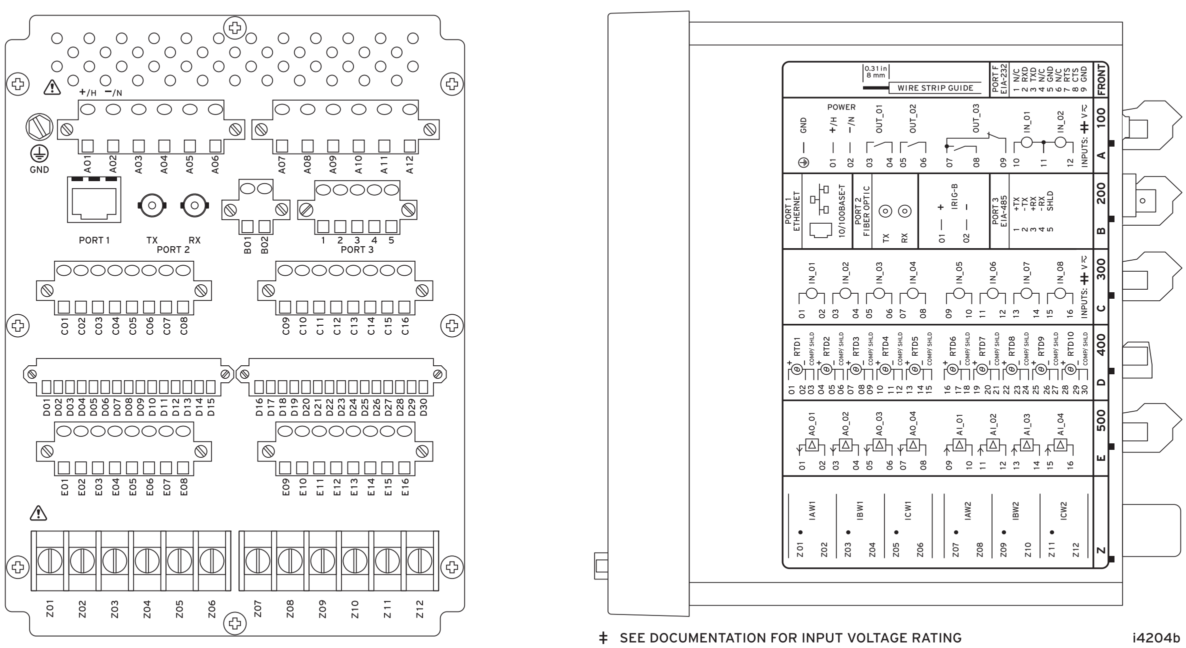
The physical layout of the connectors on the rear-panel and side-panel diagrams of three sample configurations of the SEL-787 are shown in *Figure 2.9*, *Figure 2.10*, and *Figure 2.11*.



(A) Rear-Panel Layout

(B) Side-Panel Input and Output Designations

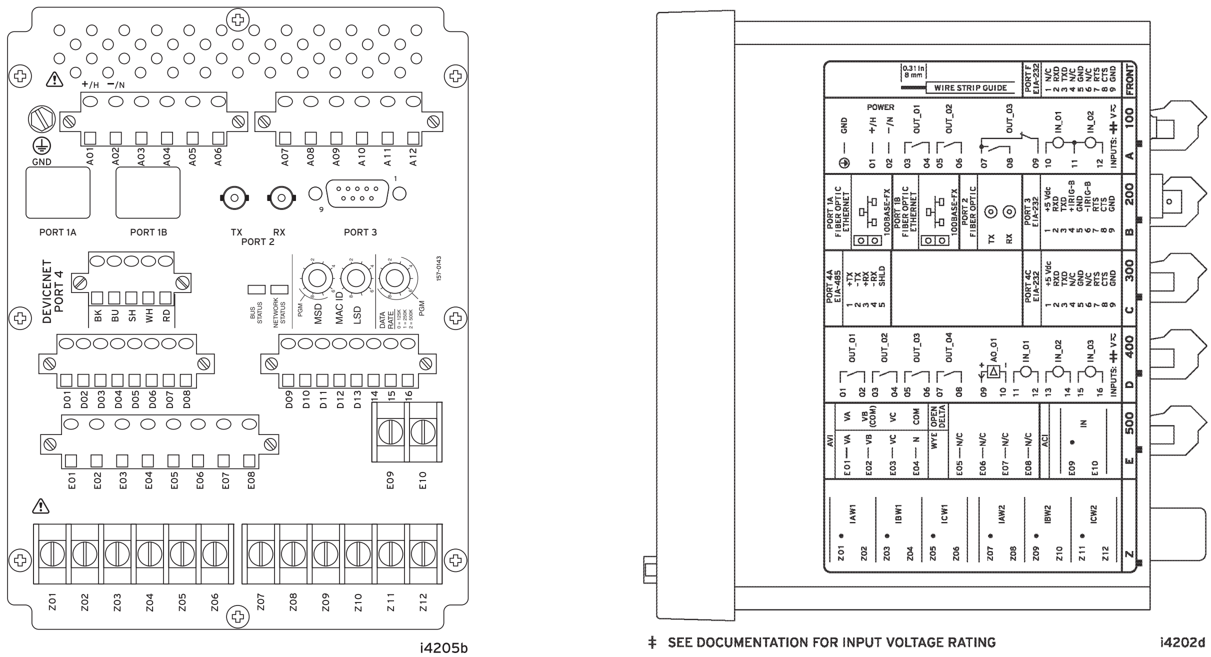
Figure 2.9 Dual-Fiber, Ethernet, EIA-232 Communication, 3 DI/4 DO/1 AO, and Current/Voltage (1 ACI/3 AVI) Option



(A) Rear-Panel Layout

(B) Side-Panel Input and Output Designations

Figure 2.10 Single Copper Ethernet, 8 DI, RTD, and 4 AI/4 AO Option



(A) Rear-Panel Layout

(B) Side-Panel Input and Output Designations

Figure 2.11 DeviceNet, Fast Hybrid 4 DI/4 DO, and Current/Voltage Option

Power Connections

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

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

The POWER terminals on the rear panel, A01 (+/H) and A02 (−/N), must connect to 110–240 Vac, 110–250 Vdc or 24–48 Vdc (see *Power Supply on page 1.9* for complete power input specifications). The POWER terminals are isolated from chassis ground. Use 14 AWG (2.1 mm^2) to 16 AWG (1.3 mm^2) size wire to connect to the POWER terminals.

For compliance with IEC 60947-1 and IEC 60947-3, place a suitable external switch or circuit breaker in the power leads for the SEL-787; this device should interrupt both the hot (+/H) and neutral (−/N) power leads. The maximum current rating for the power disconnect circuit breaker or optional overcurrent device (fuse) should be 20 A, 300 V.

Operational power is internally fused by a power supply fuse. See *Field Serviceability on page 2.32* for details. Be sure to use fuses that comply with IEC 60127-2.

Grounding (Earthing) Connections

You must connect the ground terminal labeled GND on the rear panel to a rack frame or switchgear ground for proper safety and performance. Use 14 AWG (2.1 mm^2) to 18 AWG (0.8 mm^2) wire less than 2 m (6.6 ft) in length for the ground connection.

Serial Ports

Because all ports (F, 2, 3, and 4) are independent, you can communicate to any combination simultaneously. Although serial Port 4 on the optional communications card consists of an EIA-485 (4A) and an EIA-232 (4C) port, only one port is available at a time. Use the Port 4 communications interface COMMINF setting to select between EIA-485 and EIA-232.

The serial port EIA-485 plug-in connector accepts wire size AWG 26 through AWG 14. Strip the wires 8 mm (0.31 in) and install with a small slotted-tip screwdriver. All EIA-232 ports accept 9-pin D-subminiature male connectors.

For connecting devices at distances over 100 feet, where metallic cable is not appropriate, SEL offers fiber-optic transceivers or the SEL-2812 compatible ST fiber-optic port. The SEL-2800 family of transceivers provides fiber-optic links between devices for electrical isolation and long-distance signal transmission. Contact SEL for further information on these products.

IRIG-B Time-Code Input

The SEL-710 accepts a demodulated IRIG-B time signal to synchronize the internal clock with an external source. Three options for IRIG-B signal input are given, but only one should be used at a time. You can use the IRIG-B (B01 and B02) inputs, an SEL communications processor via EIA-232 serial PORT 3, or fiber-optic serial PORT 2. The available communications processors are the SEL-2032, SEL-2030, SEL-2020, and the SEL-2100 Logic Processor. You can also use the SEL-3530 Real-Time Automation Controller (RTAC) to provide IRIG-B input.

The models with fiber-optic Ethernet and dual copper Ethernet do not have the terminals B01 and B02 for IRIG-B but have IRIG-B input via EIA-232 PORT 3. The third option for IRIG-B is via fiber-optic serial PORT 2. Use an SEL-2812MT Transceiver to connect to the SEL-2030 or SEL-2032 and bring the IRIG-B signal with the EIA-232 input. Use a fiber-optic cable pair with ST connectors (C805 or C807) to connect to PORT 2 on the SEL-710. Refer to *Section 7: Communications* for IRIG-B connection examples and for details about using an SEL-2401/2407/2404 as a time source.

Ethernet Port

The SEL-787 can be ordered with optional single/dual communications ports of a 10/100BASE-T or 100BASE-FX Ethernet port. Connect to **Port 1** of the device using a standard RJ45 connector for the copper port and an LC connector for the fiber-optic port.

Fiber-Optic Serial Port

The optional fiber-optic serial port is compatible with the SEL-2812 Fiber-Optic Transceiver and SEL-2600 RTD Modules.

I/O Diagram

A more functional representation of two of the control (I/O) connections are shown in *Figure 2.12* and *Figure 2.13*.

NOTE: All digital input and digital output (including high-current, high-speed hybrid) connections are polarity neutral.

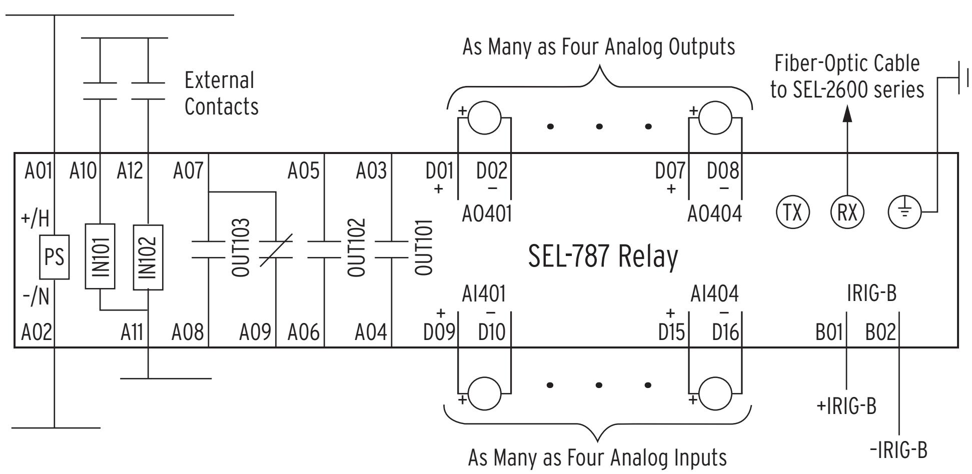
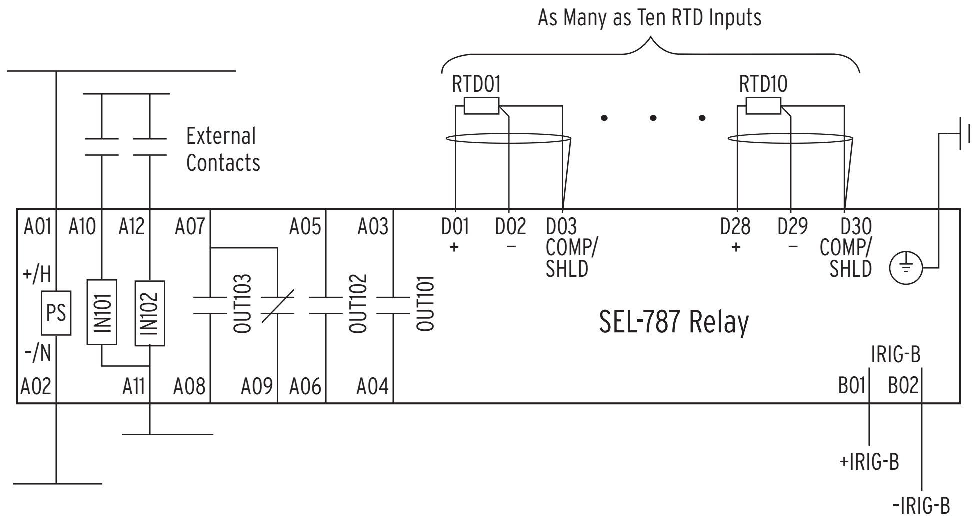


Figure 2.12 Control I/O Connections—4 AI/4 AO Option in Slot D and Fiber-Optic Port in Slot B

NOTE: All RTD comp/shield terminals are internally connected to the relay chassis and ground.



Notes:

- The chassis ground connector located on the rear-panel card Slot A must always be connected to the local ground mat.
- Power supply rating (110–240 Vac, 110–250 Vdc or 24–48 Vdc) depends on relay part number.
- Optoisolated inputs IN101 and IN102 are standard and located on the card in Slot A.
- All optoisolated inputs are single-rated: 24, 48, 110, 125, 220, or 250 Vac/Vdc. Standard inputs IN101/102 may have a different rating than the optional IN401/402/403/404 (not shown).
- Output contacts OUT101, OUT102, and OUT103 are standard and located on the card in Slot A.
- The analog (transducer) outputs shown are located on the optional I/O expansion card in Slot D.
- The fiber-optic serial port is located on the card in Slot B. A Simplex 62.5/125 µm fiber-optic cable is required to connect the SEL-787 with an SEL-2600 RTD Module. This fiber-optic cable should be 1000 meters or shorter.

Figure 2.13 Control I/O Connections—Internal RTD Option

RTD Wiring

NOTE: RTD inputs are not internally protected for electrical surges (IEC 60255-22-1 and IEC 60255-22-5). External protection is recommended if surge protection is necessary.

Table 2.13 shows the maximum cable lengths for the RTD connections that satisfy the 25-ohm limit required for connecting to SEL devices.

Table 2.13 Typical Maximum RTD Lead Length

RTD Lead AWG	Maximum Length
28	116 m
26	184 m
24	290 m
22	455 m
20	730 m
18	1155 m
16	1848 m

Refer to application guide *AG2017-09: Applying Various Types of RTDs With SEL Devices*. This application guide specifies the correct connection of two-wire, three-wire, and four-wire RTDs to three-terminal SEL measurement devices.

RTD wiring recommendations:

1. Use shielded, twisted-pair cables for RTD wiring.
2. Connect the RTD_CAL wire to the RTD CAL/SHIELD terminal on the SEL device. This will eliminate any wiring resistance error.
3. Make sure the RTD mounting ear screws are snug and secure.

Use relay wire termination kits—see *Application Note AN2014-08*—and avoid fitting multiple wires into a single terminal, the bird-caging effect of stranded wires, and bulky wire bundles.

Analog Output Wiring

NOTE: Connection of dc voltage to the analog output terminals could result in damage to the relay.

Connect the two terminals of the analog output as shown in *Figure 2.14*. Also connect the analog output cable shield to ground at the relay chassis ground, programmable logic controller (PLC), or meter location. Do not connect the shield to ground at both locations.

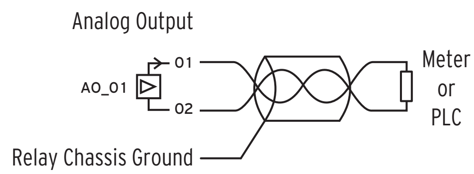


Figure 2.14 Analog Output Wiring Example

AC/DC Control Connection Diagrams

This section describes fail-safe versus nonfail-safe tripping, describes voltage connections, and provides the ac and dc wiring diagrams.

Fail-Safe/Nonfail-Safe Tripping

Figure 2.15 shows the output **OUT103** relay coil and Form C contact. When the relay coil is de-energized, the contact between **A07** and **A08** is open while the contact between **A07** and **A09** is closed.

NOTE: Fast hybrid contacts are designed for fast closing (50 µs) only. Fail-safe mode operating time (time to open the contacts) for fast-hybrid contacts is <8 ms (the same time as for a normal output contact).

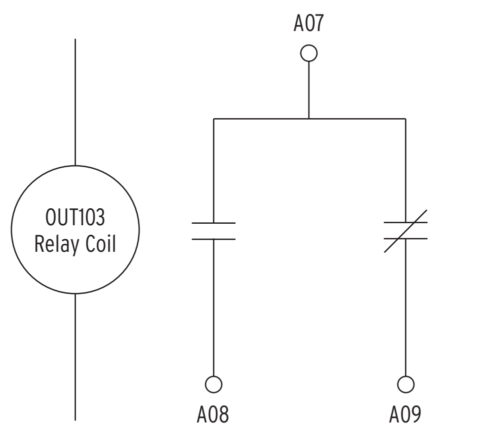


Figure 2.15 Output OUT103 Relay Output Contact Configuration

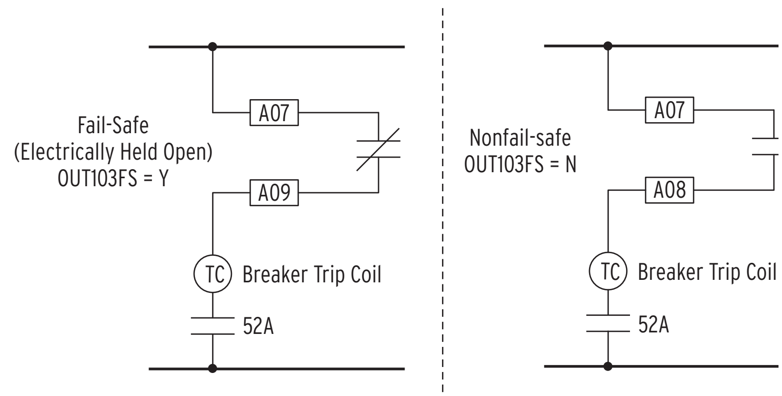
The SEL-787 provides fail-safe and nonfail-safe trip modes (setting selectable) for all output contacts. The following occurs in fail-safe mode:

➤ The relay coil is energized continuously if the SEL-787 is powered and operational.

➤ When the SEL-787 generates a trip signal, the relay coil is de-energized.

➤ The relay coil is also de-energized if the SEL-787 power supply voltage is removed or if the SEL-787 fails (self-test status is FAIL).

Figure 2.16 shows fail-safe and nonfail-safe wiring methods to control breakers.



NOTE: Contacts shown with OUT103 relay coil de-energized

Figure 2.16 Breaker Trip Coil Connection With OUT103FS := Y and OUT103FS := N

High-Speed, High-Current Interrupting Tripping Outputs

High-speed outputs are optimized for the direct tripping of power circuit breakers. High-speed outputs operate in less than 50 µs, work with dc trip coil circuits, are polarity insensitive and capable of making 30 A, and can interrupt 10 A with an 8 ms dropout time. High-speed outputs are implemented as hybrid circuits, each of which consists of the parallel combination of a high-current, solid-state switch and an electromechanical bypass relay.

Avoid using high-speed outputs to drive highly sensitive, high-resistance electronic inputs (e.g., <2 mA electronic circuits) unless such inputs are connected in parallel with a low-resistance load (e.g., a breaker trip coil). Avoid connecting multiple high-speed outputs in parallel when driving highly sensitive electronic inputs. Keep wiring short, and use fiber-based MIRRORED BITS communications to bridge longer distances.

Voltage Connections

NOTE: Current limiting fuses in direct-connected voltage applications are recommended to limit short circuit arc-flash incident energy.

With the voltage inputs option, the AC voltages may be directly connected, wye-wye VT connected, open-delta VT connected, or a single-phase VT can be used. *Figure 2.17* and *Figure 2.18* show the methods of connecting single-phase and three-phase voltages.

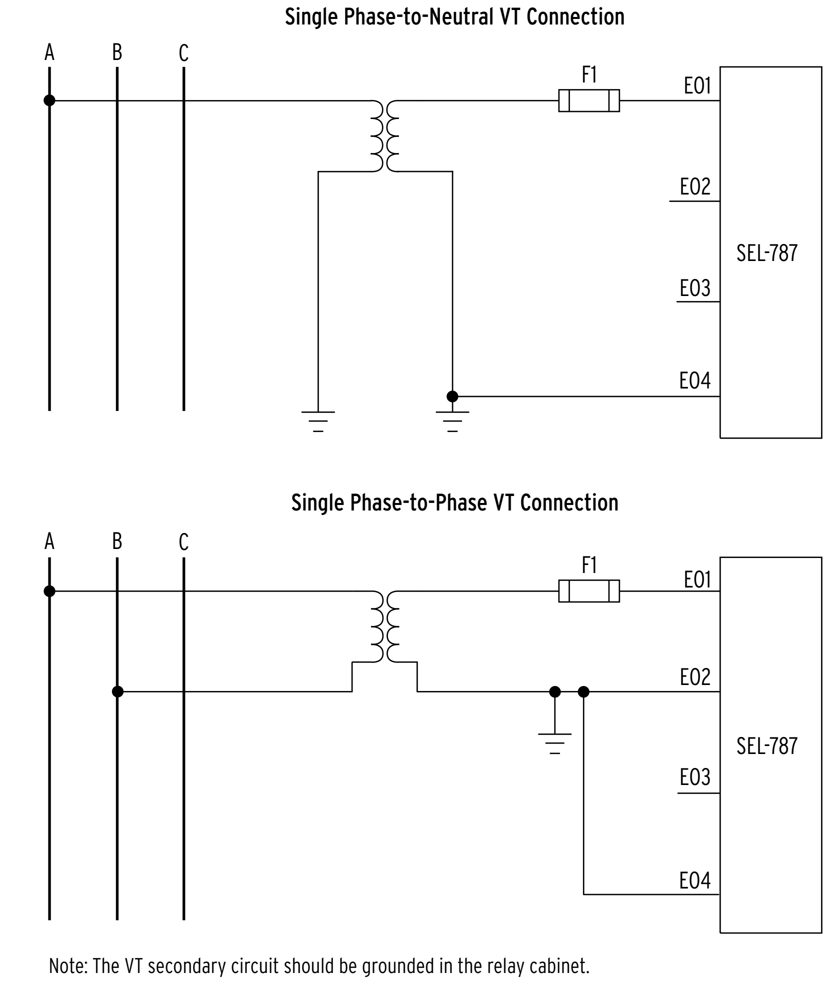
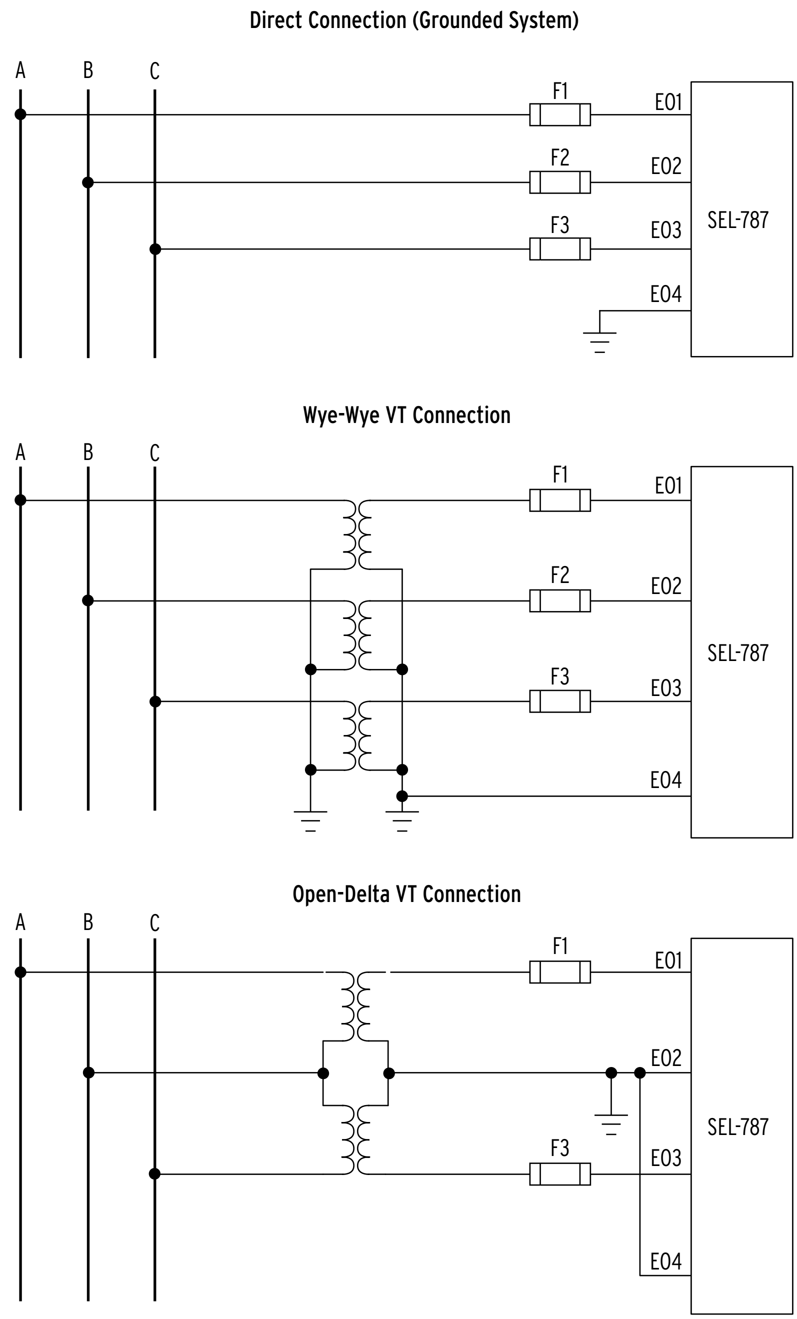


Figure 2.17 Single-Phase Voltage Connections



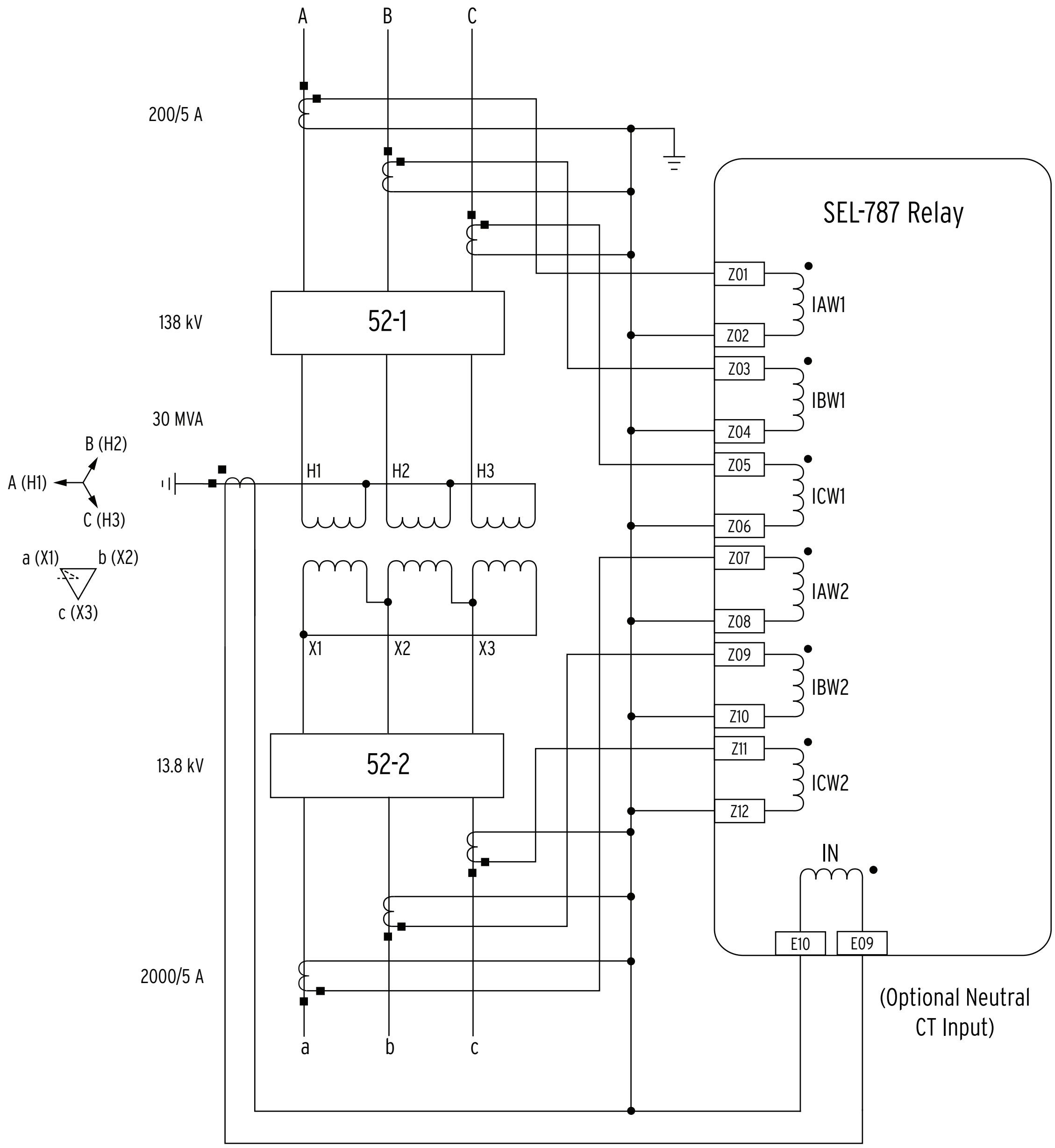
Note: The VT secondary circuit should be grounded in the relay cabinet.

Note: For open-delta VT connections, the figure shows grounding Phase B (E02). You can choose to ground Phase A or Phase C instead of Phase B, but the jumper between terminals E02 and E04 must remain as is.

Figure 2.18 Voltage Connections

Current Connections

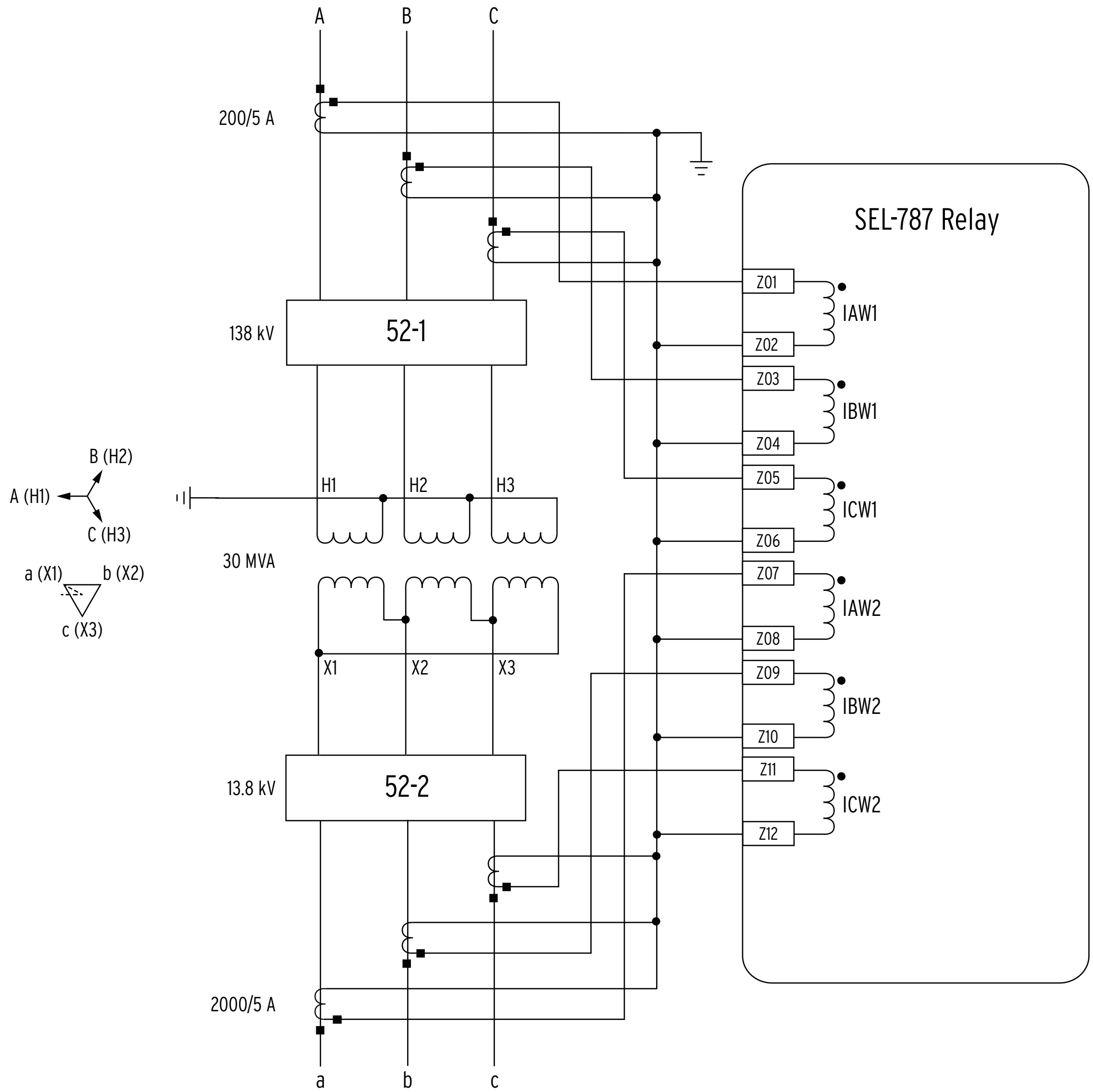
Figure 2.19 shows typical phase and neutral current connections for a Transformer application. *Figure 2.20* through *Figure 2.23* show connection diagrams for various applications. Wye-connected PTs are shown in *Figure 2.22*; see *Figure 2.17* and *Figure 2.18* for other voltage connections. Refer to *Figure 2.24* for an example of dc connections for these applications



Note 1. The IN input channel requires the optional single current channel 1 ACI current card in Slot E.

2. The CT secondary circuit should be grounded in the relay cabinet.

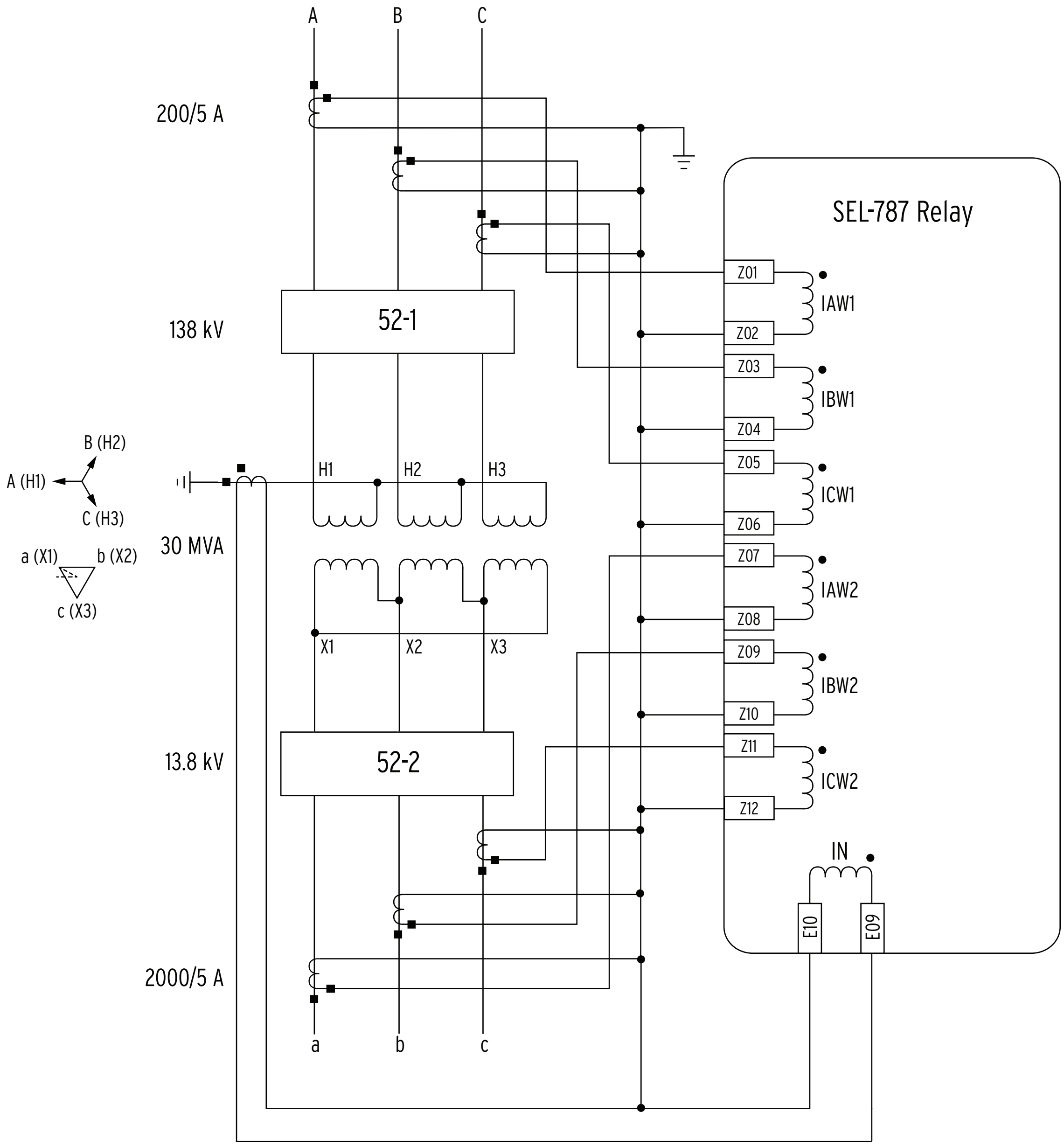
Figure 2.19 Typical Current Connections



The basic application of the SEL-787 relay is for a two-winding transformer. The SEL-787 base product offering provides six current channels that are used to monitor the two transformer windings. Relay contact inputs can be used to monitor high- and low-side breaker status. Relay contact outputs can be used to trip or close high and low side transformer breakers.

Refer to Figure 2.24, which illustrates tripping control of the two-power circuit breakers.

Figure 2.20 SEL-787 Provides Basic Two-Winding Transformer Differential Protection

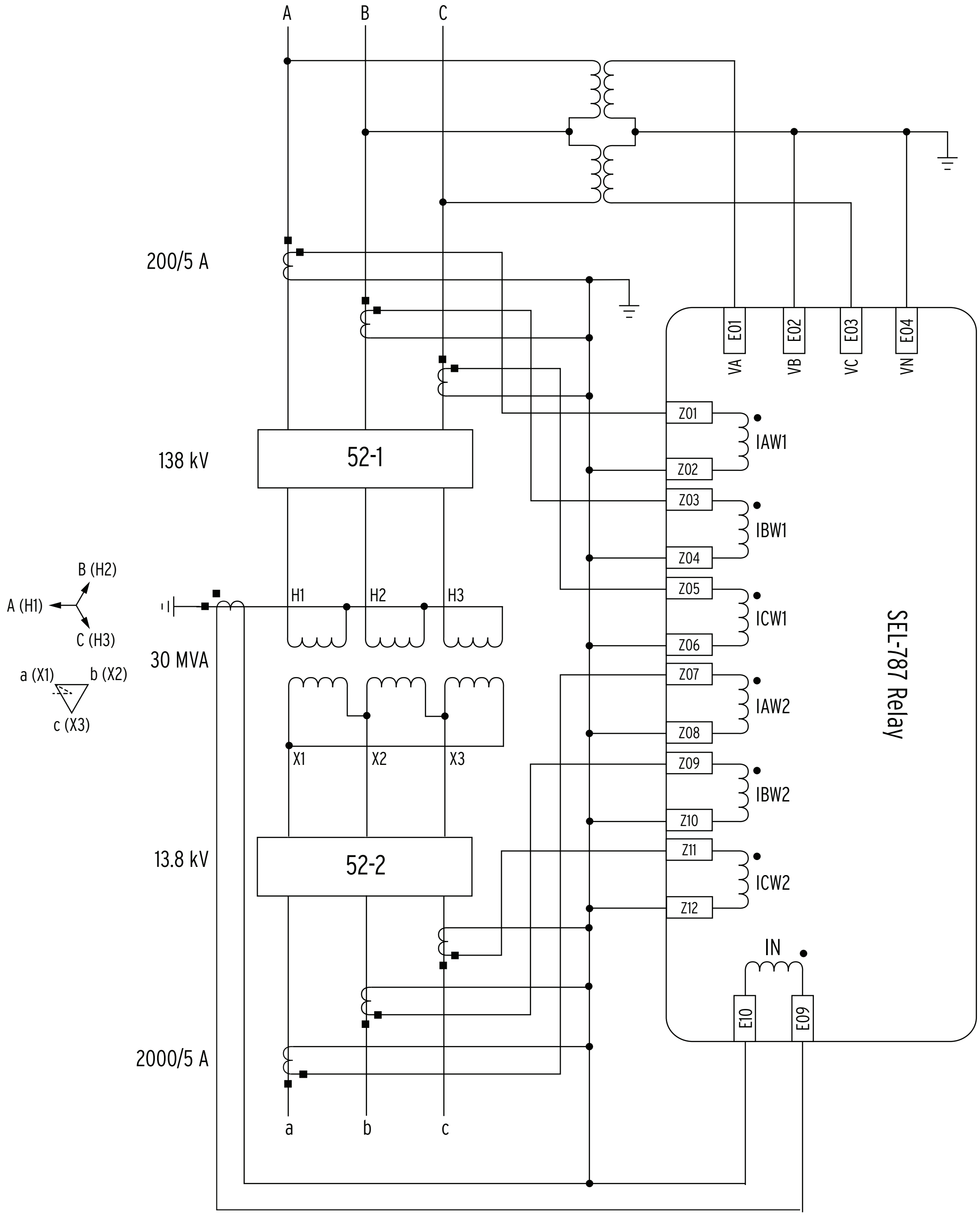


Note: The CT secondary circuit must be grounded in the relay cabinet.

By adding the 1 ACI current card option to Slot **E** of the relay, the relay can be used to provide neutral overcurrent and restricted earth fault protection (REF) of grounded wye transformer winding.

Refer to Figure 2.24, which illustrates tripping control of the two-power circuit breakers.

Figure 2.21 SEL-787 Provides Two-Winding Transformer Differential Protection With REF (Restricted Earth Fault) Protection

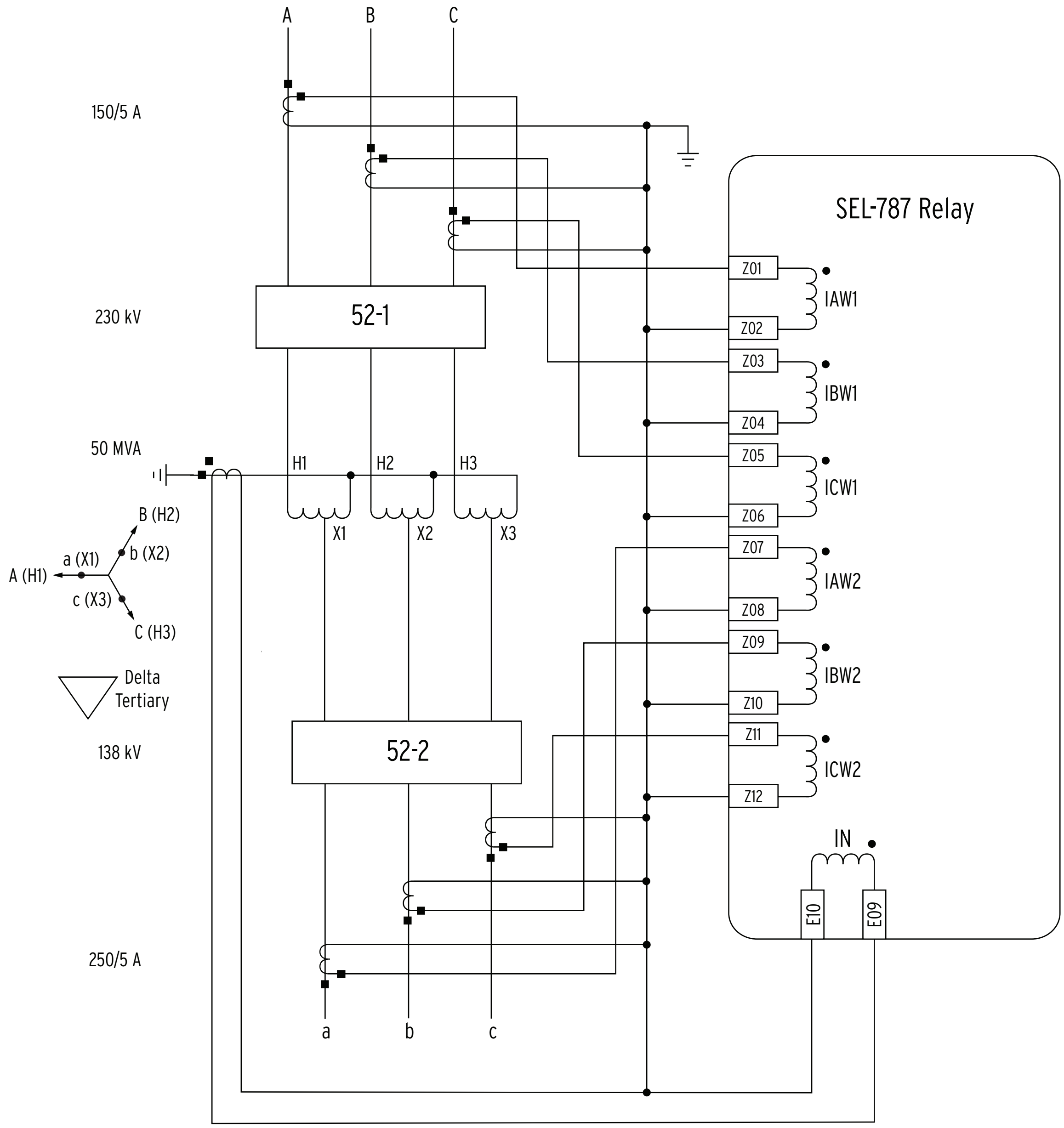


Note: The CT secondary circuit must be grounded in the relay

Installing the optional 1 ACI/3 AVI voltage/current card in Slot **E** of the SEL-787 provides neutral current and REF protection, as well as three-phase voltage inputs. These voltage inputs provide the relay with 20.0 to 70.0 Hz frequency tracking, over-/undervoltage elements, frequency elements, power elements, and volts-per-hertz protection of the transformer.

Refer to Figure 2.24, which illustrates tripping control of the two-power circuit breakers.

Figure 2.22 SEL-787 Provides Two-Winding Transformer Differential Protection With REF and Voltage-Based Protection

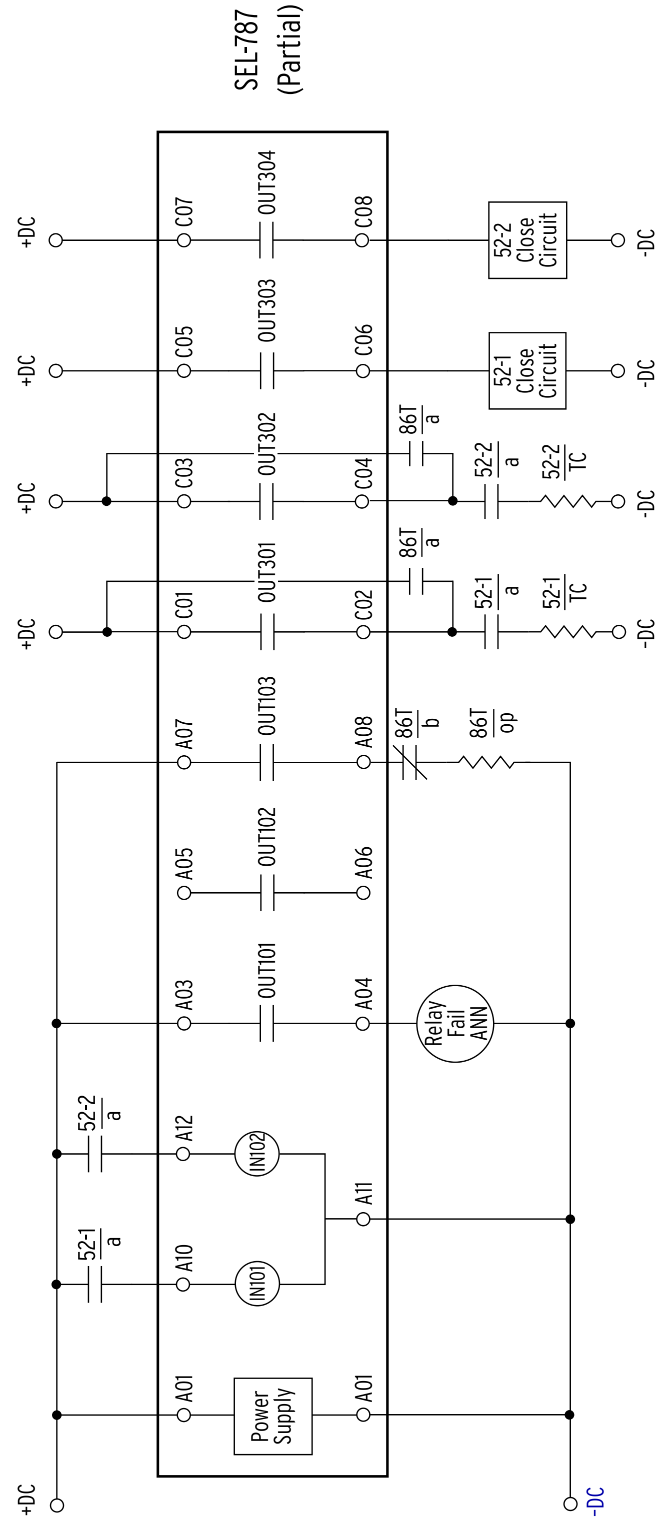


Note: The CT secondary circuit must be grounded in the relay cabinet.

This figure shows an autotransformer application with REF protection applied through the optional 1 ACI current input card in Slot **E** of the relay. In this application, the SEL-787 provides full differential protection, and uses the sum of the high- and low-voltage winding currents to calculate the zero-sequence currents necessary for REF protection.

Refer to Figure 2.24, which illustrates tripping control of the two-power circuit breakers.

Figure 2.23 SEL-787 Provides Autotransformer Differential Protection, Including REF Protection



Note 1: Assumes an optional 4DI/4DO card in Slot C for OUT301–OUT304.

Note 2: Remaining 4 inputs (IN301-IN304) and 1 output (OUT102)

Settings required for the above implementation:

OUT101 := HALARM	OUT103FS := N	OUT302 := TRIP2
OUT101FS := Y	52A1 := IN101	OUT303 := CLOSE1
OUT102 := 0	52A2 := IN102	OUT304 := CLOSE2
OUT103 := TRIPXFMR	OUT301 := TRIP1	

Figure 2.24 Example DC Connections

Field Serviceability

The SEL-787 firmware may be upgraded in the field; refer to *Appendix B: Firmware Upgrade Instructions* for firmware upgrade instructions. You may know when a self-test failure has occurred by configuring an output contact to create a diagnostic alarm as explained in *Section 4: Protection and Logic Functions*. By using the metering functions, you may know if the analog front-end (not monitored by relay self-test) is functional. Refer to *Section 10: Testing and Troubleshooting* for detailed testing and troubleshooting information.

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

The only two components that may be replaced in the field are the power supply fuse and the real-time clock battery. A lithium battery powers the clock (date and time) if the external power source is lost or removed. The battery is a 3 V lithium coin cell, Rayovac BR2335 or equivalent. At room temperature (25°C), the battery will operate nominally for 10 years at rated load. When the relay is powered from an external source, the battery experiences a low self-discharge rate. Thus, battery life may extend well beyond 10 years. The battery cannot be recharged.

Fuse Replacement

⚠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.

To replace the power supply fuse, perform the following steps:

Step 1. De-energize the relay.

Step 2. Remove the four rear-panel screws and the relay rear panel.

Step 3. Remove the Slot **A** printed circuit board.

Step 4. Locate the fuse on the board.

Step 5. Remove the fuse from the fuse holder.

Step 6. Replace the fuse with a BUSS S505 3.15A (ceramic), Schurter T3.15AH250V, or equivalent.

Step 7. Insert the printed circuit board into Slot **A**.

Step 8. Replace the relay rear panel and energize the relay.

Real-Time Clock Battery Replacement

⚠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.

To replace the real-time clock battery, perform the following steps:

Step 1. De-energize the relay.

Step 2. Remove the four rear-panel screws and the relay rear panel.

Step 3. Remove the Slot **B** printed circuit board.

Step 4. Locate the battery clip (holder) on the board.

Step 5. Carefully remove the battery from beneath the clip.

Properly dispose of the old battery.

Step 6. Install the new battery with the positive (**+**) side facing up.

Step 7. Insert the printed circuit board into Slot **B**.

Step 8. Replace the relay rear panel and energize the relay.

Step 9. Set the relay date and time.

Section 3
PC Software

Overview

SEL provides many PC software solutions (applications) to support the SEL-787 and other SEL devices. *Table 3.1* lists SEL-787 software solutions.

Table 3.1 SEL Software Solutions

Part Number	Product Name	Description
SEL-5010	SEL-5010 Relay Assistant Software	Manages a connection directory and settings of multiple devices.
SEL-5030	ACSELERATOR QuickSet SEL-5030 Software	See *Table 3.2*.
SEL-5032	ACSELERATOR Architect SEL-5032 Software	Configures IEC 61850 communications.
SEL-5040	ACSELERATOR Report Server SEL-5040 Software	Automatically retrieves, files, and summarizes reports.
SEL-5601-2	SEL-5601-2 SYNCHROWAVE Event Software	Plots COMTRADE and SEL ASCII format event report oscillography; performs custom calculations on analog, digital, and complex quantities; and analyzes the Impedance Plane for distance element (mho) operation, the Alpha Plane for differential element (78L) operation, and the Bewley Lattice for traveling-wave data.
SEL-5801	SEL-5801 Cable Selector Software	Selects the proper SEL cables for your application.
SEL-5806	SEL-5806 Curve Designer Software	Designs user-defined, volts/Hz inverse-time characteristic curve to match any transformer characteristic (refer to *Section 4: Protection and Logic Functions*).

This section describes how to get started with the SEL-787 and QuickSet. QuickSet is a powerful setting, event analysis, and measurement tool that aids in setting, applying, and using the SEL-787. *Table 3.2* shows the suite of QuickSet applications provided for the SEL-787.

Table 3.2 acSELerator QuickSet SEL-5030 Software

Application	Description
Rules-Based Settings Editor	Provides on-line or off-line device settings that include interdependency checks. Use this feature to create and manage settings for multiple devices in a database.
HMI	Provides a summary view of device operation. Use this feature to simplify commissioning.
Design Templates (available in licensed versions of QuickSet)	Allows you to customize relay settings to particular applications and store those settings in Design Templates. You can lock settings to match your standards or lock and hide settings that are not used.
Event Analysis	Provides oscillography and other event analysis tools.
Settings Database Management	QuickSet uses a database to manage the settings of multiple devices.
Terminal	Provides a direct connection to the SEL device. Use this feature to ensure proper communications and directly interface with the device.
Help	Provides general QuickSet and device-specific QuickSet context.

Setup

Follow the steps outlined in *Section 2: Installation* to prepare the SEL-787 for use. Perform the following steps to initiate communications:

Step 1. Connect the appropriate communications cable between the SEL-787 and the PC.

Step 2. Apply power to the SEL-787.

Step 3. Start QuickSet.

Communications

QuickSet uses relay communications **Port 1** through **Port 4**, or **Port F** (front panel) to communicate with the SEL-787. Perform the following steps to configure QuickSet to communicate effectively with the relay.

Step 1. Select **Communications** from the QuickSet main menu bar, as shown in *Figure 3.1*.

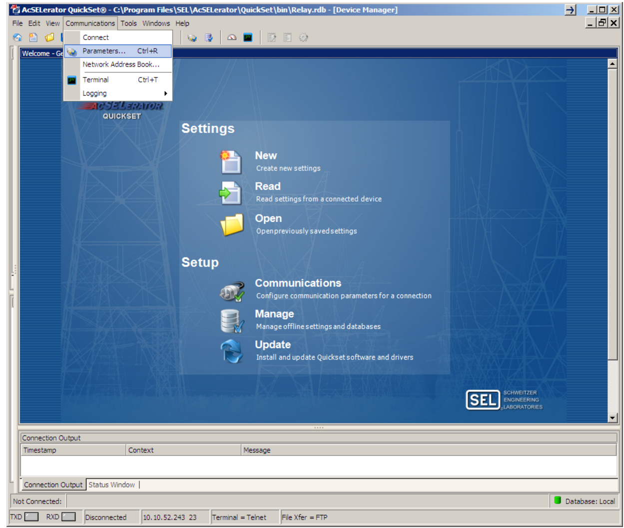


Figure 3.1 Serial Port Communication Dialog Box

Step 2. Select the **Parameters** submenu to display the screen shown in *Figure 3.2*. Configure the PC port to match the relay communications settings.

Step 3. Configure QuickSet to match the SEL-787 default settings by entering Access Level 1 and Access Level 2 passwords in the respective text boxes.

Step 4. If a telephone modem is chosen from the relay text box, enter the dial-up telephone number in the **Phone Number** text box.

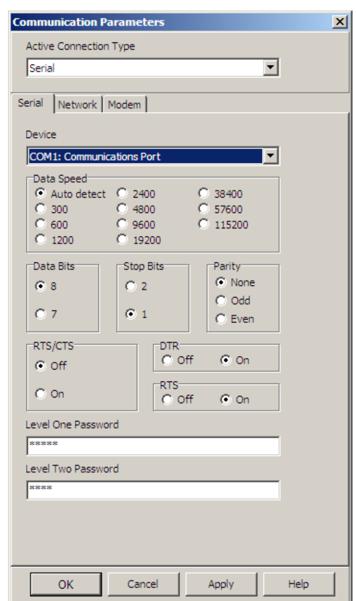


Figure 3.2 Serial Port Communication Parameters Dialog Box

Step 5. For network communications, check the **Use Network** check box and enter the network parameters as shown in *Figure 3.3*.

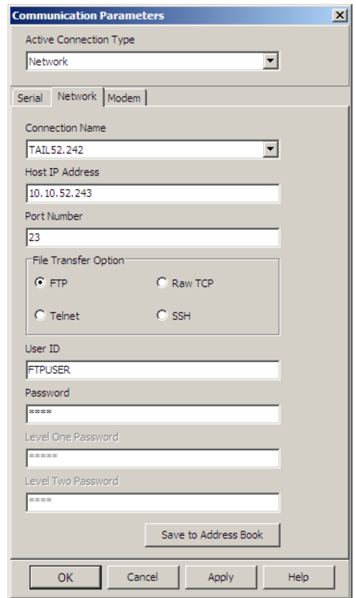


Figure 3.3 Network Communication Parameters Dialog Box

Step 6. Exit the menus by clicking **OK** when finished.

Terminal

Terminal Window

Select **Tools > Terminal** on the QuickSet main menu bar to open the terminal window (shown in *Figure 3.4*).

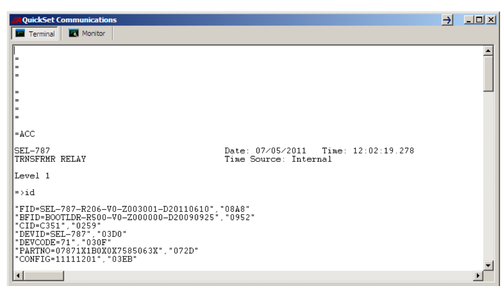


Figure 3.4 Tools Menu

The terminal window is an ASCII interface with the relay. This is a basic terminal emulation. Many third-party terminal emulation programs are available with file transfer encoding schemes. Open the terminal window by either clicking **Tools > Terminal** or by pressing **<Ctrl+T>**. Verify proper communications with the relay by opening a terminal window, pressing **<Enter>** a few times, and verifying that a prompt is received. If a prompt is not received, verify proper setup.

Terminal Logging

To create a file that contains all terminal communications with the relay, select **Terminal Logging** in the **Log** menu, and specify a file at the prompt. QuickSet records communications events and errors in this file. Click **Log > Connect Log** to view the log. Clear the log by selecting **Log > Clear Connection Log**.

Drivers and Part Number

After clicking **Tools > Terminal**, access the relay at Access Level 1. Issue the **ID** command to receive an identification report, as shown in *Figure 3.5*.

```
=>ID <Enter>

"FID=SEL-787-R100-V0-Z001001-D20080407","0947"
"BFID=BOOTLDR-R303-V0-Z000000-D20060612","0949"
"CID=26FF","0271"
"DEVID=SEL-787","03D0"
"DEVCODE=71","030F"
"PARTNO=0787EX1B0X0X7585023X","073D"
"CONFIG=11111201","03EB"
"iedName =TEMPLATE","0380"
"type =SEL-787","028F"
"configVersion =ICD-787-R100-V0-Z001001-D20080326","0629"

=>
```

Figure 3.5 Device Response to the ID Command

Locate and record the Z number (Z001001) in the FID string. The first portion of the Z number (Z001…) determines the QuickSet relay settings driver version when you are creating or editing relay settings files. The use of the Device Editor driver version will be discussed in more detail later in this section—see *Settings Editor (Editor Mode) on page 3.9*. Compare the part number (PARTNO=0787XXXXXXXXXXXXXXXX) with the Model Option Table (MOT) to ensure the correct relay configuration.

Settings Database Management and Drivers

QuickSet uses a database to save relay settings. QuickSet contains sets of all settings files for each relay specified in the Database Manager. Choose appropriate storage backup methods and a secure location for storing database files.

Database Manager

Select **File > Database Manager** on the main menu bar to create new databases and manage records within existing databases.

Settings Database

Step 1. Open the Database Manager to access the database. Click **File > Database Manager**. A dialog box appears.

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

Step 2. Enter descriptions for the database and for each relay or relay in the database in the **Database Description** and **Settings Description** dialog boxes.

Step 3. Enter special operating characteristics that describe the relay settings in the **Settings Description** dialog box. These can include the protection scheme settings and communications settings.

Step 4. Highlight one of the relays listed in **Settings in Database** and select the **Copy** option button to create a new collection of settings.

QuickSet prompts for a new name. Be sure to enter a new description in **Settings Description**.

Copy/Move Settings Between Databases

Step 1. Select the **Copy/Move Settings Between Databases** tab to create multiple databases with the **Database Manager**; these databases are useful for grouping similar protection schemes or geographic areas.

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

Step 3. Type a filename and click **Open**.

a. Highlight a device or settings file in **Settings Database A**.

b. Select **Copy** or **Move**, and click the **>** button to create a new device or settings file in **Settings Database B**.

Step 4. Reverse this process to take a device or settings file from **Settings Database B** to **Settings Database A**. **Copy** creates an identical device or settings file that appears in both databases. **Move** removes the device or settings file from one database and places the device or settings file in another database.

Create a New Database, Copy an Existing Database

To create and copy an existing database of devices to a new database:

Step 1. Click **File > Database Manager**, and select the **New** button. QuickSet prompts you for a file name.

Step 2. Type the new database name (and location if the new location differs from the existing one), and click **Save**. QuickSet displays the message `Settings [path and filename] was successfully created`.

Step 3. Click **OK**.

To copy an existing database of devices to a new database:

Step 1. Click **File > Database Manager**, and select the **Copy/Move Settings Between Databases** tab in the **Database Manager** dialog box.

QuickSet opens the last active database and assigns it as **Settings Database A**.

Step 2. Click the **Settings Database B** ... button; QuickSet prompts you for a file location.

Step 3. Type a new database name, click the **Open** button.

Settings

QuickSet offers the capability of creating settings for one or more SEL-787 Relays. Store existing relay settings downloaded from SEL-787 Relays with QuickSet, creating a library of relay settings, then modify and upload these settings from the settings library to an SEL-787. QuickSet makes setting the relay easy and efficient. However, you do not have to use QuickSet to configure the SEL-787; you can use an ASCII terminal or a computer running terminal emulation software. QuickSet provides the advantages of rules-based settings checks, SELOGIC control equation Expression Builder, operator control and metering HMI, event analysis, and help.

Settings Editor

The Settings Editor shows the relay settings in easy-to-understand categories. The SEL-787 settings structure makes setting the relay easy and efficient. Settings are grouped logically, and relay elements that are not used in the selected protection scheme are not accessible. For example, if there is only one analog card installed in the relay, you can access settings for this one card only. Settings for the other slots are dimmed (grayed) in the QuickSet menus. QuickSet shows all of the settings categories in the settings tree view. The settings tree view remains constant whether settings categories are enabled or disabled. However, any disabled settings are dimmed when accessed by clicking an item in the tree view.

Settings Menu

QuickSet uses a database to store and manage SEL relay settings. Each unique relay has its own record of settings. Use the **File** menu to **Open** an existing record, create and open a **New** record, or **Read** relay settings from a connected SEL-787 and then create and open a new record. Use **Tools** menu to **Convert** and open an existing record. The record will be opened in the **Setting Editor** as a **Setting Form** (template) or in **Editor Mode**.

Table 3.3 File/Tools Menus

Menus	Description
<<, >>	Use these navigation menu buttons to move from one category to the next
New	Open a new record
Open	Open an existing record
Read	Read device settings and then create and open a new record
Convert	Convert and open an existing record

File > New

Selecting the **New** menu item creates new settings files. QuickSet makes the new settings files from the driver that you specify in the **Settings Editor Selection** dialog box. QuickSet uses the Z number in the FID string to create a particular version of settings. To get started making SEL-787 settings with the **Settings Editor** in the **Editor Mode**, select **File > New** from the main menu bar, and SEL-787 and **001** from the **Settings Editor Selection** window as shown in *Figure 3.6*.

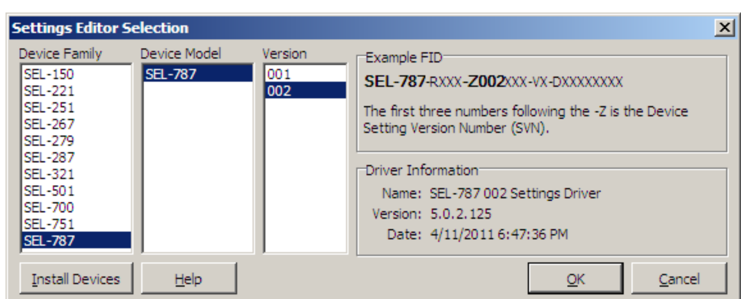


Figure 3.6 Selection of Drivers

After the relay model and settings driver selection, QuickSet presents the **Relay Part Number** dialog box. Use this dialog box to configure the Relay Editor to produce settings for a relay with options determined by the part number, as shown in *Figure 3.7*. Press **OK** when finished.

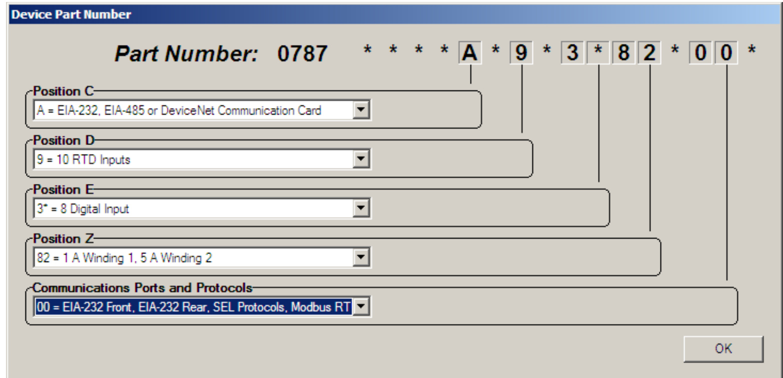


Figure 3.7 Update Part Number

Figure 3.8 shows the **Settings Editor** screen. View the bottom of the Settings Editor window to check the **Settings Driver** number. Compare the QuickSet Settings Driver number and the first portion of the Z number in the FID string (select **Tools > Meter & Control > Status**). These numbers must match. QuickSet uses this first portion of the Z number to determine the correct **Settings Editor** to display.

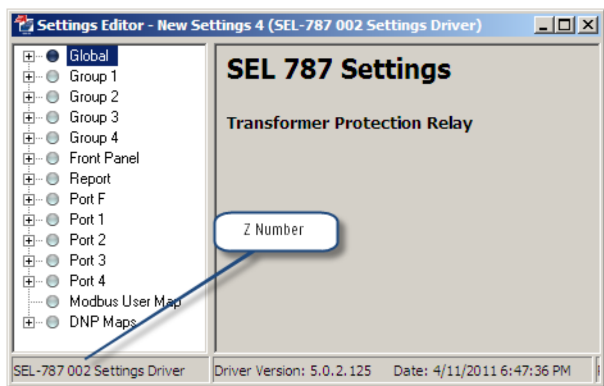


Figure 3.8 New Setting Screen

File > Open

The **Open** menu item opens an existing device from the active database folder. QuickSet prompts for a device to load into the **Settings Editor**.

File > Read

When the **Read** menu item is selected, QuickSet reads the device settings from a connected device. As QuickSet reads the device, a **Transfer Status** window appears. QuickSet uses serial protocols to read settings from SEL devices.

Tools > Convert

Use the **Convert** menu item to convert from one settings version to another. Typically, this utility is used to upgrade an existing settings file to a newer version because devices are using a newer version number. QuickSet provides a **Convert Settings** report that shows missed, changed, and invalid settings created as a result of the conversion. Review this report to determine whether changes are required.

Settings Editor (Editor Mode)

Use the **Settings Editor (Editor Mode)** to enter settings. These features include the QuickSet settings driver version number (the first three digits of the Z number) in the lower left corner of the Settings Editor.

Entering Settings

NOTE: Setting changes made during the edit session are not read by the relay unless they are transferred to the relay with a Send menu item.

Step 1. Click the **+** marks and the buttons in the **Settings Tree View** to expand and select the settings you want to change.

Step 2. Use **Tab** to navigate through the settings, or click on a setting.

Step 3. To restore the previous value for a setting, right-click the mouse over the setting and select **Previous Value**.

Step 4. To restore the factory-default setting value, right-click in the setting dialog box and select **Default Value**.

Step 5. If you enter a setting that is out of range or has an error, QuickSet shows the error at the bottom of the **Settings Editor**. Double-click the error listing to go to the setting and enter a valid input.

Expression Builder

NOTE: Be sure to enable the functions you need (Logic Settings > SELOGIC Enable) before using Expression Builder.

SELOGIC control equations are a powerful means for customizing device performance. QuickSet simplifies this process with the Expression Builder, a rules-based editor for programming SELOGIC control equations. The Expression Builder organizes device elements, analog quantities, and SELOGIC control equation variables.

Access the Expression Builder

Use the Ellipsis buttons ... in the Settings dialog boxes of **Settings Editor** windows to create expressions, as shown in *Figure 3.9*.

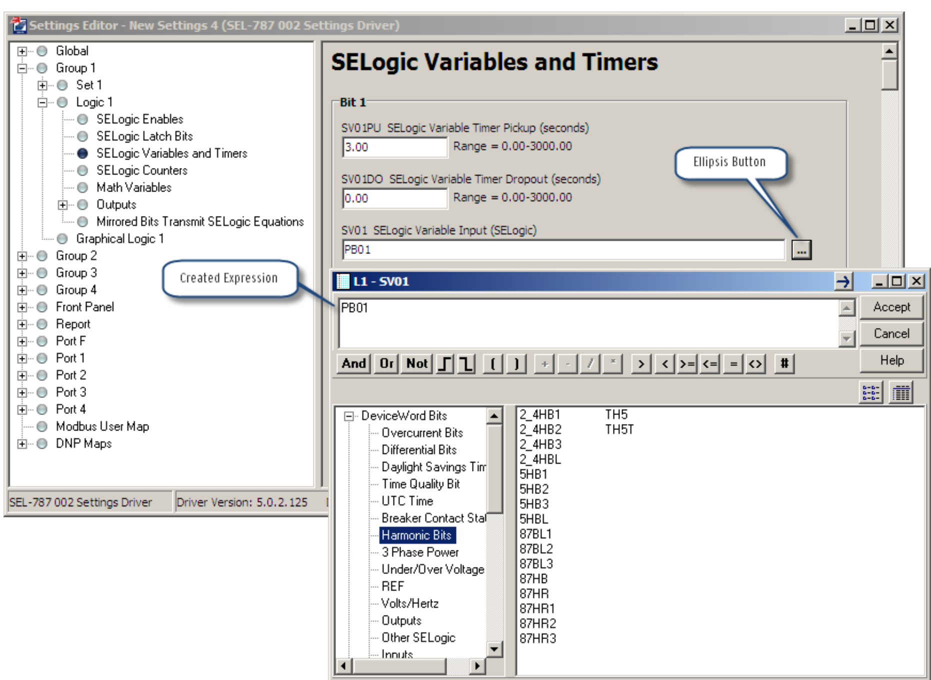


Figure 3.9 Expressions Created With Expression Builder

Expression Builder Organization

The **Expression Builder** dialog box is organized into two main parts representing the left side (LVALUE) and right side (RVALUE) of the SELOGIC control equation. The LVALUE is fixed for all settings.

Using the Expression Builder

Use the right side of the equation (RVALUE) to select broad categories of device elements, analog quantities, counters, timers, latches, and logic variables. Select a category in the RVALUE tree view, and the **Expression Builder** displays all operands for that category in the list box at the bottom right side. Directly underneath the right side of the equation, choose operators to include in the RVALUE. These operators include basic logic, rising- and falling-edge triggers, expression compares, and comments.

File > Save

Select the **Save** menu item from the **File** menu item of the **Settings Editor** once settings are entered into QuickSet. This will help ensure the settings are not lost.

File > Send

To transfer the edits made in the QuickSet edit session, you must send the settings to the relay. Select **Send** from the **File** menu. In the dialog box that opens, select the settings section you want transferred to the relay by checking the appropriate box.

Edit > Part Number

Use this menu item to change the part number if it was entered incorrectly during an earlier step.

Text Files

Select **Tools > Import** and **Tools > Export** on the QuickSet menu bar to import or export settings from or to a text file. Use this feature to create a small file that can be more easily stored or sent electronically.

Event Analysis

QuickSet has integrated analysis tools that help you retrieve information about relay operations quickly and easily. Use the event information that the SEL-787 stores to evaluate the performance of a system (select **Tools > Events > Get Event Files**). *Figure 3.10* shows composite screens for retrieving events.

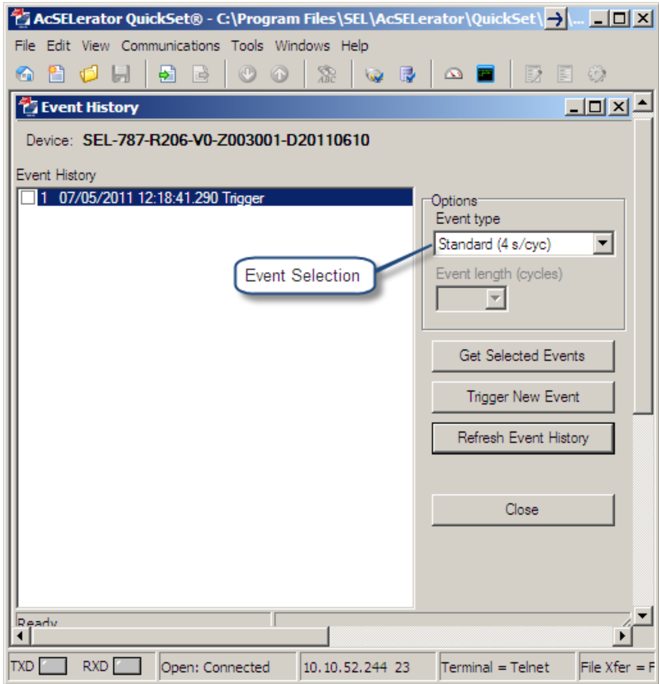


Figure 3.10 Retrieve Events Screen

Event Waveforms

The relay provides two types of event data captures: event reports that use 4 samples/cycle filtered data and 16 samples/cycle unfiltered (raw) data. See *Section 9: Analyzing Events* for information on recording events. Use the **Options** function in *Figure 3.10* to select the 16 samples/cycle unfiltered (raw) data event (default is 4 samples/cycle filtered data).

View Event History

You can retrieve event files stored in the relay and transfer these files to a computer. For information on the types of event files and data capture, see *Section 9: Analyzing Events*. To download event files from the device, click **Tools > Events > Get Event Files**. The **Event History** dialog box appears, as shown in *Figure 3.10*.

Get Event

Highlight the event you want to view (e.g., Event 3 in *Figure 3.10*), select the event type with the Options Event type function (4 samples or 16 samples), and click the **Get Selected Event** button. QuickSet then queries where to save the file on your computer, as shown in *Figure 3.11*.

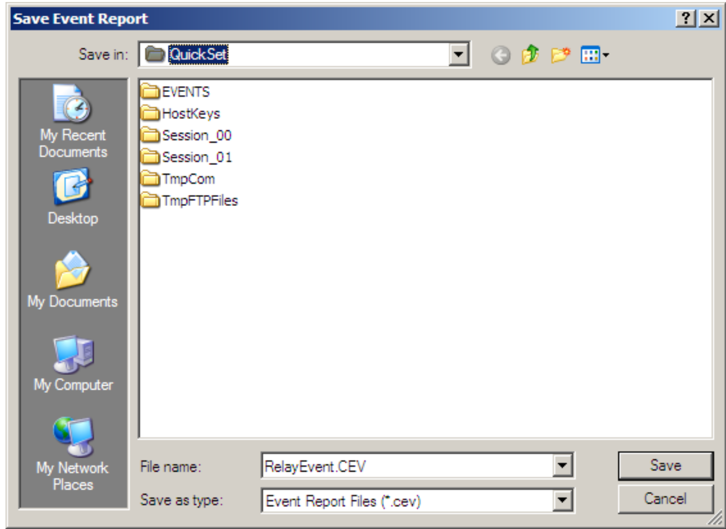


Figure 3.11 Saving the Retrieved Event

Enter a suitable name in the **File name** text box, and select the appropriate location where QuickSet should save the event record.

View Event Files

To view the saved events, you need SYNCHROWAVE Event. Use the **View Event Files** function from the **Tools > Events** menu to select the event you want to view (QuickSet remembers the location where you stored the previous event record). Use **View Combined Event Files** to simultaneously view as many as three separate events.

Meter and Control

Click on **Tools > Meter & Control** to bring up the screen shown in *Figure 3.12*. The HMI tree view shows all the functions available from the HMI function. Unlike the self-configuration of the device, the HMI tree remains the same regardless of the type of cards installed. For example, if no analog input card is installed, the analog input function is still available, but the device responds as follows:

```
No Analog Input Card Present.
```

Device Overview

The device overview screen provides an overview of the device. The Contact I/O portion of the window displays the status of the two inputs and three outputs of the main board. You cannot change these assignments.

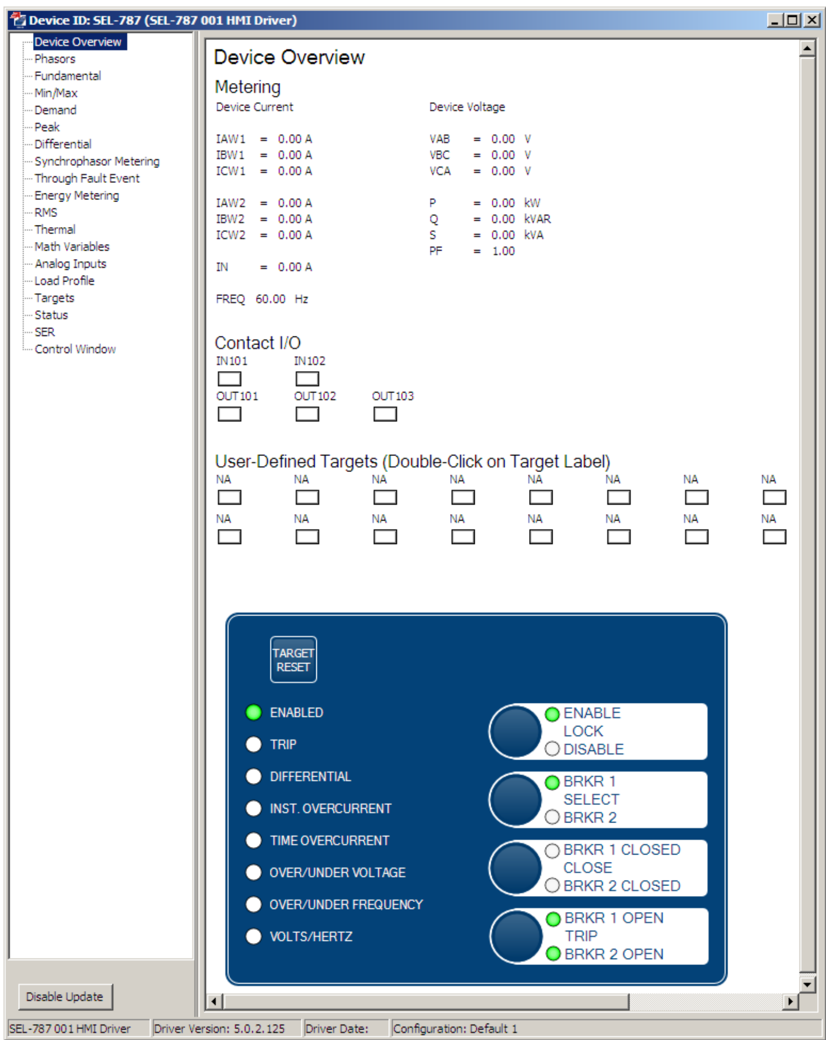


Figure 3.12 Device Overview Screen

You can assign any Relay Word bit to the 16 user-defined target LEDs. To change the present assignment, double-click on the text above the square you want to change. After double-clicking on the text, a box with available Relay Word bits appears in the lower left corner of the screen. Select the appropriate Relay Word bit, and click the **Update** button to assign the Relay Word bit to the LED. To change the color of the LED, click in the square and make your selection from the color palette.

The front-panel LEDs display the status of the 16 front-panel LEDs. Use the front-panel settings to change the front-panel LED assignment.

The **Phasors**, **Fundamental**, **Min/Max**, etc., screens display the corresponding values.

Click on the **Targets** button to view the status of all the Relay Word bits. When a Relay Word bit has a value of 1 (ENABLED = 1), the Relay Word bit is asserted. Similarly, when a Relay Word bit has a value of 0 (RB02 = 0), the Relay Word bit is deasserted.

The **Status** and **SER** screens display the same information as the ASCII **STA** and **SER** commands.

Figure 3.13 shows the control screen. From here you can clear the Event History, MIRRORED BITS report, SER, trigger events, and reset metering data. You can also reset the targets, synchronize with IRIG, and set the time and date. The Through-Fault Event (TFE) Monitor Pre-load can be entered here also.

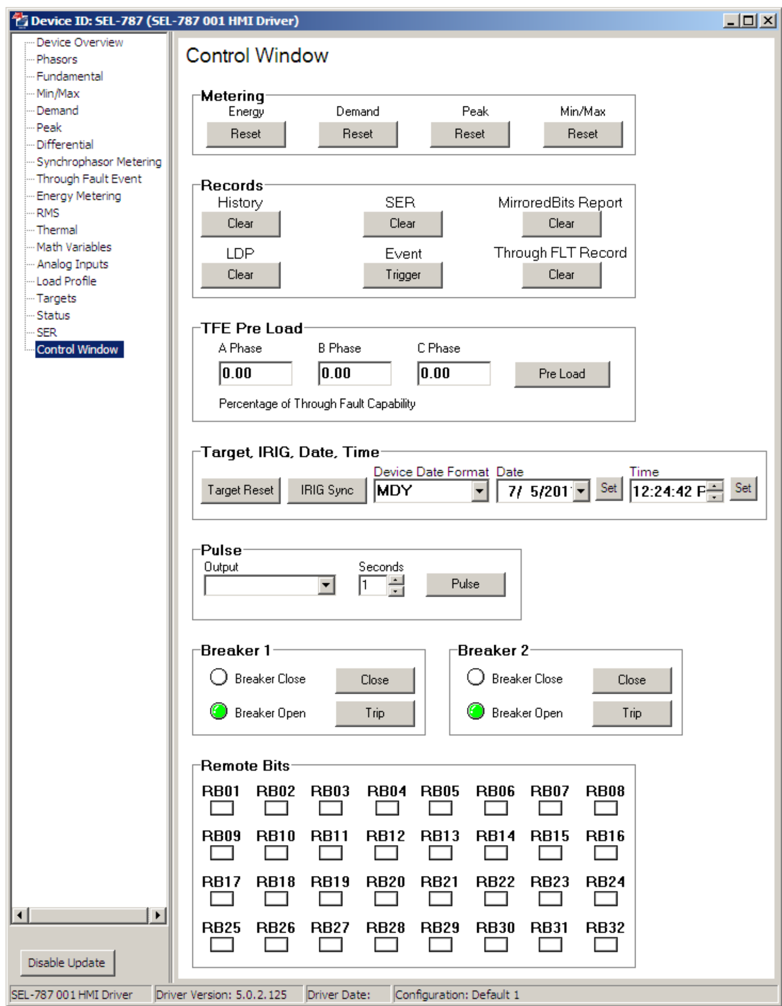


Figure 3.13 Control Screen

To control the remote bits, click on the appropriate square, then select the operation from the box shown in *Figure 3.14*.

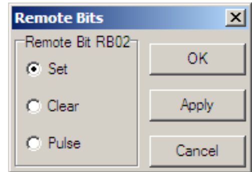


Figure 3.14 Remote Operation Selection

QuickSet Help

Various forms of QuickSet help are available, as shown in *Table 3.4*. Press **<F1>** to open a context-sensitive help file with the appropriate topic as the default.

Table 3.4 QuickSet Help

Help	Description
General QuickSet	Select **Help > Contents** from the main menu bar.
Relay Settings	Select **Help > Settings Help** from the main menu bar.

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Section 4
Protection and Logic Functions

Overview

NOTE: Each SEL-787 is shipped with default factory settings. Calculate the settings for your application to ensure secure and dependable protection. Document and enter the settings (see Section 6: Settings).

This section describes the SEL-787 Transformer Protection Relay settings, including the protection elements and basic functions, control I/O logic, as well as the settings that control the communications ports and front-panel displays.

This section includes the following subsections:

Application Data. Lists information that you will need to know about the protected equipment before calculating the relay settings.

Group Settings (SET Command). Lists settings that configure the relay inputs to accurately measure and interpret the ac current and optional voltage input signals.

Basic Protection. Lists settings for the differential, optional restricted earth fault, and the overcurrent protection elements.

RTD-Based Protection. Lists settings associated with the RTD inputs. You can skip this subsection if your application does not include RTD inputs.

Voltage-Based Protection. Lists settings associated with the optional ac voltage-based protection elements. You can skip this subsection if your relay is not equipped with optional voltage inputs.

Demand Metering. Lists settings associated with demand metering.

Trip/Close Logic. Lists Trip and Close logic.

Logic Settings (SET L Command). Lists settings associated with latches, timers, and output contacts.

Global Settings (SET G Command). Lists settings that allow you to configure the relay to your power system, date format, analog inputs/outputs, and logic equations of global nature.

Port Settings (SET P Command). Lists settings that configure the relay front and rear ports.

Front-Panel Settings (SET F Command). Lists settings for the front-panel display, pushbuttons, and LED control.

Report Settings (SET R Command). Lists settings for the sequential event reports, event reports, and load profile reports.

DNP Map Settings (SET DNP n Command, n = 1, 2, or 3). Shows DNP user map register settings.

Modbus Map Settings (SET M Command). Shows Modbus user map register settings.

When you calculate the protection element settings, proceed through the subsections listed earlier. Skip the RTD, voltage-based, and frequency protection subsections if they do not apply to your specific relay model or installation. See *Section 6: Settings* for the list of all settings (*SEL-787 Settings Sheets*) and various methods of accessing them. All current and voltage settings in the SEL-787 are in secondary.

NOTE: The DeviceNet port parameters can only be set at the rear of the relay on the DeviceNet card (see Figure G.1).

You can enter the settings by using the front-panel SET RELAY function (see *Section 8: Front-Panel Operations*), the serial ports (see *Section 7: Communications*), the DeviceNet port (see *Appendix G: DeviceNet Communications*), or the Ethernet port (see *Section 7: Communications*).

Application Data

It is faster and easier for you to calculate settings for the SEL-787 if you collect the following information before you begin:

NOTE: The terms winding and terminal are used interchangeably in this manual.

- Power transformer data: MVA rating, winding configurations and voltages, impedance, etc.
- Highest expected load current
- Current transformer primary and secondary ratings and connections
- System phase rotation and nominal frequency
- Voltage transformer ratios and connections, if used
- Type and location of resistance temperature devices (RTDs), if used
- Expected fault current magnitudes for ground and three-phase faults

Group Settings (SET Command)

ID Settings

All models of the SEL-787 have the identifier settings described in *Table 4.1*.

Table 4.1 Identifier Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
UNIT ID LINE 1	16 Characters	RID := SEL-787
UNIT ID LINE 2	16 Characters	TID := TRNSFRMR RELAY

The SEL-787 prints the Relay and Terminal Identifier strings at the top of the responses to serial port commands to identify messages from individual relays.

Enter as many as 16 characters, including letters A–Z (not case sensitive), numbers 0–9, periods (.), dashes (-), and spaces. Suggested identifiers include the location or number of the protected transformer.

Configuration Settings

Table 4.2 Configurations and Ratings (Phase CTs, Power Transformer)

Setting Prompt	Setting Range	Setting Name := Factory Default
WDG1 CT CONN	DELTA, WYE	W1CT := WYE
WDG2 CT CONN	DELTA, WYE	W2CT := WYE
WDG1 PHASE CTR	1–10000 {5 A IW1NOM} 1–50000 {1 A IW1NOM}	CTR1 := 100
WDG2 PHASE CTR	1–10000 {5 A IW2NOM} 1–50000 {1 A IW2NOM}	CTR2 := 1000
MAX XFMR CAP	OFF, 0.2–5000.0 MVA	MVA := 50.0
DEFINE CT COMP	Y, N	ICOM := N
WDG1 CT COMP	0, 1, … 12	W1CTC := 12
WDG2 CT COMP	0, 1, … 12	W2CTC := 12
WDG1 L-L VOLTS	0.20–1000.00 kV	VWDG1 := 138.00
WDG2 L-L VOLTS	0.20–1000.00 kV	VWDG2 := 13.80

The winding CT connection settings are used to appropriately configure protection (differential, overcurrent, etc.) and power metering functions.

The CT ratio settings configure the relay to accurately scale measured values and report the primary quantities. Calculate the phase and neutral CT ratios by dividing the primary rating by the secondary rating.

EXAMPLE 4.1 Phase CT Ratio Setting Calculations

Consider an application where the Winding 1 CT rating is 600:5 A.

Set CTR1 := 600/5 := 120.

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

The ICOM setting defines whether the input currents need any correction, either to accommodate phase shifts in the transformer or CTs or to remove zero-sequence components from the secondary currents. If this setting is Y, the relay permits the user, in the next group of settings, to define the amount of shift needed to properly align the secondary currents for the differential calculation.

The amount of compensation to each set of winding currents is defined by settings W1CTC and W2CTC for Winding 1 and 2 respectively. These settings properly account for phase shifts in transformer winding connections and also in CT connections. For example, this correction is needed if both wye and delta power transformer windings are present, but all of the CTs are connected in wye. The effect of the compensation is to create phase shift and removal of zero-sequence current components.

Set VWDG1 and VWDG2 equal to the nominal line-to-line transformer terminal voltages of Winding 1 and Winding 2 respectively. If the transformer differential zone includes a load tap-changer, assume that it is in the neutral position. The setting units are kilovolts.

Table 4.3 shows additional configuration settings for relay models with optional voltage and/or neutral CT inputs.

Table 4.3 Configurations and Ratings (Optional Neutral CT, Phase PT)

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUT 1 CT RATIO	1–10000 {5 A InNOM} 1–50000 {1 A InNOM}	CTRN1 := 120
PHASE PT RATIO	1.00–10000.00	PTR := 120.00
NOMINAL VOLTAGE	0.20–10000.00 kV	VNOM:= 13.80
PT CONNECTION	DELTA, WYE	DELTA_Y := DELTA
VOLT-CURR WDG	1, 2	VIWDG := 2
COMP ANGLE	0–360 deg	COMPANG := 0
SINGLE V INPUT	Y, N	SINGLEV := N

Neutral CT ratio setting is used to convert the current input to primary, similar to the phase CT ratio settings.

The remaining settings shown in *Table 4.3* configure the optional relay voltage inputs to correctly measure and scale the voltage signals. Set the phase PT ratio (PTR) setting equal to the VT ratio (see Example 4.2 for sample calculations).

EXAMPLE 4.2 Phase VT Ratio Setting Calculations

Consider a 13.8 kV Transformer application where 14400:120 V rated voltage transformers (connected in open delta) are used.

Set PTR := 14400/120 := 120, VNOM := 13.8, and DELTA_Y := DELTA.

VNOM is the rated transformer line-to-line voltage in kV at the protected winding determined by setting VIWDG. Consider the transformer tap when calculating this setting. For example, a 345 kV transformer set on the 327.75 kV TAP would have VNOM := 327.75. VNOM is used by the *Volts Per Hertz Elements* and the *Loss-of-Potential (LOP) Protection*.

When phase-to-phase potentials are connected to the relay, set DELTA_Y to DELTA. When phase-to-neutral potentials are connected to the relay, set DELTA_Y to WYE.

Use the VIWDG setting to tell the relay which winding current to use when calculating power for the meter report. For example, set VIWDG := 2 when the voltage inputs to the relay are derived from Winding 2 side.

COMPANG setting adjusts the power metering to account for angular differences that may be present resulting from delta connected CTs. Set the COMPANG equal to the angle by which the current input lags the corresponding phase voltage input (e.g. IA and VA inputs) at unity power factor.

In applications where only a single voltage is available, set SINGLEV equal to Y. As shown in *Figure 2.17*, the single voltage must be connected to the A-phase input, but it may be an A-N or an A-B voltage. Be sure to set DELTA_Y equal to WYE for an A-N input or DELTA_Y equal to DELTA for an A-B input voltage.

When you set SINGLEV equal to Y, the relay performance changes in the following ways:

- **Power and Voltage Elements**. When you use one voltage, the relay assumes that the system voltages are balanced in both magnitude and phase angle. Power, power factor, and positive-sequence impedance are calculated assuming balanced voltages.
- **Metering.** When you use one voltage, the relay displays magnitude and phase angle for the measured PT. The relay displays zero for the magnitudes of the unmeasured voltages. Balanced voltages are assumed for power, power factor, VG, and 3V2 metering.

Relays that are not equipped with phase voltage inputs hide these settings and disable voltage-based protection and metering functions.

VNOM Range Check

The relay performs a range check for the VNOM setting that depends upon the voltage-input delta or wye configuration. Valid nominal voltage is 100–250 V secondary (l-l) when DELTA_Y is DELTA; it is 100–440 V when DELTA_Y is WYE.

Note that the VNOM setting is always in line-to-line primary kV, even when set for a wye configuration. You should be careful to use a solidly-grounded wye system for VNOM inputs greater than 250 V (l-l, secondary) to avoid a 1.73 increase in terminal voltages from a line-to-ground fault.

Basic Protection

Differential Element

Protect your apparatus with dual-slope percentage differential protection. Percentage differential protection provides more sensitive and secure protection than traditional differential protection; the dual-slope characteristic compensates for steady-state, proportional, and transient differential errors within the zone of protection. Steady-state errors are those that do not vary with loading through the differential zone. These include transformer magnetizing current and unmonitored loads. Proportional errors are those that vary with loading. These include relay measuring error, CT ratio errors, and errors because of tap changing. Transient errors are those that occur temporarily due to transients such as CT saturation.

The relay allows you to choose harmonic blocking, harmonic restraint, or both, providing stability during transformer inrush conditions. Even-numbered harmonics (second and fourth) provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions.

Operating Characteristic

The SEL-787 has three differential elements (87R-1, 87R-2, and 87R-3). These elements employ Operate (IOP) and Restraint (IRT) quantities that the relay calculates from the winding input current. *Figure 4.1* shows the relay characteristic. You can set the characteristic as either a single-slope, percentage differential characteristic or as a dual-slope, variable-percentage differential characteristic. Tripping occurs if the Operate quantity is greater than the curve value for the particular restraint quantity. A minimum pickup level for the Operate quantity must also be satisfied.

The four settings that define the characteristic are:

O87P = minimum IOP level required for operation

SLP1 = initial slope, beginning at the origin and intersecting O87P at IRT = O87P • 100/SLP1

IRS1 = limit of IRT for SLP1 operation; intersection where SLP2 begins

SLP2 = second slope must be greater than or equal to SLP1

By careful selection of these settings, you can duplicate closely the characteristics of existing differential relays that have been in use for many years.

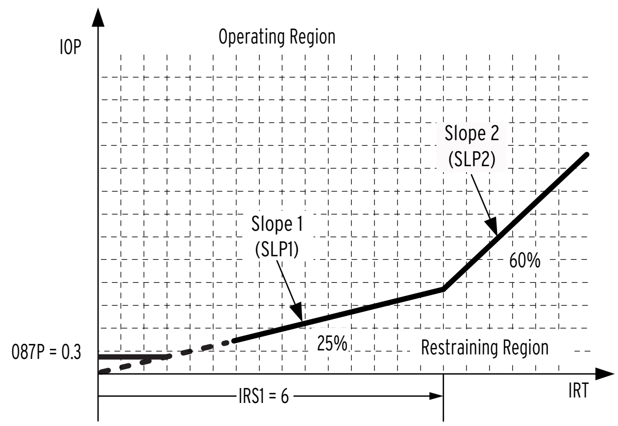


Figure 4.1 Percentage Restraint Differential Characteristic

Figure 4.2, *Figure 4.3*, and *Figure 4.4* illustrate how input currents are acquired and used in the unrestrained and restrained differential elements. Data acquisition, filtering, tap scaling, and transformer and CT connection compensation for Winding 1 are shown in *Figure 4.2*.

Four digital filters extract the fundamental, second, fourth, and fifth (not shown) harmonics of the input currents.

Using the transformer MVA rating as a common reference point, TAP scaling converts all secondary currents entering the relay from the two windings to per unit values, thus changing the ampere values into dimensionless multiples of TAP. Throughout the text, the term "TAP" refers to the per-unit value common to both windings, whereas "TAP*n*" refers to the ampere value of a particular winding(s); TAPmin and TAPmax refer to the least and greatest of the two TAP*n* values. This method ensures that, for full-load through-current conditions, all incoming current multiples of tap sum to 1.0 and all outgoing current multiples of tap sum to –1.0, with a reference direction into the transformer windings.

Transformer and CT connection compensation adjusts the sets of three-phase currents for the phase angle and phase interaction effects introduced by the winding connection of the transformer and CTs. Settings W1CTC and W2CTC determine the mathematical corrections to the three-phase currents for Winding 1 and Winding 2, respectively. CTC1 is shown in *Figure 4.2* as the phase angle and sequence quantity adjustment for Winding 1.

I1W1C1, I2W1C1, and I3W1C1 are the fundamental frequency A-phase, B-phase, and C-phase compensated currents for Winding 1. Similarly, I1W1C2, I2W1C2, and I3W1C2 are the second-harmonic compensated currents for Winding 1. The fourth-harmonic and fifth-harmonic compensated currents use similar names. The I1 compensated currents are used with differential element 87-1, I2 with element 87-2, and I3 with element 87-3.

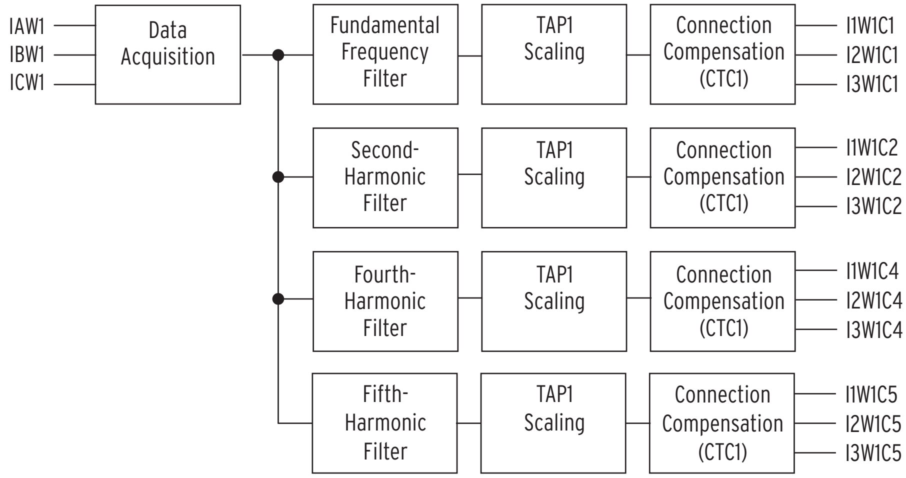


Figure 4.2 Winding 1 Compensated Currents

NOTE: The SEL-787 restraint quantity IRTn calculation differs from the SEL-587 and SEL-387 by a factor of 2.

Figure 4.3 illustrated how the IOP1 (operate), IRT1 (restraint), I1H24 (harmonic restraint), I1H2 (second harmonic), I1H4 (fourth harmonic), and I1H5 (fifth harmonic) quantities are calculated for the 87-1 element. IOP1 is generated by summing the winding currents in a phasor addition. IRT1 is generated by summing the magnitudes of the winding currents in a simple scalar addition. The 87-2 and 87-3 quantities are calculated in a similar manner.

For each restraint element (87R-1, 87R-2, 87R-3), the quantities are summed as phasors and the magnitude becomes the Operate quantity (IOP*n*). For a through-current condition, IOP*n* should calculate to about 1 + (–1) = 0, at rated load. Calculation of the restraint quantity (IRT*n*) occurs through a summation of all current magnitudes. For a through-current condition, this will calculate to about (| 1 | + | –1 |) = 2, at rated load.

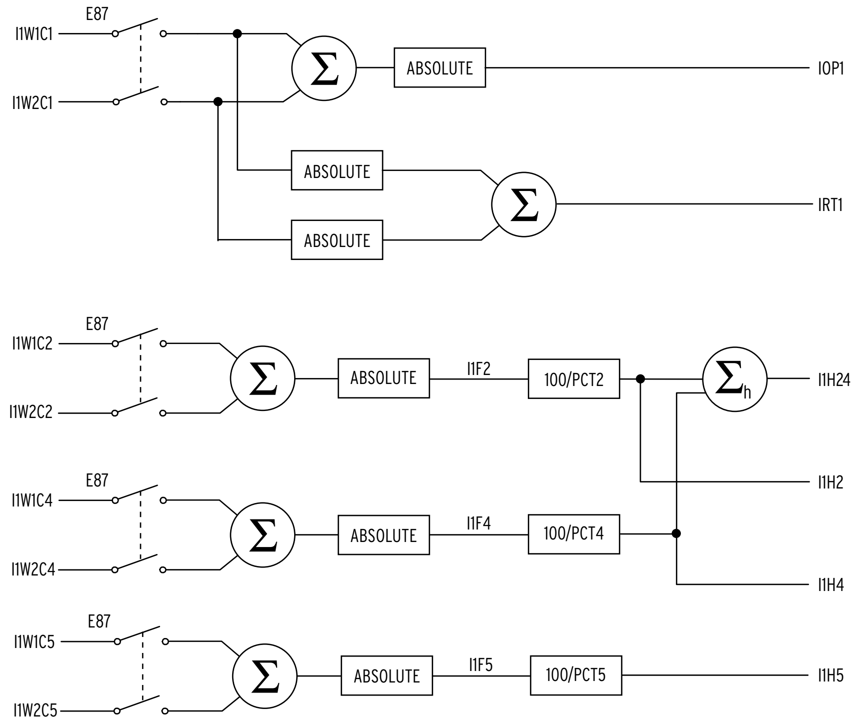


Figure 4.3 Differential Element (87-1) Quantities

Figure 4.4 shows how the differential element quantities are used to generate the unrestrained 87U*n* (87U1, 87U2, 87U3) and restrained 87R*n*/87HR*n* (87R1, 87R2, 87R3, 87HR1, 87HR2, 87HR3) elements.

Unrestrained elements (87U1, 87U2, and 87U3) compare the IOP quantity to a setting value (U87P), typically about 10 times TAP, and trip if this level is exceeded. Elements 87U1, 87U2, and 87U3 are combined to form element 87U, as shown in the lower left corner of *Figure 4.4*. Harmonic blocking or restraint is not performed on the unrestrained elements. Use these elements to protect your transformer bushings and end windings while maintaining security for inrush and through-fault conditions. Operating current elements 87O*n* (87O1, 87O2, 87O3) are not available as Relay Word bits.

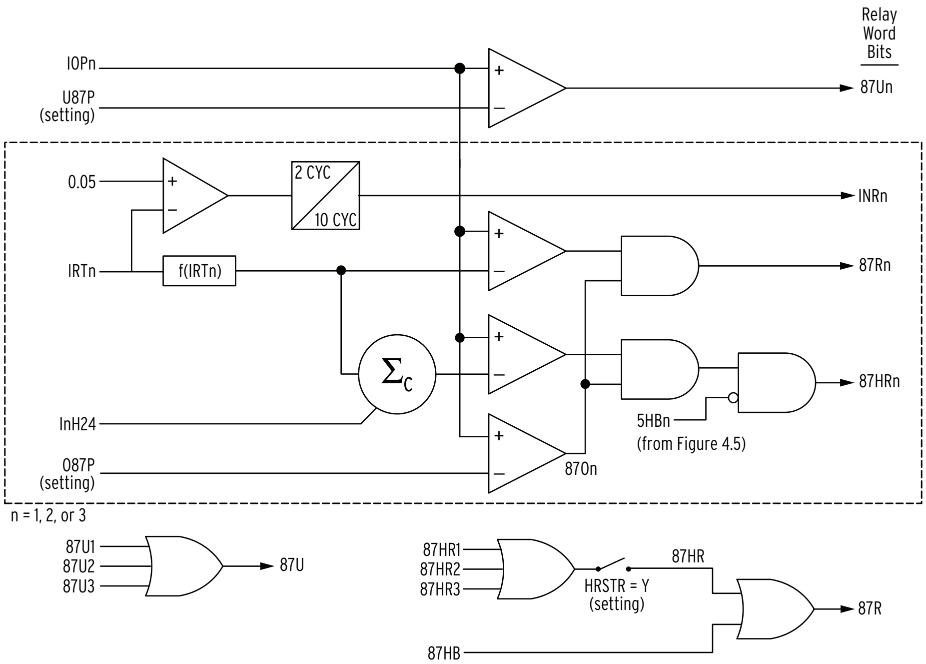


Figure 4.4 Differential Element Decision Logic

Restrained elements (87R1, 87R2, and 87R3) determine whether the IOP quantity is greater than the restraint quantity using the differential characteristic shown in *Figure 4.1*. This characteristic is modified by increasing the restraint current threshold as a function of the second- and fourth-harmonic content in the input currents for the harmonic restraint elements (87HR1, 87HR2, and 87HR3). Set HRSTR = Y to activate the harmonic restraint element 87HR.

In element 87R*n*, for example, the IOP*n* and IRT*n* quantities determine whether the relay trips. The logic enclosed within the dotted line of *Figure 4.4* implements the *Figure 4.1* characteristic. The differential element calculates a threshold as a function of IRT*n.* IOP*n* must exceed this threshold to assert 87R*n*. The function uses the SLP1, SLP2, and IRS1 setting values, along with IRT*n*, to calculate the IOP value. The relay uses SLOPE2 in place of SLOPE1 when the Relay Word bit INR*n* is asserted. This features provides a high security mode of operation for 10 cycles when the transformer is energized. The differential element decision logic compares the calculated value, denoted f(IRT*n*), to the actual IOP*n*. If IOP*n* is greater, one input of the AND gate at the right receives a logic 1. Comparison of IOP*n* with the O87P setting determines the second AND input. If IOP*n* is greater than O87P, the bit 87O*n* asserts. The AND gate condition is then satisfied, and Relay Word bit 87R*n* asserts, indicating operation of the restrained differential element, *n*. This does not, as yet, produce a trip. The relay still needs the results of the harmonic blocking decision logic, which is described later.

Harmonic Restraint

Consider the harmonic restraint feature (HRSTR = Y) if your practices require independent harmonic restraint. Blocking features are discussed in more detail later in this section.

For harmonic blocking, the harmonic content of the differential current must exceed the individual (PCT2 or PCT4) threshold values, i.e., the thresholds are treated as independent measurements of each harmonic value. For harmonic restraint, the values of the second- and fourth-harmonic currents are summed, and that value is used in the relay characteristic. Consider, for example, the simple case of Slope 1, i.e., a straight line through the origin. The general equation for a line is:

$$y = m \bullet x + c$$

More specifically, in the SEL-787:

$$IOP = SLP1 \bullet IRT + c$$

Because the line starts at the origin, the value of c is normally zero. The sum of the second- and fourth-harmonic currents now forms the constant c in the equation, raising the relay characteristic proportionally to the harmonic values.

Harmonic Blocking

While the restrained differential elements are making decisions, a parallel blocking decision process occurs regarding the magnitudes of specific harmonics in the IOP quantities.

Figure 4.5 shows how blocking elements, (87BL1, 87BL2, and 87BL3) supervise the restrained differential elements if the second-, fourth-, or fifth-harmonic operating current is above its set threshold. The blocking prevents improper tripping during transformer inrush or allowable overexcitation conditions. The SEL-787 uses common (cross-phase) blocking. Common blocking prevents all restrained elements (87R*n*) from tripping if any blocking element is picked up.

However, an independent blocking is used for the fifth-harmonic current. In this logic, an individual element will only disable tripping of that element.

An additional alarm function for fifth harmonic to warn of overexcitation (not shown in *Figure 4.5*) employs a separate threshold (TH5P) and an adjustable timer (TH5D). This threshold and timer may be useful for transformer applications in or near generating stations.

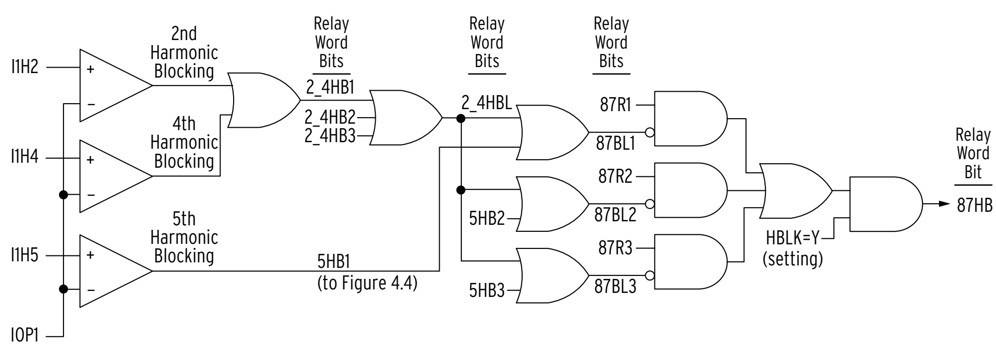


Figure 4.5 Differential Element Harmonic Blocking Logic

Relay Word bits 87R and 87U are high-speed elements that must trip all breakers. The factory default assigns 87R and 87U to trip variable setting TRXFMR. If either bit asserts, this variable asserts bit TRIPXFMR, which drives contact OUT103. OUT103 connects to an 86 lockout device, which trips all breakers via multiple sets of contacts.

Table 4.4 Differential Element Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
XFMR DIFF ENABLE	Y, N	E87 := Y
WDG1 CURR TAP	0.50–31.00 A[a]	TAP1 := 2.09

Table 4.4 Differential Element Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
WDG2 CURR TAP	0.50–31.00 A[a]	TAP2 := 2.09
OPERATE CURR LVL	0.10–1.00 TAP	O87P := 0.30
DIFF CURR AL LVL	OFF, 0.05–1.00 TAP	87AP := 0.15
DIFF CURR AL DLY	1.0–120.0 sec	87AD := 5.0
RESTRAINT SLOPE1	5%–90%	SLP1 := 25
RESTRAINT SLOPE2	5%–90%	SLP2 := 70
RES SLOPE1 LIMIT	1.0–20.0 TAP	IRS1 := 6.0
UNRES CURR LVL	1.0–20.0 TAP	U87P := 10.0
2ND HARM BLOCK	OFF, 5%–100%	PCT2 := 15
4TH HARM BLOCK	OFF, 5%–100%	PCT4 := 15
5TH HARM BLOCK	OFF, 5%–100%	PCT5 := 35
5TH HARM AL LVL	OFF, 0.02–3.20 TAP	TH5P := OFF
5TH HARM AL DLY	0.0–120.0 sec	TH5D := 1.0
HARMONIC RESTRNT	Y, N	HRSTR := Y
HARMONIC BLOCK	Y, N	HBLK := N

[a] Range shown for I_{NOM} = 5 A; Range for I_{NOM} = 1 A is 0.10–6.20 A.

Selecting Y for E87 enables differential element settings.

When a value is entered in the MVA setting (i.e., MVA is not set to “OFF”), the relay uses the MVA, winding voltage, CT ratio, and CT connection settings (see *Table 4.2*) you have entered and automatically calculates the TAP1 and TAP2 values. You can also directly enter tap values when MVA := OFF. The ratio of maximum (TAP*n*/INOM*n*) to the minimum (TAP*n*/INOM*n*) must be less than or equal to 7.5, where INOM*n* (*n* = 1, 2) is the nominal rating of the CT, 5 A or 1 A.

Set the operating current level O87P at a minimum for increased sensitivity (0.2 to 0.3 for transformers and around 1.0 for buses), but high enough to avoid operation because of unmonitored loads and transformer excitation current. O87P must be greater than or equal to the maximum of 0.1 • INOM*n*/TAP*n*, where *n* = 1, 2.

The SEL-787 includes a differential current alarm feature. Set the 87AP level above the highest expected differential current under normal operations (typically lower than the O87P setting) and a security delay 87AD. See *Figure 4.6* for the logic diagram of this feature. Assertion of Relay Word bit 87AT indicates a problem in the differential current circuit (e.g., open CT). You must program the 87AT bit to take appropriate action (alarm, display message, SER, etc.) as desired.

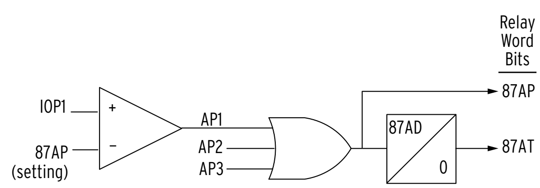


Figure 4.6 Differential Current Alarm Logic Diagram

Use the restraint slope percentage settings to discriminate between internal and external faults. Set SLP1 to accommodate current differences from steady-state and proportional errors such as power transformer tap-changer, CT errors, and relay error. Set SLP2 to accommodate transient error caused by CT saturation.

A two-slope, or variable-percentage differential application, improves sensitivity in the region where CT error is less and increases security in the high-current region where CT error is greater. We must define both slopes, as well as the Slope 1 limit or point IRS1, where SLP1 and SLP2 intersect. If you want a single slope characteristic, set both SLOPE1 and SLOPE2 to the desired slope value.

The purpose of the instantaneous unrestrained current element is to react quickly to very heavy current levels that clearly indicate an internal fault. Set the pickup level U87P to 8 to 10 times tap. The unrestrained differential element only responds to the fundamental frequency component of the differential operating current. It is unaffected by the SLP1, SLP2, IRS1, PCT2, or PCT5 settings. Thus, you must set the element pickup level high enough so as not to react to large inrush currents.

Energization of a transformer causes a temporary large flow of magnetizing inrush current into one terminal of a transformer, without the other terminal seeing this current. Thus, it appears as a differential current that could cause improper relay operation. Magnetizing inrush currents contain greater amounts of even-harmonic current than do fault currents. This even-harmonic current can be used to identify the inrush phenomenon and to prevent relay misoperation. The SEL-787 measures the amount of second-harmonic and fourth-harmonic currents flowing in the transformer. You can set the relay to block the percentage restrained differential element if the ratio of the second-harmonic and/or fourth-harmonic current to fundamental current (IF2/IF1, IF4/IF1) is greater than the PCT2 or PCT4 setting, respectively. The differential element automatically goes into high-security mode when the transformer is de-energized and IRN*n* asserts. The relay will stay in this mode for 10 cycles after energization is detected. See *Figure 4.4* and the associated description.

According to industry standards (ANSI/IEEE C37.91, C37.102), overexcitation occurs when the ratio of the voltage to frequency (V/Hz) applied to the transformer terminals exceeds 1.05 per unit at full load or 1.1 per unit at no load. Transformer overexcitation produces odd-order harmonics (primarily fifth harmonic), which can appear as differential current to a transformer differential relay. The SEL-787 measures the amount of fifth-harmonic current flowing in the transformer. You can set the relay to block the percentage restrained differential element if the ratio of fifth-harmonic current to fundamental current (IF5/IF1) is greater than the PCT5 setting. Unit-generator step-up transformers at power plants are the primary users of fifth-harmonic blocking. Transformer voltage and generator frequency may vary somewhat during startup, overexciting the transformers.

Fifth-harmonic alarm level and delay settings (TH5P and TH5D) use the presence of fifth-harmonic differential current to assert a Relay Word bit TH5T. This bit indicates that the rated transformer excitation current is exceeded. You may consider triggering an alarm and/or event report if fifth-harmonic current exceeds the fifth-harmonic threshold that you set.

The SEL-787 includes common harmonic blocking (cross-phase blocking) and harmonic restraint logic; you can select either one or both of them. The combination of both logic functions provides optimum differential element operating speed and security. Use the HRSTR := Y setting to enable the harmonic restraint logic and the HBLK := Y setting to enable the harmonic blocking logic.

Common harmonic blocking provides superior security against tripping on magnetizing inrush during transformer energization, yet allows faster differential element tripping for an energized transformer fault. Differential tripping through the harmonic restraint logic is slightly slower, but provides a dependable tripping function when energizing a faulted transformer that might otherwise have the differential tripping element blocked by common harmonic blocking logic.

Differential Element Settings in SEL-787, SEL-387, and SEL-587

The SEL-787 restraint quantity IRT*n* calculation differs from the SEL-587 and SEL-387 by a factor of 2. To achieve the same characteristics for the differential elements in the SEL-787, SEL-387, and SEL-587, we must account for this factor of 2. Find below the settings relationships among the three products.

Convert SEL-387 and SEL-587 Relay Settings to the SEL-787 Relay

$O87P_{787} = O87P_{387/587}$

$SLP1_{787} = 1/2 \bullet SLP1_{387/587}$

$SLP2_{787} = 1/2 \bullet SLP2_{387/587}$

$IRS1_{787} = 2 \bullet IRS1_{387/587}$

$U87P_{787} = U87P_{387/587}$

Convert SEL-787 Relay Settings to the SEL-387 and SEL-587 Relays

$O87P_{387/587} = O87P_{787}$

$SLP1_{387/587} = 2 \bullet SLP1_{787}$

$SLP2_{387/587} = 2 \bullet SLP2_{787}$

$IRS1_{387/587} = 1/2 \bullet IRS1_{787}$

$U87P_{387/587} = U87P_{787}$

Setting Calculation

Connection Compensation Settings

The relay offers connection compensation settings, W*n*CTC (*n* = 1 or 2), to compensate for the phase shift across the transformer. These settings offer a range, 0–12, that represents 3x3 matrices, CTC(0)–CTC(12), permitting compensation from 0 degrees to 360 degrees, in increments of 30 degrees, respectively. The general expression for current compensation is as follows:

$$\begin{bmatrix} \mathrm{I1W}n\mathrm{C} \\ \mathrm{I2W}n\mathrm{C} \\ \mathrm{I3W}n\mathrm{C} \end{bmatrix} = [\mathrm{CTC}(m)] \bullet \begin{bmatrix} \mathrm{IAW}n \\ \mathrm{IBW}n \\ \mathrm{ICW}n \end{bmatrix}$$

where IAW*n*, IBW*n*, and ICW*n* are the three-phase currents entering Terminal *n* of the relay; I1W*n*C, I2W*n*C, and I3W*n*C are the corresponding phase currents after compensation that the relay uses to calculate the operate and restraint quantities; and CTC(*m*) (*m* = 0–12) is the three-by-three compensation matrix corresponding to the W*n*CTC setting. The complete list of compensation matrices and the corresponding correction compensation they result in are shown in *Table 4.5*.

Table 4.5 WnCTC Setting: Corresponding Phase and Direction of Correction (Sheet 1 of 2)

WnCTC Setting[a]	Matrix	Compensation Matrices	Amount and Direction of Correction	
			ABC Phase Rotation	ACB Phase Rotation
0	CTC(0)	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	0°	0°
1	CTC(1)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$	30° CCW	30° CW
2	CTC(2)	$\frac{1}{3} \bullet \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & 1 \end{bmatrix}$	60° CCW	60° CW
3	CTC(3)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix}$	90° CCW	90° CW
4	CTC(4)	$\frac{1}{3} \bullet \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix}$	120° CCW	120° CW
5	CTC(5)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$	150° CCW	150° CW
6	CTC(6)	$\frac{1}{3} \bullet \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix}$	180° CCW	180° CW
7	CTC(7)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix}$	210° CCW	210° CW
8	CTC(8)	$\frac{1}{3} \bullet \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix}$	240° CCW	240° CW
9	CTC(9)	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{bmatrix}$	270° CCW	270° CW

Table 4.5 WnCTC Setting: Corresponding Phase and Direction of Correction (Sheet 2 of 2)

WnCTC Setting[a]	Matrix	Compensation Matrices	Amount and Direction of Correction	
			ABC Phase Rotation	ACB Phase Rotation
10	CTC(10)	$\frac{1}{3}\bullet\begin{bmatrix}1 & 1 & -2\\ -2 & 1 & 1\\ 1 & -2 & 1\end{bmatrix}$	300° CCW	300° CW
11	CTC(11)	$\frac{1}{\sqrt{3}}\bullet\begin{bmatrix}1 & 0 & -1\\ -1 & 1 & 0\\ 0 & -1 & 1\end{bmatrix}$	330° CCW	330° CW
12	CTC(12)	$\frac{1}{3}\bullet\begin{bmatrix}2 & -1 & -1\\ -1 & 2 & -1\\ -1 & -1 & 2\end{bmatrix}$	0° (360°) CCW	0° (360°) CW

[a] n = 1 or 2.

Compensation matrix CTC(0) is intended to create no change at all in the currents and merely multiplies them by an identity matrix. Compensation matrix CTC(12) is similar to CTC(0), in that it produces no phase shift (or, more correctly, 360 degrees of shift) in a balanced set of phasors separated by 120 degrees. However, it removes zero-sequence components from the winding current, as do all of the matrices with non-zero values of *m*.

Use the following guidelines to determine correct compensation settings for each winding.

Step 1. Determine the phase shift as seen by the relay. The following information is required to accurately determine the phase shift.

- ➢ Transformer winding connection diagram (transformer nameplate)
- ➢ Three-line connection diagram showing: (1) system phase-to-transformer bushing connections, (2) current transformer (CT) connections, and (3) CT-to-relay connections

Step 2. Choose one of the relay current inputs as the reference winding.

- ➢ If a delta winding exists and is wired into the relay, choose it as the reference. Select matrix CTC(0) for the compensation of the delta winding.
- ➢ If a delta winding does not exist, select matrix CTC(11) for the compensation of one of the wye windings.

Step 3. With the winding in *Step 2* as reference, determine the required compensation settings for all other windings. Use odd matrices for compensating wye-windings. Avoid the use of even matrices when possible.

Refer to *Appendix L: Protection Application Examples* for more details on application of these guidelines in determining correct compensation settings.

Winding Line-to-Line Voltages

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

Current TAP

The relay uses a standard equation to set TAP*n*, based on settings entered for the particular winding (*n* denotes the winding number.)

$$\mathrm{TAPn} = \frac{\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet \mathrm{VWDG} \bullet \mathrm{CTR}n} \bullet \mathrm{C}$$

where:

C = 1 if W*n*CT setting = Y (wye-connected CTs)
C = $\sqrt{3}$ if W*n*CT setting = D (delta-connected CTs)
MVA = maximum power transformer capacity setting (must be the same for all TAP*n* calculations)
VWDG*n* = winding line-to-line voltage setting, in kV
CTR*n* = current transformer ratio setting

The relay calculates TAP*n* with the following limitations:

- The tap settings are within the range 0.1 • I_{NOMn} and 6.2 • I_{NOMn}
- The ratio of the highest (TAP*n*/INOM*n*) to the lowest (TAP*n*/INOM*n*) is less than or equal to 7.5, where *n* = 1, 2

Restrained Element Operating Current Pickup

The O87P setting range is 0.1 to 1.0; we suggest an O87P setting of 0.2 to 0.3. The setting must be at a minimum for increased sensitivity but high enough to avoid operation because of steady-state errors such as unmonitored station service loads, transformer excitation current, and relay measuring error at very low current levels. The setting must also yield an operating current greater than or equal to the maximum of 0.1 • INOM*n*/TAP*n*, where *n* = 1, 2.

Restraint Slope Percentage

The purpose of the percentage restraint characteristic is to allow the relay to differentiate between differential current from an internal fault versus differential current during normal or external fault conditions. You must select slope characteristic settings that balance security and dependability. To do this, it is helpful to determine what slope ratio is characteristic of normal conditions (slope must exceed that for security) and what slope ratio is characteristic of an internal fault (the slope must be below that for dependability). In the case of the SEL-787 Relay, the slope ratio for a bolted internal fault is 100%.

The sources of differential current for external faults fall into three categories:

- Differential current that is not proportional to the current flow through the zone (steady state).
- Differential current that is proportional to current flow through the zone (proportional).
- Differential current that is transient in nature (transient).

SLP1 should be set above normal steady-state and proportional errors. SLP2 is used to accommodate transient errors. The following is a list of typical sources of error that must be considered.

- Excitation current (typically 1 to 4%)
- CT accuracy (typically less than 3% in the nominal range)
- No-Load Tap Changer (NLTC) (typically ±5%)
- Load Tap-Changer (LTC) (typically ±10%)
- Relay accuracy (±5% or ±0.02 • I_{NOM}, whichever is largest.)

We recognize that the excitation current of the transformer is not proportional to load flow. However, a conservative approach would include it as a proportional error.

CTs create both steady-state and transient errors, which can result in false differential current. IEEE Standard Requirements for Instrument Transformers, IEEE Standard C57.13-1993 specifies that a relay-accuracy CT must be 3 percent accurate at rated current and 10 percent accurate at 20 times rated current when ZB is the standard burden. It is important to note that the rated current specified in the standard is a symmetrical sinusoidal waveform (it does not have a transient DC component). Because the burden is usually designed to be much smaller than the standard burden, the error current will likely be much less than 3 percent for current flow at low multiples of the nominal rating of the CTs.

The errors can be added to determine the amount of error that the SLP1 characteristic must accommodate for normal system conditions. At that point, use the following equation and add margin to determine SLP1 and determine the minimum limit of the allowable slope ratio.

$$SLP1_{MIN}\% = \left(\frac{Err\%}{(200 - Err\%) \bullet k}\right) \bullet 100$$

where:

$SLP1_{MIN}$ = slope ratio that will just accommodate Err with no margin
Err = amount of error expected in normal operation
k = AVERAGE restraint scaling factor (1 for the SEL-787)

The variable restraint characteristic provided by SLP2 at high multiples of TAP for a through fault accommodates transient CT error. SLP2 can be set fairly high without jeopardizing sensitivity for low-grade partial winding faults. The CTs should be evaluated for the likelihood of going into saturation for a through fault, and SLP2 should be adjusted accordingly. Another consideration for selecting the SLP2 setting is that the effectiveness of the variable percentage depends on SLP1 and IRS1, which determine the starting point of SLP2. If SLP1 is set very low, a higher SLP2 may be warranted.

Unrestrained Element Current Pickup

The instantaneous unrestrained current element is intended to react quickly to very heavy current levels that clearly indicate an internal fault. Set the pickup level (U87P) to approximately 8 to 10 times TAP. The unrestrained differential element only responds to the fundamental frequency component of the differential operating current. It is not affected by the SLP1, SLP2, IRS1, PCT2, or PCT5 settings. Thus, it must be set high enough so as not to react to large inrush currents.

Note that the U87P must be set lower than the minimum of 6.2 • INOM*n*/TAP*n*, where *n* = 1, 2.

Second-Harmonic Blocking

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

Fourth-Harmonic Blocking

Transformer magnetizing inrush currents are generated during transformer energization when the current contains a dc offset due to point-on-wave switching. Inrush conditions typically are detected using even harmonics and are used to prevent misoperations due to inrush. The largest even-harmonic current component is usually second harmonic followed by fourth harmonic. Use fourth-harmonic blocking to provide additional security against inrush conditions; set PCT4 less than PCT2.

Fifth-Harmonic Blocking

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

You may use the presence of fifth-harmonic differential current to assert an alarm output during startup. This alarm indicates that the rated transformer excitation current is exceeded. At full load, a TH5P setting of 0.1 corresponds to 10 percent of the fundamental current. A delay, TH5D, that you can set prevents the relay from indicating transient presence of fifth-harmonic currents.

You may consider triggering an event report if transformer excitation current exceeds the fifth-harmonic threshold.

There are two criteria for setting TH5P:

TH5P ≥ minimum (0.05 •INOM*n*/TAP*n*)

where:

n = 1, 2 and INOM*n* is nominal current of corresponding CT

Example of Setting the SEL-787 Relay

The example represents a typical transformer application and demonstrates the use of CT compensation settings and tap calculations.

Figure 2.21 illustrates the application. The transformer is a 138 kV to 13.8 kV. The transformer has a maximum rating of 30 MVA. Both windings have wye-connected current transformers, with ratios of 200/5 A at 138 kV, and 2000/5 A at 13.8 kV. We have connected the transformer per IEEE standards, with the low voltage delta lagging the high-voltage wye by 30 degrees.

Step 1. Enable the differential settings as follows:

E87 := Y

Step 2. Select settings for the current transformer connection and ratio for each winding.

All CTs connect in wye. The ratios are equal to primary current divided by secondary current. The settings are as follows:

138 kV	13.8 kV
W1CT = WYE	W2CT = WYE
CTR1 = 40	CTR2 = 400

Step 3. Set the transformer maximum rating.

We use this rating for all windings in the later tap calculation:

MVA = 30

Step 4. Determine compensation settings.

Because the CTs on either side of the transformer (wye and delta sides), are wye-connected, we must adjust for the phase angle shift. In the "traditional" differential relay connection, the wye transformer windings have their CTs connected in delta to produce a shift in the same direction as that produced in the transformer. Using the guidelines in *Steps to Determine the Compensation Settings (WnCTC) on page L.5*, it can be determined that the phase-to-transformer bushing connections are standard. The primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 leading IAW1 by 150 degrees as seen by the relay. Primary currents and secondary currents as measured by the relay are shown in Figure 4.7. For simplicity, only Terminal 1 and Terminal 2 currents are shown.

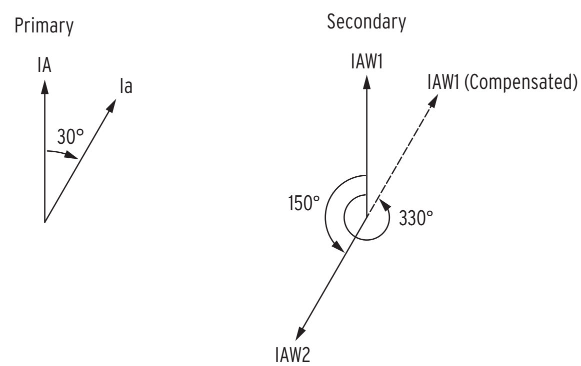


Figure 4.7 Primary Currents and Secondary Currents as Measured by the Relay

Further, select the delta winding as the reference. The X-side delta current is connected to Terminal W2 of the SEL-787 Relay. Therefore, set W2CTC = 0. The H-side currents are connected to Terminal W1 of the SEL-787 Relay so W1CTC must be determined. IAW1 must be rotated 330 degrees (11 multiples of 30 degrees) in the counterclockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW2. Therefore, set W1CTC = 11. The resulting compensation settings are:

ICOM = Y (choose to define the CT compensation)

W1CTC = 11

W2CTC = 0

The relay multiplies the wye CT currents from the wye transformer windings by the CTC(11) matrix to give the same results as the physical DAC CT connection.

Step 5. Enter winding line-to-line voltages.

The relay needs these voltages for the tap calculation. Voltages are in units of kV. For this example we enter the following values:

VWDG1 = 138 VWDG2 = 13.8

The relay now calculates each tap current, using the formula stated previously:

$$TAPn = \frac{MVA \bullet 1000}{\sqrt{3} \bullet VWDGn \bullet CTRn} \bullet C$$

where

$C = 1$ for wye CTs

Thus, we have the following:

$$TAP1 = \frac{30MVA \bullet 1000}{\sqrt{3} \bullet 138kV \bullet 40}$$

$$TAP1 = 3.14$$

$$TAP2 = \frac{30MVA \bullet 1000}{\sqrt{3} \bullet 13.8kV \bullet 400}$$

$$TAP2 = 3.14$$

The relay calculates these taps automatically if MVA is given. If MVA is set to OFF, you must calculate the taps and enter them individually.

The relay will check to see if a violation of the maximum tap ratio has occurred, and will notify you of the violation.

Step 6. Set the differential element characteristic. Select the settings according to our suggestions in the earlier setting descriptions.

For this example, we have selected a two slope, variable-percentage differential characteristic for maximum sensitivity at low currents and greater tolerance for CT saturation on external high-current faults.

The minimum error for selecting SLP1 for this application is determined as follows:

- ➢ Excitation current (4%)
- ➢ CT accuracy (3%)
- ➢ No-Load Tap Changer (NLTC) (5%)
- ➢ Load Tap-Changer (LTC) (0%)
- ➢ Relay accuracy (±5% or ±0.02 • INOM, whichever is largest) (5%)

$$SLP1_{MIN}\% = \left(\frac{17}{(200-17)}\right) \bullet 100 = 9.3\%$$

The CTs have been evaluated for maximum through fault and found to be unlikely to saturate severely. So, SLP2 does not have to be set higher than normal.

The settings are as follows:

O87P =	0.3 (Operate current pickup in multiple of tap)
SLP1 =	15 (15 percent initial slope)
SLP2 =	50 (50 percent second slope)
IRS1 =	6.0 (limit of Slope 1, Restraint current in multiple of tap)
U87P =	10 (unrestrained differential Operate current level, multiple of tap)
PCT4 =	15 (block operation if fourth harmonic is above 15 percent)
PCT5 =	35 (block operation if fifth harmonic is above 35 percent)
TH5P =	OFF (no fifth-harmonic alarm)
HRSTR =	Y (harmonic restraint enabled)
HBLK =	Y (harmonic blocking enabled)

Remember that the O87P setting must yield an operating current value that is greater than or equal to the maximum of 0.1 • INOM*n*/TAP*n*, where *n* = 1, 2. In this case, O87P = maximum ((0.1 • INOM*n*)/TAP*n*) = 0.5/3.14 = 0.159. Therefore, the O87P setting of 0.3 is valid.

The differential unit settings are complete for this specific application. At this point you can also choose to set backup overcurrent elements which we discuss at the end of this section.

Application Guidelines

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

CT Arrangements

Use separate relay restraint circuits for each power source to the relay. In the SEL-787 you may apply two restraint inputs to the relay. You may connect CT secondary windings in parallel only if both circuits meet the following criteria:

- They are connected at the same voltage level.
- Both have CTs that are matched in ratio and C voltage ratings.
- Both circuits are radial (no fault current contributions).

CT Sizing

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

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

CT Ratio Selection

Step 1. Determine the secondary side burdens in ohms for all current transformers connected to the relay.

Step 2. Select the CT ratio, considering the maximum continuous secondary current, I_{HS}, based on the highest MVA rating of the transformer.

For wye-connected CTs, the relay current, I_{REL}, equals I_{HS}. For delta-connected CTs, I_{REL} equals $\sqrt{3} \bullet I_{HS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \bullet I_{NOM}$ and $1.0 \bullet I_{NOM}$ A secondary, where I_{NOM} is the relay nominal secondary current, 1 A or 5 A.

Step 3. Select the remaining CT ratios (e.g., CTR2) by considering the maximum continuous secondary current, I_{LS}.

As before, for wye-connected CTs I_{REL} equals I_{LS}. For delta-connected CTs I_{REL} equals $\sqrt{3} \bullet I_{LS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \bullet I_{NOM}$ and $1.0 \bullet I_{NOM}$ A secondary.

The SEL-787 calculates settings TAP1 and TAP2 if the ratio of maximum (TAP*n*/INOM*n*) to minimum (TAP*n*/INOM*n*) is less than or equal to 7.5. When the relay calculates the tap settings, it reduces CT mismatch to less than 1 percent. Allowable tap settings are in the range $(0.1\text{-}6.2) \bullet I_{NOM}$.

If the ratio of maximum (TAP*n*/INOM*n*) to minimum (TAP*n*/INOM*n*) is greater than 7.5, select a different CT ratio to meet the previous conditions. You can often do this by selecting a higher CT ratio for the smallest rated winding, but you may need to apply auxiliary CTs to achieve the required ratio. In this case, repeat *Step 2* and *Step 3*.

Step 4. Calculate the maximum symmetrical fault current for an external fault, and verify that the CT secondary currents do not exceed your utility standard maximum allowed CT current, typically $20 \bullet I_{NOM}$. If necessary, reselect the CT ratios and repeat *Step 2* through *Step 4*.

Step 5. For each CT, multiply the burdens calculated in *Step 1* by the magnitude, in secondary amperes, of the expected maximum symmetrical fault current for an external fault. Select a nominal accuracy class voltage for each CT that is greater than twice the calculated voltage.

If necessary, select a higher CT ratio to meet this requirement, then repeat *Step 2* through *Step 5*. This selection criterion helps reduce the likelihood of CT saturation for a fully offset fault current signal.

Please note that the effective C voltage rating of a CT is lower than the nameplate rating if a tap other than the maximum is used. Derate the CT C voltage rating by a factor of ratio used/ratio max.

Restricted Earth Fault Element

Restricted earth-fault (REF) protection comes from a zero-sequence directional element that provides sensitive detection of ground faults near the neutral of a grounded wye-connected transformer winding. The REF element is intended for resistance and solidly grounded transformer applications. This element should not be applied to protect high-impedance grounded transformers.

To provide REF protection, the element compares the direction of a polarizing current, derived from the line-end CTs, with the operating current, obtained from the neutral CT. *Figure 4.8* shows the characteristic of the REF element, with the shaded area indicating the tripping area.

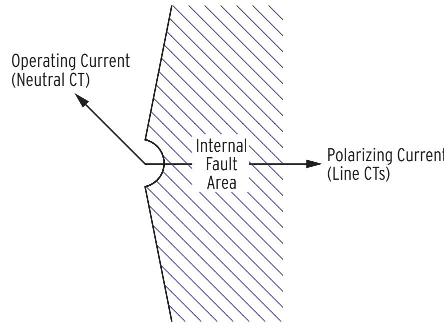


Figure 4.8 REF Directional Element

Because the REF element employs a neutral CT at one end of the winding and a set of three CTs at the line end of the winding, REF protection can detect only ground faults within that particular wye-connected winding. The element is restricted in the sense that protection is limited to ground faults within a zone defined by neutral and line CT placement.

The REF element uses comparison of zero-sequence currents, so the line-end CTs must be connected in wye for the element to function. Delta-connected CTs cancel out all zero-sequence components of the currents, eliminating one of the quantities the REF element needs for comparison.

The SEL-787 has one REF element, REF1. The settings are identified in *Table 4.6*. The operating quantity associated with the REF1 element is tied to the relay input IN1 (E09–E10) as identified in *Table 2.5*.

Figure 4.9 through *Figure 4.12* show the REF1 element logic diagrams. *Figure 4.9* shows the REF1 element enable output, REF1E. The operating quantity is the output current from the neutral CT connected to the relay input IN1 (E09–E10). The polarizing quantity is the zero-sequence current from the selected terminal CTs that are part of the scheme. Both the operating and polarizing currents are normalized for use within the logic. The normalization, as shown in *Figure 4.10*, is explained later.

The comparator C1 compares the magnitude of the normalized IN1 value, defined as INWPU1, against the 50REF1P setting and asserts 50NREF1 if the measured quantity exceeds the threshold. Comparator C2 compares 0.8 of the 50REF1P setting value against the magnitude of the normalized polarizing current, IGWPU1, and asserts 50GREF1 if the measured quantity exceeds the threshold. The 0.8 multiplier secures the operation of the REF1F element by ensuring that 50GREF1 always asserts before 50NREF1. If 50NREF1, 50GREF1, and the SELOGIC torque control, REF1TC, all evaluate to logical 1, then the output REF1E is asserted. When REF1E asserts, the relay enables the logic that performs the directional calculations as shown in *Figure 4.10*.

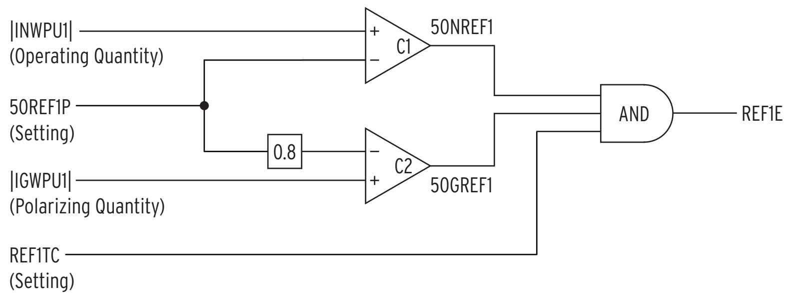


Figure 4.9 REF1 Enable Logic

Figure 4.10 shows the REF1 torque control output, REFTQ1. The Switch S1 (S1a and S1b) selects the zero-sequence vector currents from the line CTs that are part of the REF calculations as determined by the setting REF1POL. As an example, refer to *Figure 4.12*. For a single-wye winding, the logic requires one neutral CT and one set of line CTs for the REF function. If this set of line CTs is from Terminal 1, then Switch S1a will be in Position 2, while Switch S1b remains in Position 1. Current inputs from those terminals in Position 1 are not included in any REF element calculations. After closing the appropriate cells of Switch S1, the relay converts the currents to primary values by multiplying each current times the appropriate CT ratio. The relay then sums these currents vectorially to produce the polarizing current in vector form. To bring this value to the same base as the neutral CT, the algorithm divides the polarizing current by the product of the neutral CT ratio and the neutral CT nominal rating (CTRN1 • INOM1). These calculations produce IGWPU1, the normalized polarizing current in vector form. For the operating current, the algorithm normalizes IN1 with INOMN1 to produce INWPU1, the normalized operating current in vector form. INOMN1 is the nominal rating of the neutral CT, 5 A or 1 A.

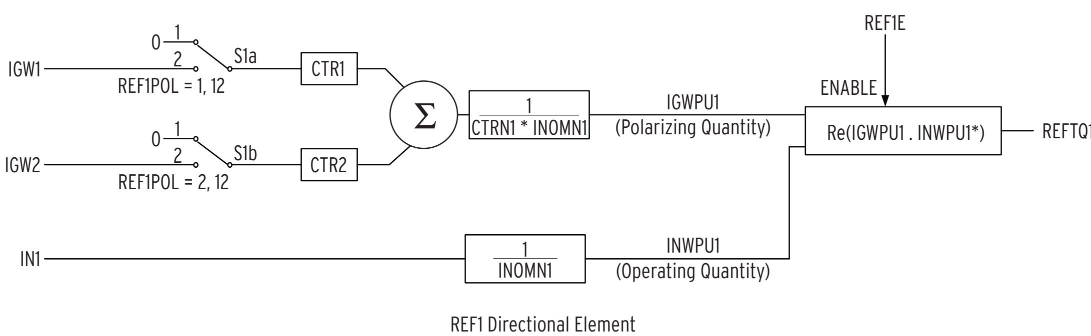


Figure 4.10 REF1 Directional Element

When the algorithm meets the conditions in *Figure 4.9*, REF1E asserts and enables the calculations of the directional element. To determine the direction, the algorithm calculates the real part of the product of the polarizing quantity and the conjugate of the operating quantity. This calculation yields the signed torque quantity REFTQ1 (this calculation is equivalent to |IOP1| times |IPOL1| times the cosine of the angle between them). REFTQ1 is positive if the angle is within ±90 degrees, indicating a forward or internal fault. Conversely, REFTQ1 is negative if the angle is greater than +90 or less than –90 degrees, indicating a reverse or external fault.

Figure 4.11 shows the logic that compares REFTQ1 to positive threshold (THRES1P) and negative threshold (THRES1N), to ensure security for very small currents or for an angle near +90 or –90 degrees.

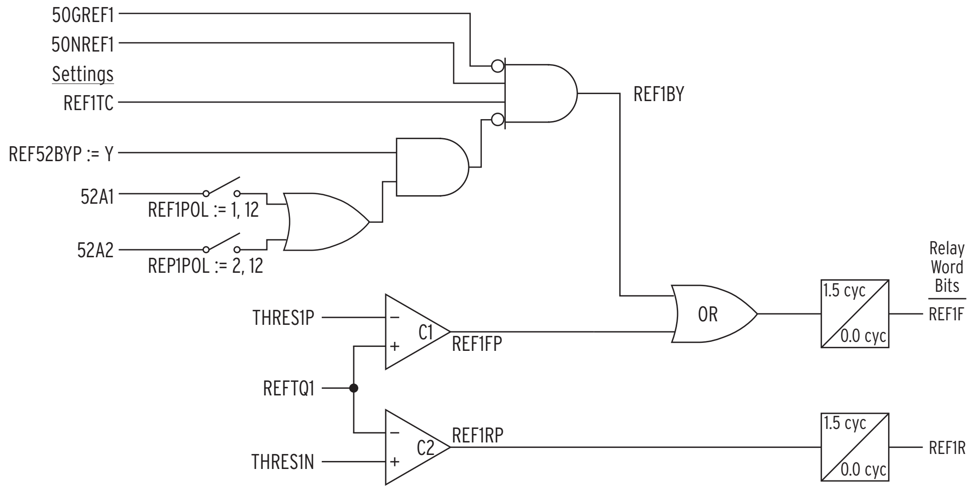


Figure 4.11 REF Element Trip Output

If REFTQ1 exceeds either threshold, it must persist for at least 1.5 cycles before Relay Word bit REF1F (forward) or REF1R (reverse) asserts. Assertion of REF1F constitutes an internal ground fault.

A second path can also assert the REF1F bit. This path comes from the output of the AND gate in *Figure 4.11*, REF1 bypass logic. Assertion of this gate indicates substantial neutral current and no line-end current flow. *Figure 4.12* shows the need for the bypass logic. For the directional element to produce a meaningful result, both operating and restraint quantities must be present. If Fault F1 occurs with the LV breaker open, no current flows through the LV CT, and there is no polarizing quantity present. Assertions of 50NREF1 and a negated 50GREF1 identify this condition in *Figure 4.11*. Under this condition, the output of the bypass logic, REF1BYP, causes the REF1F bit to assert to clear the internal fault. In most applications with REF52BYP:=Y, a 52A interlock enhances performance of the logic. Set REF52BYP := 0 if your application requires disregarding 52A for the bypass (e.g., the protected transformer is the only source of zero-sequence fault current).

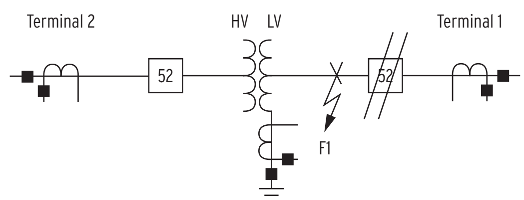


Figure 4.12 Internal Fault With LV Breaker Open

For fast tripping, include REF1F, the output of the REF1 element, into one or more of the trip equations, TR*x* (where *x* = 1, 2, or XFMR) as appropriate. If you want additional security, the relay is programmed to use REF1F to torque control an inverse-time curve for delayed tripping, as discussed in the following text. *Figure 4.13* shows the output of the REF1 protection function. Timing is on an extremely inverse-time overcurrent curve (Curve U4) at the time-dial setting (0.5) and with 50REF1P as the pickup setting.

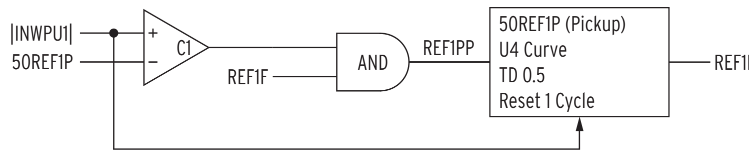


Figure 4.13 REF Protection Output (Extremely Inverse-Time O/C)

Relay Word bit REF1F (forward fault) torque controls the timing curve, and IN1PU operates the timing function. The curve resets in one cycle if current drops below pickup or if REF1F deasserts. When the curve times out, Relay Word bit REF1P asserts. You can use this bit directly as an input to the appropriate trip variables, TRx (where x = 1 or XFMR), to trip the breaker or breakers that feed the fault.

Setting Descriptions and Applications

Table 4.6 identifies the settings associated with the REF1 element.

Table 4.6 Restricted Earth Fault Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
POL QTY FROM WDG	OFF, 1, 2, 12	REF1POL := OFF
REF1 TRQ CTRL	SELOGIC	REF1TC := 1
REF1 CURR LEVEL	0.05–3.00 pu	50REF1P := 0.25
52A BYPASS ENABL	Y, N	REF52BYP := Y

The setting REF1POL tells the relay which winding or combination of windings it should use in calculating residual current, which acts as the polarizing quantity for the corresponding directional element, *Figure 4.10*. The setting REF1TC is a SELOGIC control equation setting that defines the conditions under which the relay enables the corresponding REF1 element.

You can set the neutral current sensitivity threshold, 50REF1P, to as low as 0.05 times nominal current for a 1 A CT (0.25 A for 5 A nominal CT current), the minimum neutral current sensitivity of the relay. However, the minimum acceptable value of 50REF1P must meet two criteria:

1. 50REF1P must be greater than any natural 3I0 unbalance resulting from load conditions.
2. 50REF1P must be greater than a minimum value determined by the relationship of the CTR*n* values used in the REF function.

You must set the threshold setting, 50REF1P, at the greater of the two criteria values. Determine the first criterion for load unbalance. The second criterion relates to the relative sensitivity of the winding CTs compared to the neutral CT. See *REF Current Pickup Level on page 4.27* for sample calculations.

Selection of the Restraint Quantity

The operating quantity/polarizing quantity relationship is according to software assignment (instead of a fixed relationship), so you can apply the REF element to any primary plant configuration with the correct CT arrangement. In general, identify all lines that are electrically connected to the grounded winding that you want to protect with the REF element. Then enter those terminals at the REF1POL setting. Following are examples of a few applications, assuming that both differential and REF elements protect the transformer in each example.

Figure 4.14 shows an ungrounded HV winding and a grounded-wye LV winding. Because two terminals are needed for the differential protection, assign Terminal 1 to the HV side and Terminal 2 to the LV side. Configure the REF1 element for REF protection. This element requires that the neutral CT is wired to Terminal IN. Although Terminals 1 and 2 are enabled, only Terminal 2 electrically connects to the winding earmarked for REF protection. Therefore, set REF1POL := 2.

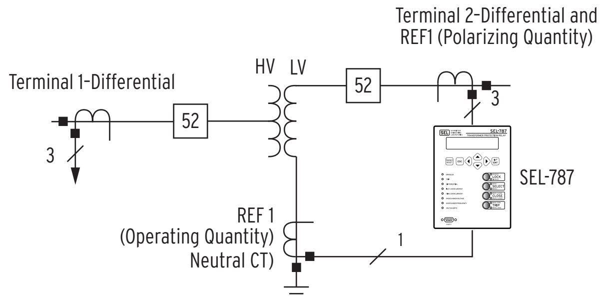


Figure 4.14 Single-Wye Winding REF Application (REF1POL := 2)

Figure 4.15 shows an autotransformer. Because two terminals are needed for the differential protection, assign Terminal 1 to the HV side and Terminal 2 to the LV side. In this case, both Terminal 1 and Terminal 2 connect electrically to the winding earmarked for REF protection. Therefore, set REF1POL := 12.

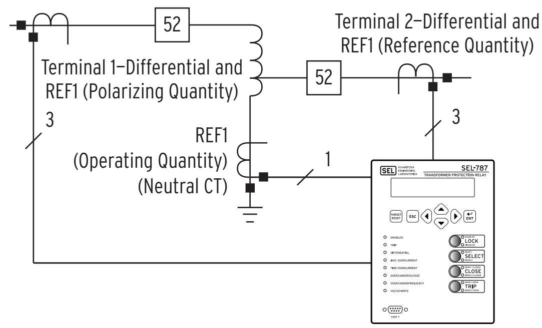


Figure 4.15 Autotransformer REF Application (REF1POL := 12)

REF Current Pickup Level

The second criterion of 50REF1P relates to the relative sensitivity of the winding CTs compared to the neutral CT. Use the following equation to determine the minimum second criterion for 50REF1P:

$$50\text{REF1P} \geq 0.05 \bullet \left[\frac{\text{MAX(INOM}n \bullet \text{CTR}n)}{(\text{CTRN1} \bullet \text{INOMN1})}\right]$$

where MAX(INOMn • CTRn) is the greatest primary rating of the CTs being used for the REF function.

The REF1POL setting defines which line CTs the relay uses for REF. For example, if REF1POL = 12, use the higher primary rated current of CTR1 or CTR2 in the previous equation.

An example 50REF1P calculation is as follows, assuming that CTRN1 = 40, INOMN1 = 5 A, MAX (I_{NOM} • CTR) = (160 • 5) = 800, and load unbalance is 10 percent:

$$50REF1P \geq 0.05 \bullet \frac{800}{40 \bullet 5}$$

$$50REF1P \geq 0.20 \text{ pu}$$

The minimum setting of 50REF1P is 0.20 pu for the second criterion. With a 10 percent load unbalance, we can assume the first criterion value to be 0.1 pu. Because 50REF1P must be set at the greater of the two criteria values, you would select a setting of 0.20 pu.

Overcurrent Elements

Four levels of phase, and two levels each of residual and negative sequence, instantaneous/definite-time overcurrent elements are available for each of the two transformer windings as shown in *Table 4.7* through *Table 4.9* and in *Figure 4.16*.

Each element can be torque controlled using appropriate SELOGIC control equations (e.g., when 50P11TC := IN401, the 50P11 element will be operational only if IN401 is asserted).

Table 4.7 Winding n Maximum Phase Overcurrent Settings (n = 1 or 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50P*n*1P := OFF 50P*n*1P := OFF
PHASE IOC DELAY	0.00–5.00 sec	50P*n*1D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*1TC := 1
PHASE IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50P*n*2P := OFF 50P*n*2P := OFF
PHASE IOC DELAY	0.00–5.00 sec	50P*n*2D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*2TC := 1
PHASE IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50P*n*3P := OFF 50P*n*3P := OFF
PHASE IOC DELAY	0.00–5.00 sec	50P*n*3D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*3TC := 1
PHASE IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50P*n*4P := OFF 50P*n*4P := OFF
PHASE IOC DELAY	0.00–5.00 sec	50P*n*4D := 0.00
PH IOC TRQCTRL	SELOGIC	50P*n*4TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.

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

The phase instantaneous overcurrent elements (50P*n*1 through 50P*n*4; see *Figure 4.16*) normally operate using the output of the one cycle cosine filtered phase current. During severe CT saturation, the cosine filtered phase current magnitude may be substantially reduced because of the distorted secondary waveform. If the overcurrent element relied only on the output of the cosine filtered secondary current, this may severely delay and may even jeopardize the operation of any high-set instantaneous overcurrent element. For any phase instantaneous overcurrent element in the SEL-787 relay set above eight times the relay current input rating (40 A in a 5 A relay), the overcurrent element also operates on the output of a bipolar peak detector if the current waveform is highly distorted, as is the case with severe CT saturation. This ensures fast operation of the 50P phase overcurrent elements even with severe CT saturation.

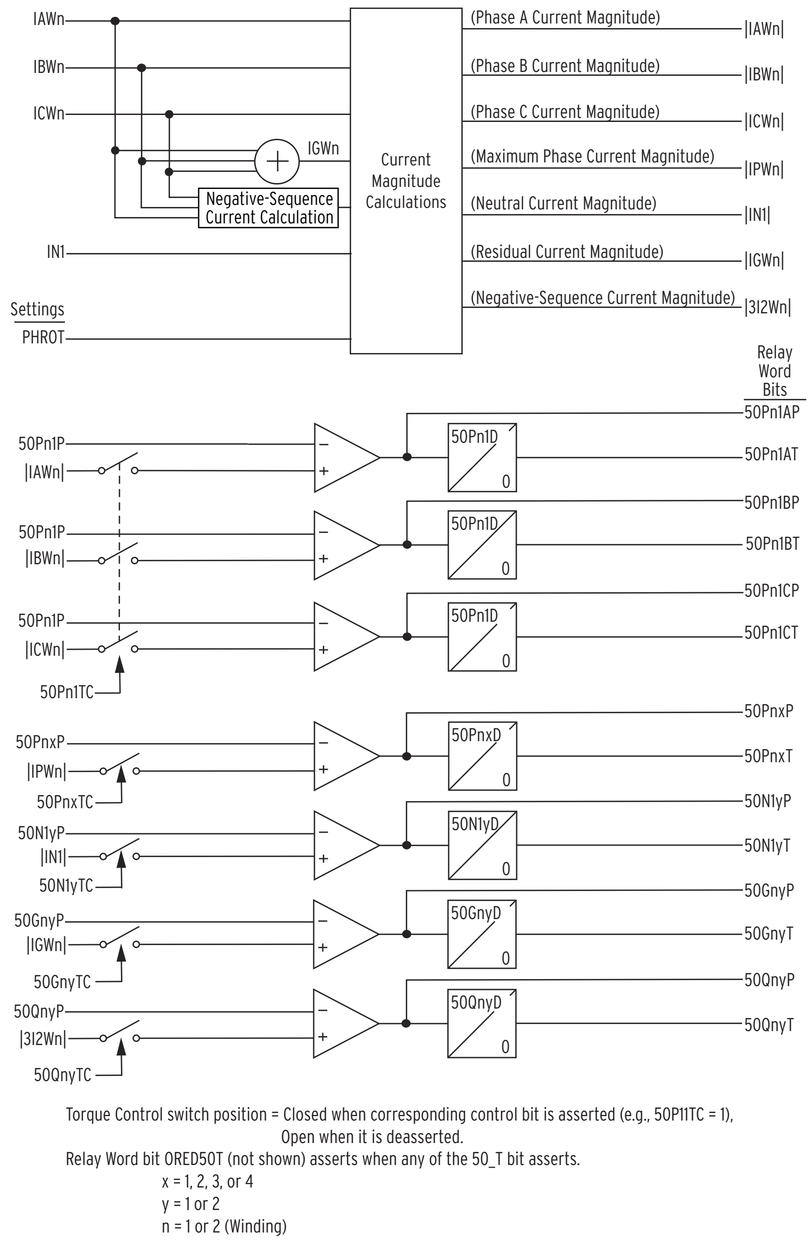


Figure 4.16 Instantaneous Overcurrent Element Logic

When the harmonic distortion index exceeds the fixed threshold, which indicates severe CT saturation, the phase overcurrent elements operate on the output of the peak detector. When the harmonic distortion index is below the fixed threshold, the phase overcurrent elements operate on the output of the cosine filter.

Table 4.8 Winding n Residual Overcurrent Settings (n = 1, 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
RES IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50G*n*1P := OFF
RES IOC DELAY	0.00–5.00 sec	50G*n*1D := 0.50
RES IOC TRQCTRL	SELOGIC	50G*n*1TC := 1
RES IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50G*n*2P := OFF
RES IOC DELAY	0.00–5.00 sec	50G*n*2D := 0.50
RES IOC TRQCTRL	SELOGIC	50G*n*2TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.

The relay offers two types of ground fault detecting overcurrent elements. The neutral overcurrent elements (50N11T and 50N12T) operate with current measured by the IN1 input (see *Table 4.14* and *Table 4.15*). The residual (RES) overcurrent elements (50G*n*1T and 50G*n*2T) operate with the current derived from each winding phase currents (see *Figure 4.16*).

Table 4.9 Winding n Negative-Sequence Overcurrent Settings (n = 1 or 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
NSEQ IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50Q1P := OFF
NSEQ IOC DELAY	0.10–120.00 sec	50Q1D := 0.20
NSEQ IOC TRQCTRL	SELOGIC	50Q1TC := 1
NSEQ IOC LEVEL	OFF, 0.50–96.00 A[a], 0.10–19.20 A[b]	50Q2P := OFF
NSEQ IOC DELAY	0.10–120.00 sec	50Q2D := 0.20
NSEQ IOC TRQCTRL	SELOGIC	50Q2TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.

The relay offers two negative-sequence overcurrent elements per winding to detect phase-to-phase faults, phase reversal, single phasing, and unbalance load.

Time-Overcurrent Elements

One level of inverse time element is available for maximum phase, A-phase, B-phase, C-phase, residual, and negative-sequence overcurrent per transformer winding. See *Table 4.10* through *Table 4.13* for available settings.

You can select from five U.S. and five IEC inverse characteristics. *Table 4.16* and *Table 4.17* show equations for the curves and *Figure 4.22* through *Figure 4.31* show the curves. The curves and equations shown do not account for constant time adder and minimum response time (settings 51_CT and 51_MR respectively, each assumed equal to zero). Use the 51_CT if you want to raise the curves by a constant time. Also, you can use the 51_MR if you want to ensure the curve times no faster than a minimum response time.

Each element can be torque controlled using appropriate SELOGIC equations (e.g., when 51P1TC := IN401, the 51P1P element is operational only if IN401 is asserted).

Table 4.10 Winding n Maximum Phase Time-Overcurrent (n = 1 or 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE TOC LEVEL	OFF, 0.50–16.00 A[a], 0.10–3.20 A[b]	51P*n*P := OFF 51P*n*P := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P*n*C := U3
PHASE TOC TDIAL	0.50–15.00[c], 0.05–1.00[d]	51P*n*TD := 3.00
EM RESET DELAY	Y, N	51P*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51P*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P*n*MR := 0.00
PH TOC TRQCTRL	SELOGIC	51P*n*TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.
[c] For 51_C := U_.
[d] For 51_C := C_.

The maximum phase time-overcurrent elements, 51P1T and 51P2T, respond to the highest of A, B, and C-phase currents as shown in *Figure 4.17*.

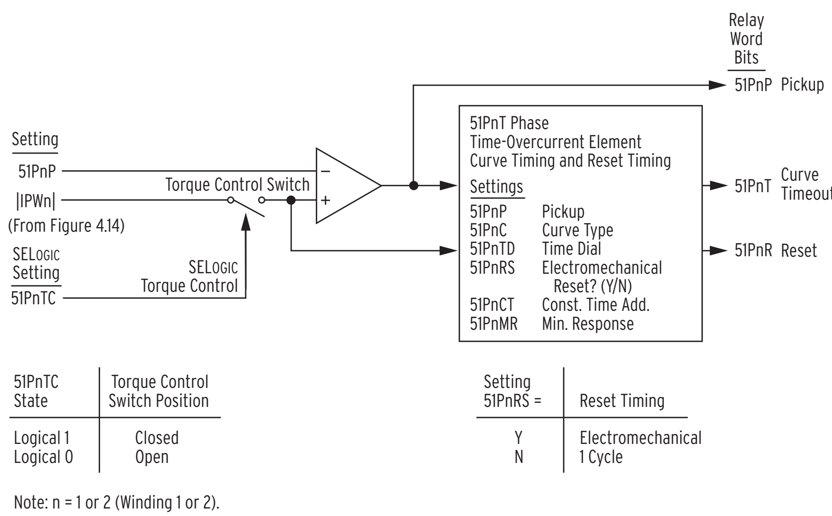


Figure 4.17 Maximum Phase Time-Overcurrent Elements 51P1T and 51P2T

The phase time-overcurrent elements, 51P*n*AT, 51P*n*BT, and 51P*n*CT, respond to the A, B, and C-phase currents for winding *n* as shown in *Figure 4.18*.

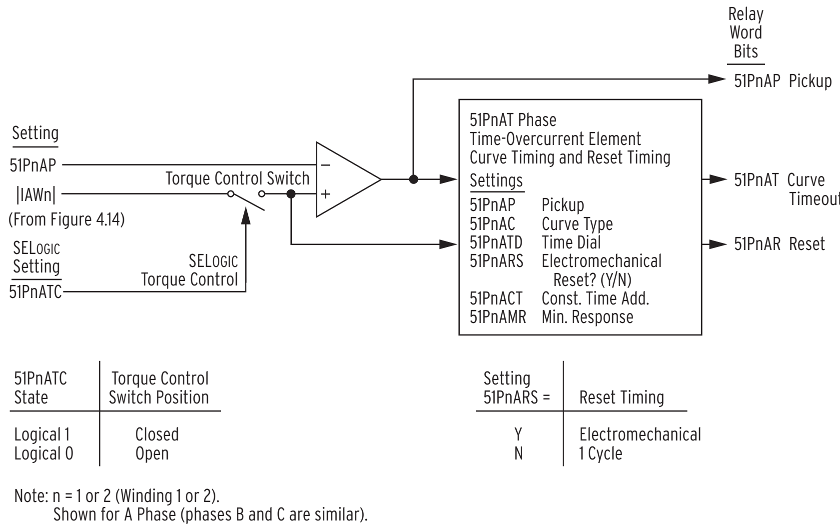


Figure 4.18 Phase A, B, and C Time-Overcurrent Elements

Table 4.11 Winding n Phase A, B, and C Time-Overcurrent (n = 1 or 2) (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE TOC LVL	OFF, 0.50–16.00 A[a] 0.10–3.20 A[b]	51P*n*AP := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P*n*AC := U3
PHASE TOC TDIAL	0.50–15.00[c] 0.05–1.00[d]	51P*n*ATD := 3.00
EM RESET DELAY	Y, N	51P*n*ARS := N
CONST TIME ADDER	0.00–1.00 sec	51P*n*ACT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P*n*AMR := 0.00
PH A TOC TRQCTRL	SELOGIC	51P*n*ATC := 1
PHASE TOC LVL	OFF, 0.50–16.00 A[a] 0.10–3.20 A[b]	51P*n*BP := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P*n*BC := U3
PHASE TOC TDIAL	0.50–15.00[c] 0.05–1.00[d]	51P*n*BTD := 3.00
EM RESET DELAY	Y, N	51P*n*BRS := N
CONST TIME ADDER	0.00–1.00 sec	51P*n*BCT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P*n*BMR := 0.00
PH B TOC TRQCTRL	SELOGIC	51P*n*BTC := 1
PHASE TOC LVL	OFF, 0.50–16.00 A[a] 0.10–3.20 A[b]	51P*n*CP := OFF
PHASE TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51P*n*CC := U3
PHASE TOC TDIAL	0.50–15.00[c] 0.05–1.00[d]	51P*n*CTD := 3.00

Table 4.11 Winding n Phase A, B, and C Time-Overcurrent (n = 1 or 2) (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
EM RESET DELAY	Y, N	51P*n*CRS := N
CONST TIME ADDER	0.00–1.00 sec	51P*n*CCT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51P*n*CMR := 0.00
PH A TOC TRQCTRL	SELOGIC	51P*n*CTC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.
[c] For 51_C := U_.
[d] For 51_C := C_.

Table 4.12 Residual Time-Overcurrent Settings (n = 1 or 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
RES TOC LEVEL	OFF, 0.50–16.00 A[a], 0.10–3.20 A[b]	51G*n*P := OFF 51G*n*P := OFF
RES TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51G*n*C := U3
RES TOC TDIAL	0.50–15.00[c], 0.05–1.00[d]	51G*n*TD := 1.50
EM RESET DELAY	Y, N	51G*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51G*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51G*n*MR := 0.00
RES TOC TRQCTRL	SELOGIC	51G*n*TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.
[c] For 51_C := U_.
[d] For 51_C := C_.

The residual time-overcurrent elements, 51G1T and 51G2T, respond to residual currents IGW1 and IGW2 as shown in *Figure 4.19*.

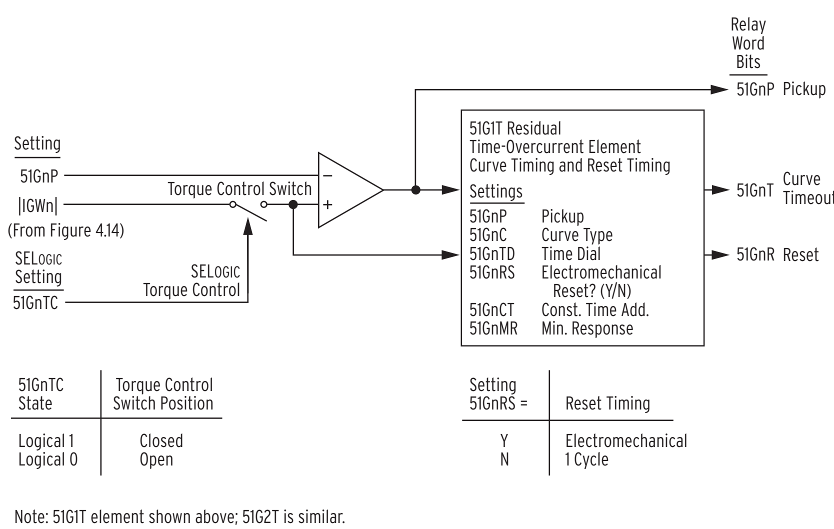


Figure 4.19 Residual Time-Overcurrent Elements 51G1T and 51G2T

Table 4.13 Winding n Negative-Sequence Time-Overcurrent Settings (n = 1, 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
NSEQ TOC LEVEL	OFF, 0.50–16.00 A[a], 0.10–3.20 A[b]	51Q*n*P :=OFF 51Q*n*P := OFF
NSEQ TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51Q*n*C := U3
NSEQ TOC TDIAL	0.50–15.00[c], 0.05–1.00[d]	51Q*n*TD := 3.00
EM RESET DELAY	Y, N	51Q*n*RS := N
CONST TIME ADDER	0.00–1.00 sec	51Q*n*CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51Q*n*MR := 0.00
NSEQ TOC TRQCTRL	SELOGIC	51Q*n*TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.
[c] For 51_C := U_.
[d] For 51_C := C_.

The negative-sequence time-overcurrent element 51Q*n*T responds to the 3I2 current as shown in *Figure 4.20*.

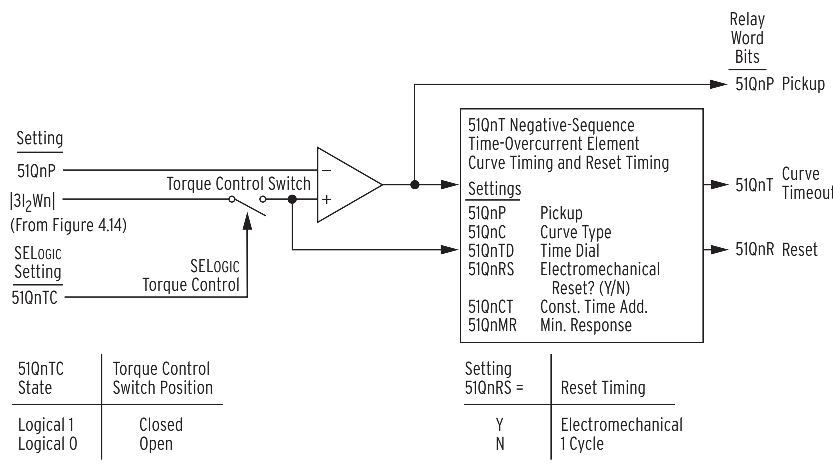


Figure 4.20 Negative-Sequence Time-Overcurrent Element 51Q1T and 51Q2T

False negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears. To avoid tripping for this transient condition, do not use a time-dial setting that results in curve times below three cycles.

Table 4.14 Neutral Overcurrent Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUT IOC LEVEL	OFF, 0.50–96.00 A[a] 0.10–19.20 A[b]	50N11P := OFF
NEUT IOC DELAY	0.00–5.00 sec	50N11D := 0.50
NEUT IOC TRQCTRL	SELOGIC	50N11TC := 1
NEUT IOC LEVEL	OFF, 0.50–96.00 A 0.10–19.20 A[b]	50N12P := OFF

Table 4.14 Neutral Overcurrent Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUT IOC DELAY	0.00–5.00 sec	50N12D := 0.50
NEUT IOC TRQCTRL	SELOGIC	50N12TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.

Table 4.15 Neutral Time-Overcurrent Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
NEUT TOC LEVEL	OFF, 0.50–16.00 A[a] 0.10–3.20 A[b]	51N1P := OFF
NEUT TOC CURVE	U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	51N1C := U3
NEUT TOC TDIAL	0.50–15.00[c] 0.05–1.00[d]	51N1TD := 1.50
EM RESET DELAY	Y, N	51N1RS := N
CONST TIME ADDER	0.00–1.00 sec	51N1CT := 0.00
MIN RESPONSE TIM	0.00–1.00 sec	51N1MR := 0.00
NEUT TOC TRQCTRL	SELOGIC	51N1TC := 1

[a] For I_{NOM} = 5 A.
[b] For I_{NOM} = 1 A.
[c] For 51_C := U_.
[d] For 51_C := C_.

The neutral overcurrent and time-overcurrent elements, 50N11T, 50N12T, and 51N1T, respond to neutral channel current IN1 as shown in *Figure 4.16* and *Figure 4.21*.

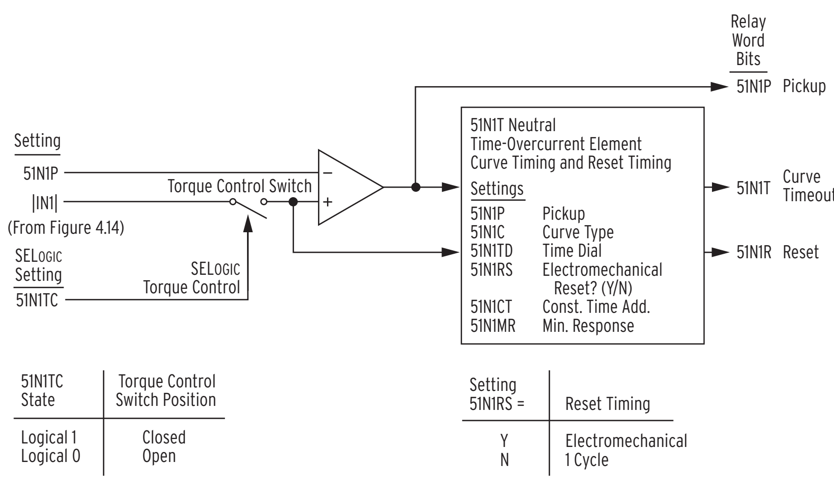


Figure 4.21 Neutral Time-Overcurrent Elements 51N1T and 51N2T

Relay Word Bit ORED51T

Relay Word bit ORED51T is asserted if any of the relay word bits 51P1T, 51P2T, 51G1T, 51G2T, 51Q1T, 51Q2T, OR 51N1T are asserted.

Time-Overcurrent Curves

The following information describes the curve timing for the curve and time dial settings made for the time-overcurrent elements (see *Table 4.16* and *Table 4.17*). The U.S. and IEC time-overcurrent relay curves are shown in *Figure 4.22* through *Figure 4.31*. Curves U1, U2, and U3 (*Figure 4.22* through *Figure 4.24*) conform to IEEE C37.112-1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays.

Table 4.16 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$t_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 4.22*
U2 (Inverse)	$t_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 4.23*
U3 (Very Inverse)	$t_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 4.24*
U4 (Extremely Inverse)	$t_p = TD \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.67}{1 - M^2}\right)$	*Figure 4.25*
U5 (Short-Time Inverse)	$t_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 4.26*

t_p = operating time in seconds
t_r = electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)
TD = time-dial setting
M = applied multiples of pickup current [for operating time (t_p), M >1; for reset time (t_r), M ≤ 1]

Table 4.17 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$t_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 4.27*
C2 (Very Inverse)	$t_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 4.28*
C3 (Extremely Inverse)	$t_p = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 4.29*
C4 (Long-Time Inverse)	$t_p = TD \bullet \left(\frac{120}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 4.30*
C5 (Short-Time Inverse)	$t_p = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$t_r = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 4.31*

t_p = operating time in seconds
t_r = electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)
TD = time-dial setting
M = applied multiples of pickup current [for operating time (t_p), M >1; for reset time (t_r), M ≤ 1]

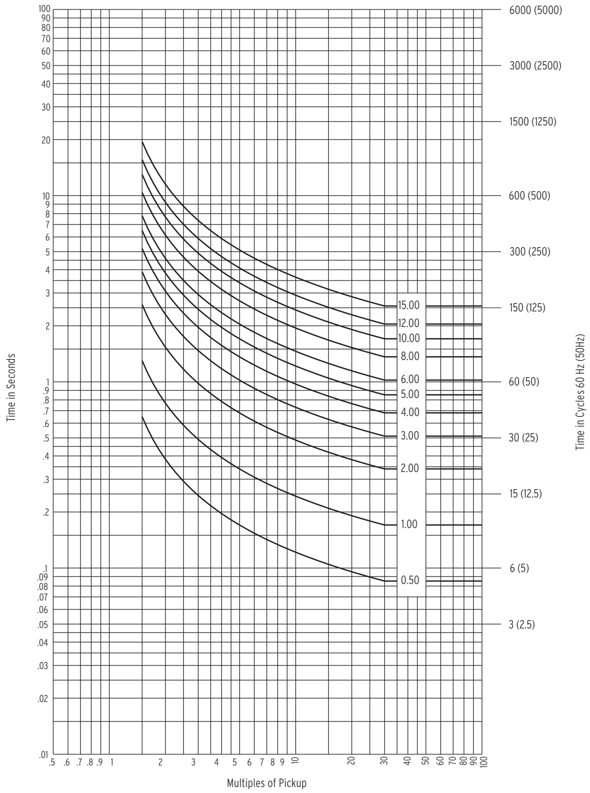


Figure 4.22 U.S. Moderately Inverse Curve: U1

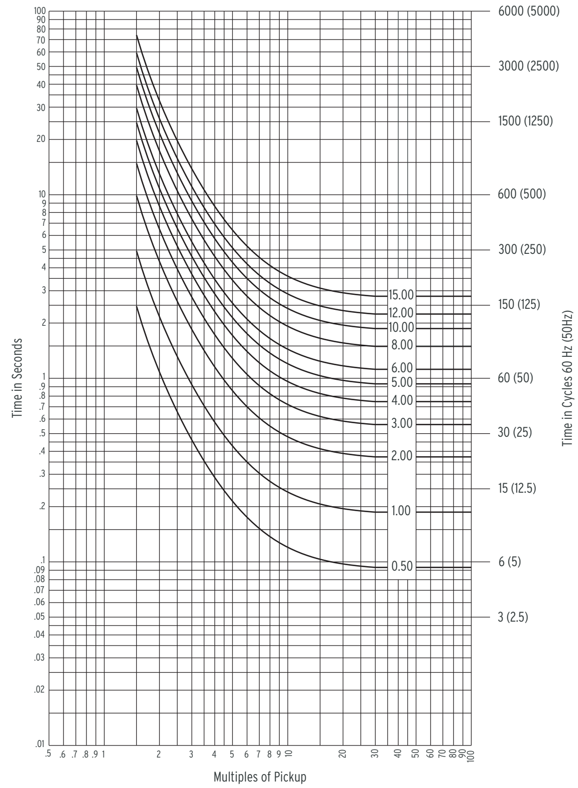


Figure 4.23 U.S. Inverse Curve: U2

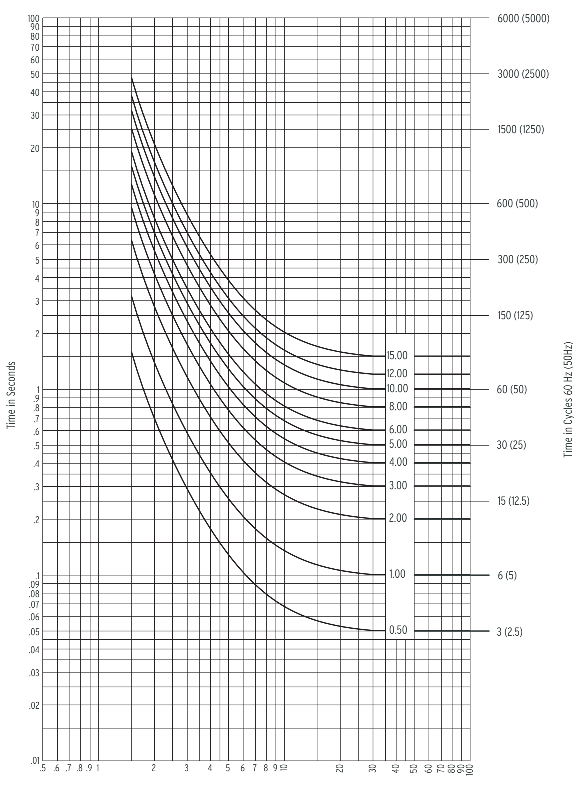


Figure 4.24 U.S. Very Inverse Curve: U3

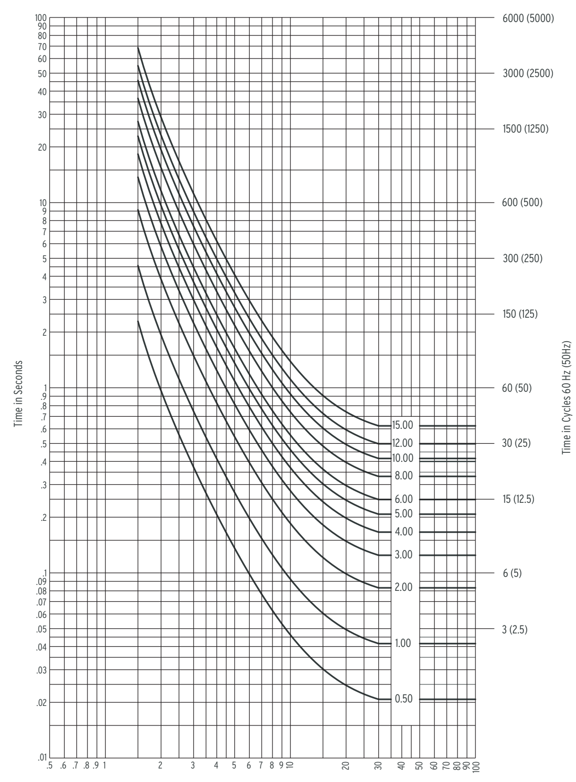


Figure 4.25 U.S. Extremely Inverse Curve: U4

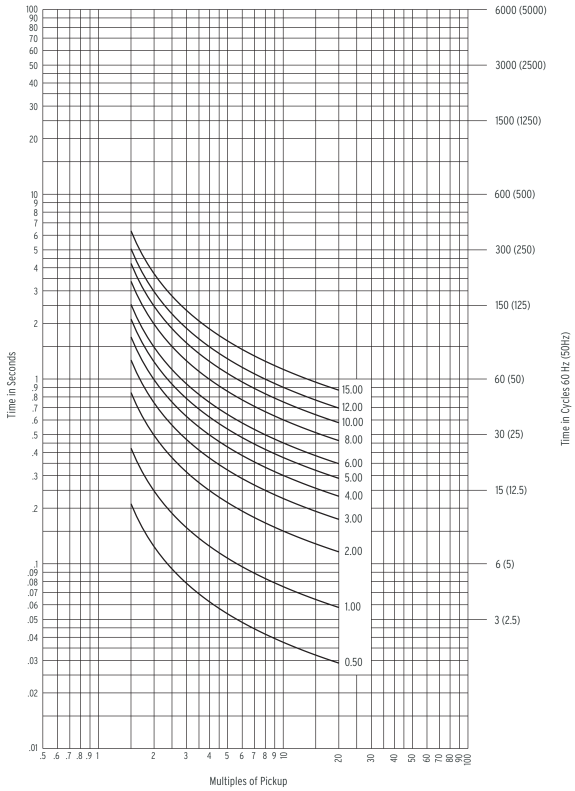


Figure 4.26 U.S. Short-Time Inverse Curve: U5

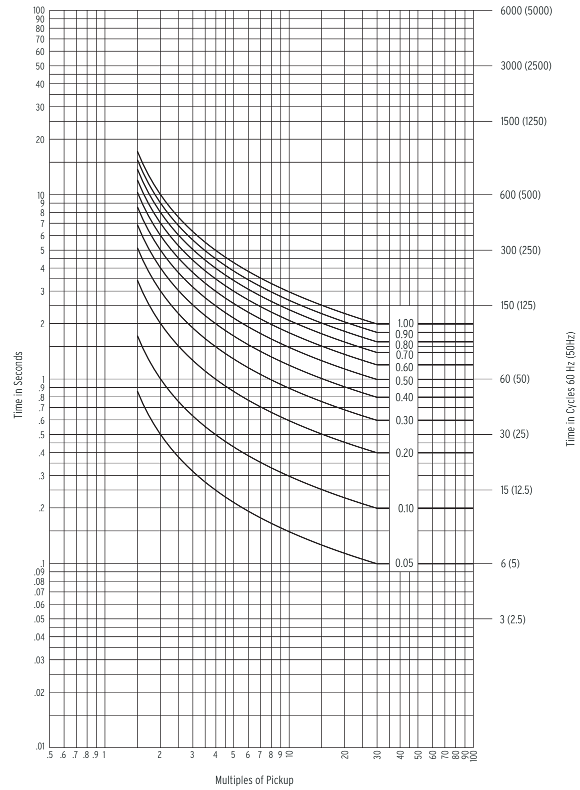


Figure 4.27 IEC Class A Curve (Standard Inverse): C1

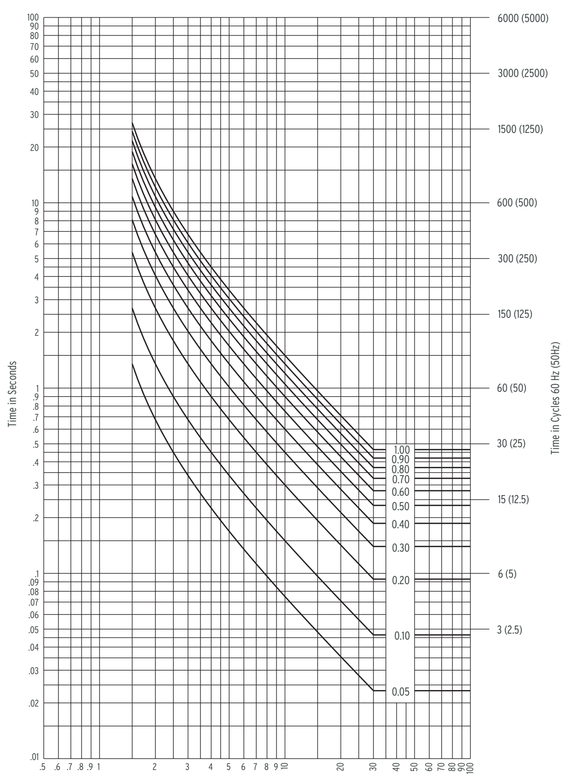


Figure 4.28 IEC Class B Curve (Very Inverse): C2

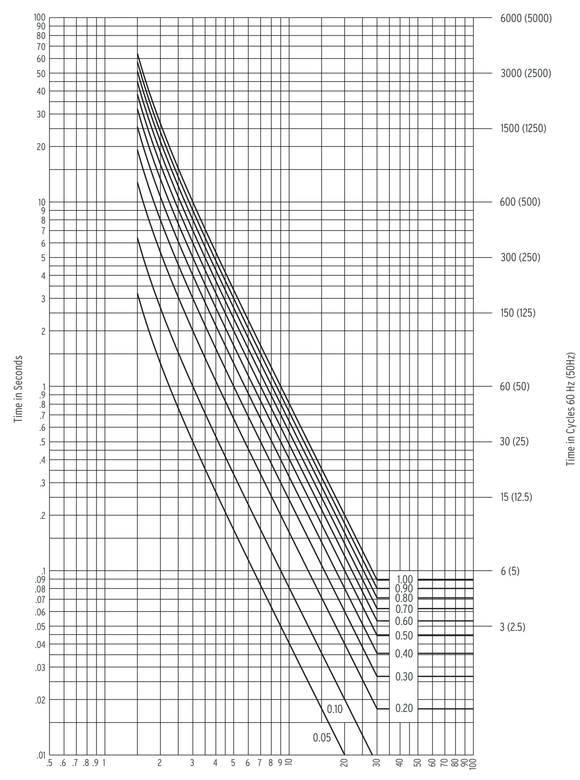


Figure 4.29 IEC Class C Curve (Extremely Inverse): C3

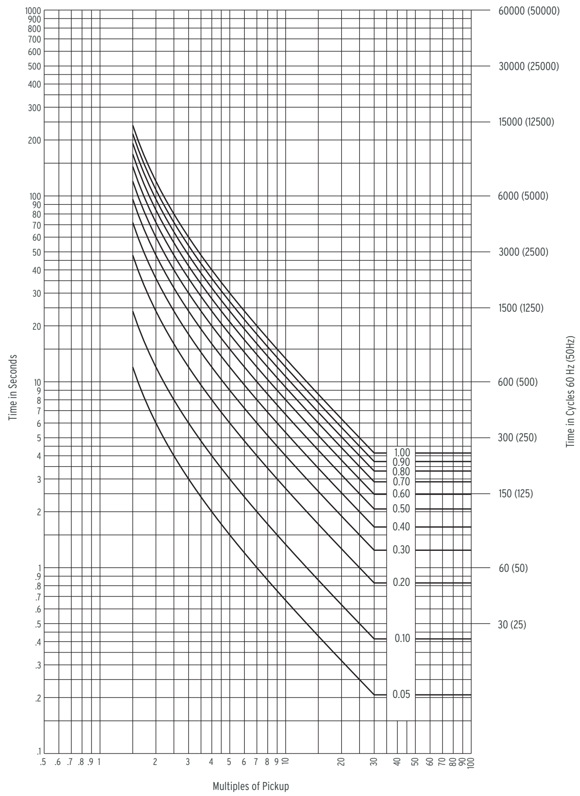


Figure 4.30 IEC Long-Time Inverse Curve: C4

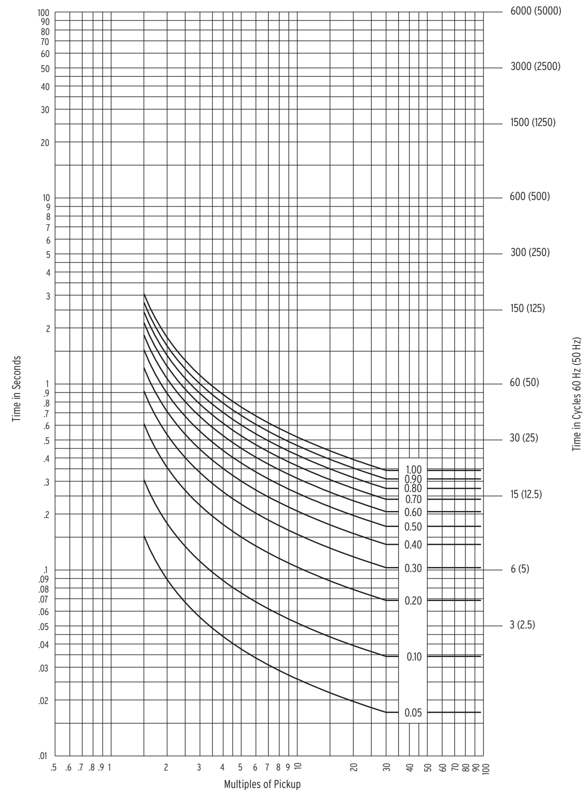


Figure 4.31 IEC Short-Time Inverse Curve: C5

RTD-Based Protection

RTD Input Function

When you connect an SEL-2600 RTD Module (set E49RTD := EXT) or order the internal RTD card (set E49RTD := INT) option, the SEL-787 offers several protection and monitoring functions, settings for which are described in *Table 4.18*. See *Figure 2.12* for the RTD module fiber-optic cable connections If relay does not have internal or external RTD inputs, set E49RTD := NONE.

NOTE: The SEL-787 can monitor as many as 10 RTDs connected to an internal RTD card or as many as 12 RTDs connected to an external SEL-2600 RTD Module. Table 4.18 shows Location, Type, and Trip/Warn Level settings only for RTD1; settings for RTD2–RTD12 are similar.

NOTE: RTD curves in SEL products are based on the DIN/IEC 60751 standard.

Table 4.18 RTD Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
RTD ENABLE	INT, EXT, NONE	E49RTD := NONE
RTD1 LOCATION	OFF, AMB, OTH	RTD1LOC := OFF
RTD1 IDENTIFIER	10 characters	RTD1NAM :=
RTD1 TYPE	PT100, NI100, NI120, CU10	RTD1TY := PT100
RTD1 TRIP LEVEL	OFF, 1–250 °C	TRTMP1 := OFF
RTD1 WARN LEVEL	OFF, 1–250 °C	ALTMP1 := OFF
•	•	•
•	•	•
•	•	•
RTD12 LOCATION	OFF, AMB, OTH	RTD12LOC := OFF
RTD12 IDENTIFIER	10 characters	RTD12NAM :=

Table 4.18 RTD Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
RTD12 TYPE	PT100, NI100, NI120, CU10	RTD12TY := PT100
RTD12 TRIP LEVEL	OFF, 1–250 °C	TRTMP12 := OFF
RTD12 WARN LEVEL	OFF, 1–250 °C	ALTMP12 := OFF

RTD Location

The relay allows you to independently define the location of each monitored RTD by using the RTD location settings.

Define the RTD location settings through use of the following suggestions:

- ➤ If an RTD is not connected to an input or has failed in place and will not be replaced, set the RTD location for that input equal to OFF.
- ➤ For the input connected to an RTD measuring ambient air temperature, set the RTD location equal to AMB. Only one ambient temperature RTD is allowed.
- ➤ For inputs connected to monitor temperatures of apparatus, such as transformer oil and winding temperature, set the RTD location equal to OTH. Use the RTD identifier setting to assign an appropriate name to the RTD, for example set RTD1NAM := XFRMR1 OIL.

If an RTD location setting is equal to OFF, the relay does not request that an RTD type setting be entered for that input.

RTD Type

The four available RTD types are:

- ➤ 100-ohm platinum (PT100)
- ➤ 100-ohm nickel (NI100)
- ➤ 120-ohm nickel (NI120)
- ➤ 10-ohm copper (CU10)

RTD Trip/Warning Levels

The SEL-787 provides temperature warnings and trips through use of the RTD temperature measurements and the warning and trip temperature settings in *Table 4.18*.

NOTE: An open condition for an RTD is detected if the temperature is greater than 250°C and a short condition is detected if the temperature is less than –50°C.

NOTE: To improve security, RTD FAULT, ALARM, and TRIP are delayed by approximately 12 seconds.

The relay issues a temperature warning if any of the healthy RTDs indicates a temperature greater than the relay RTD warning temperature setting. The relay issues a temperature trip if one of the healthy RTDs indicates a temperature greater than the RTD trip temperature setting.

To disable any of the temperature warning or trip functions, set the appropriate temperature setting to OFF.

Only healthy RTDs can contribute temperatures to the warning and trip functions. The relay includes specific logic to indicate if RTD leads are shorted or open.

Table 4.19 lists the RTD resistance versus temperature for the four supported RTD types.

Table 4.19 RTD Resistance Versus Temperature

Temp (°F)	Temp (°C)	100 Platinum	120 Nickel	100 Nickel	10 Copper
–58	–50.00	80.31	86.17	74.30	7.10
–40	–40.00	84.27	92.76	79.10	7.49
–22	–30.00	88.22	99.41	84.20	7.88
–4	–20.00	92.16	106.15	89.30	8.26
14	–10.00	96.09	113.00	94.60	8.65
32	0.00	100.00	120.00	100.00	9.04
50	10.00	103.90	127.17	105.60	9.42
68	20.00	107.79	134.52	111.20	9.81
86	30.00	111.67	142.06	117.10	10.19
104	40.00	115.54	149.79	123.00	10.58
122	50.00	119.39	157.74	129.10	10.97
140	60.00	123.24	165.90	135.30	11.35
158	70.00	127.07	174.25	141.70	11.74
176	80.00	130.89	182.84	148.30	12.12
194	90.00	134.70	191.64	154.90	12.51
212	100.00	138.50	200.64	161.80	12.90
230	110.00	142.29	209.85	168.80	13.28
248	120.00	146.06	219.29	176.00	13.67
266	130.00	149.83	228.96	183.30	14.06
284	140.00	153.58	238.85	190.90	14.44
302	150.00	157.32	248.95	198.70	14.83
320	160.00	161.05	259.30	206.60	15.22
338	170.00	164.77	269.91	214.80	15.61
356	180.00	168.47	280.77	223.20	16.00
374	190.00	172.17	291.96	231.80	16.39
392	200.00	175.85	303.46	240.70	16.78
410	210.00	179.15	315.31	249.80	17.17
428	220.00	183.17	327.54	259.20	17.56
446	230.00	186.82	340.14	268.90	17.95
464	240.00	190.45	353.14	278.90	18.34
482	250.00	194.08	366.53	289.10	18.73

Voltage-Based Protection

The following information applies to relay models with voltage inputs.

Undervoltage Function

Table 4.20 Undervoltage Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE UV LEVEL	OFF, 12.5–300.0 V	27P1P := OFF
PHASE UV DELAY	0.0–120.0 sec	27P1D := 0.5

Table 4.20 Undervoltage Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE UV LEVEL	OFF, 12.5–300.0 V	27P2P := OFF
PHASE UV DELAY	0.0–120.0 sec	27P2D := 5.0

Overvoltage Function

Table 4.21 Overvoltage Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE OV LEVEL	OFF, 12.5–300.0 V	59P1P := OFF
PHASE OV DELAY	0.0–120.0 sec	59P1D := 0.5
PHASE OV LEVEL	OFF, 12.5–300.0 V	59P2P := OFF
PHASE OV DELAY	0.0–120.0 sec	59P2D := 5.0
NSEQ OV LEVEL	OFF, 12.5–300.0 V	59Q1P := OFF
NSEQ OV DELAY	0.0–120.0 sec	59Q1D := 0.5
NSEQ OV LEVEL	OFF, 12.5–300.0 V	59Q2P := OFF
NSEQ OV DELAY	0.0–120.0 sec	59Q2D := 5.0

When you connect the SEL-787 voltage inputs to phase-to-phase connected VTs (single-phase or three-phase), as in *Figure 2.17* or *Figure 2.18*, the relay provides two levels of phase-to-phase overvoltage and undervoltage elements.

When you connect the SEL-787 voltage inputs to phase-to-neutral connected VTs (single-phase or three-phase), as shown in *Figure 2.17* or *Figure 2.18*, the relay provides two levels of phase-to-neutral overvoltage and undervoltage elements. The SEL-787 also includes two levels of negative-sequence overvoltage elements. Use these elements for alarm or trip when three-phase voltage inputs (wye or delta) are connected to the relay.

Each of the elements has an associated time delay. You can use these elements as you choose for tripping and warning. *Figure 4.32* and *Figure 4.33* show the logic diagram for the undervoltage and overvoltage elements, respectively. To disable any of these elements, set the level settings equal to OFF.

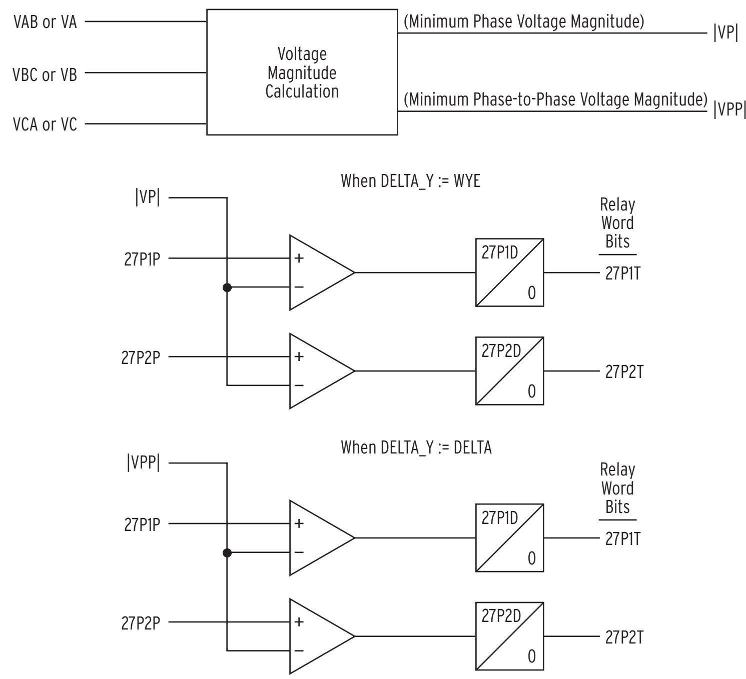


Figure 4.32 Undervoltage Element Logic

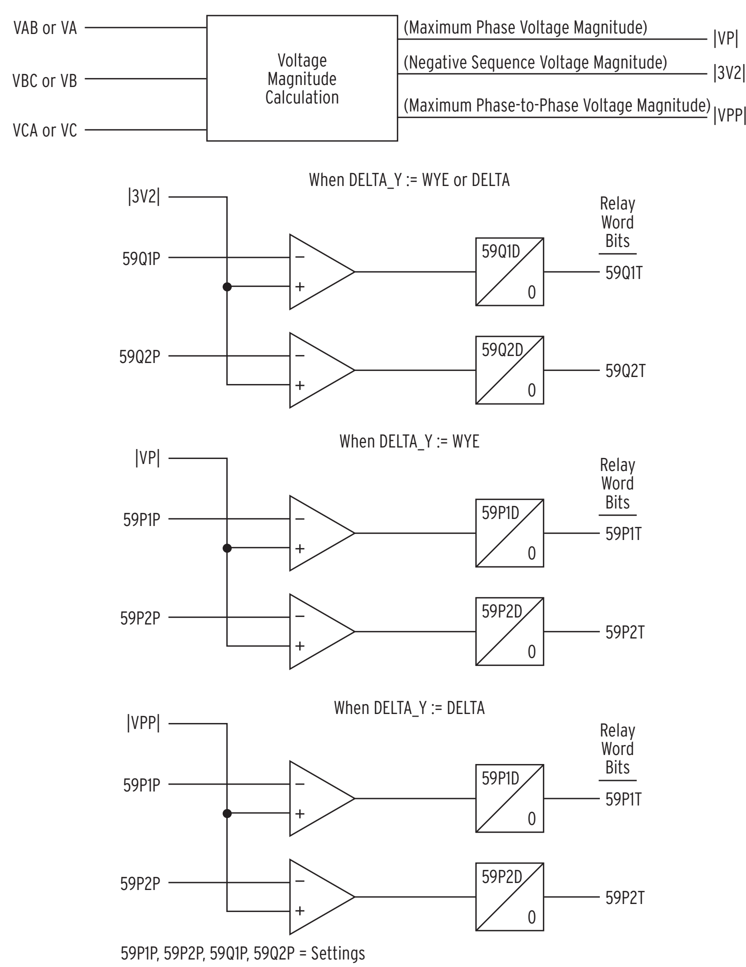


Figure 4.33 Overvoltage Element Logic

Volts Per Hertz Elements

Overexcitation occurs when a transformer magnetic core becomes saturated. When this happens, stray flux is induced in nonlaminated components, causing overheating. In the SEL-787 Relay a volts/hertz element detects overexcitation. The SEL-787 provides a sensitive definite time volts/hertz element, plus a tripping element with a composite operating time. The relay calculates the present transformer volts/hertz as a percent of nominal, based on the present and nominal voltages and frequencies. The settings VNOM and FNOM define the nominal transformer voltage and frequency, respectively.

Figure 4.34 shows a logic diagram of the volts/hertz elements. If the torque-control 24TC SELOGIC control equation is true and the present volts/hertz exceed the 24D1P setting, the relay asserts the 24D1 Relay Word bit and starts the 24D1D timer. If the condition remains for 24D1D seconds, the relay asserts the 24D1T Relay Word bit. Typically, you should apply this element as an overexcitation alarm.

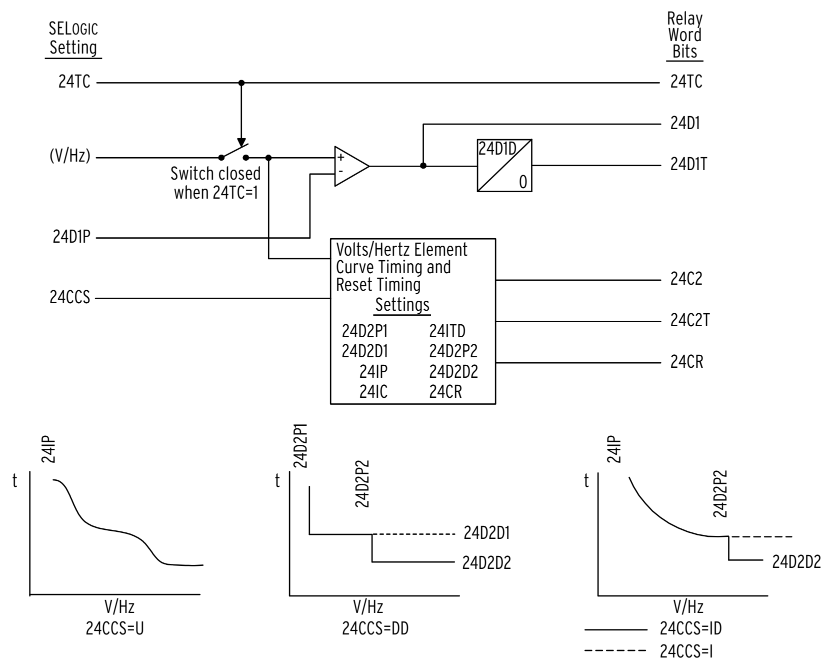


Figure 4.34 V/Hz Element Logic

For volts/hertz tripping the relay provides a time-integrating element with a settable operating characteristic. You can set the element to operate as an inverse-time element; a user-defined curve element (using the SEL-5806 PC Software); a composite element with an inverse-time characteristic and a definite-time characteristic; or as a dual-level, definite-time element. In any case, the element provides a linear reset characteristic with a settable reset time. This element also is supervised by the 24TC torque-control setting.

The volts/hertz tripping element has a percent-travel operating characteristic similar to that employed by an induction-disk time-overcurrent element. This characteristic coincides well with the heating effect that overexcitation has on transformer components.

The element compares the three phase voltages and uses the highest of the values for the volts/hertz magnitude calculations. The relay asserts 24C2 Relay Word bit without time delay when the transformer volts/hertz exceeds the element pickup setting, and asserts 24C2T Relay Word bit after a delay determined by the characteristic setting. The relay tracks the frequency over the range 20 to 70 Hz.

Volts/hertz tripping elements are usually used to trip the transformer breaker. Volts/hertz logic is discussed in the following section.

Figure 4.35 and *Figure 4.36* are similar to *IEEE C37.102 : 2006 IEEE Guide* for *AC Generator Protection Figure 4.5.4-1* and *Figure 4.5.4-2*.

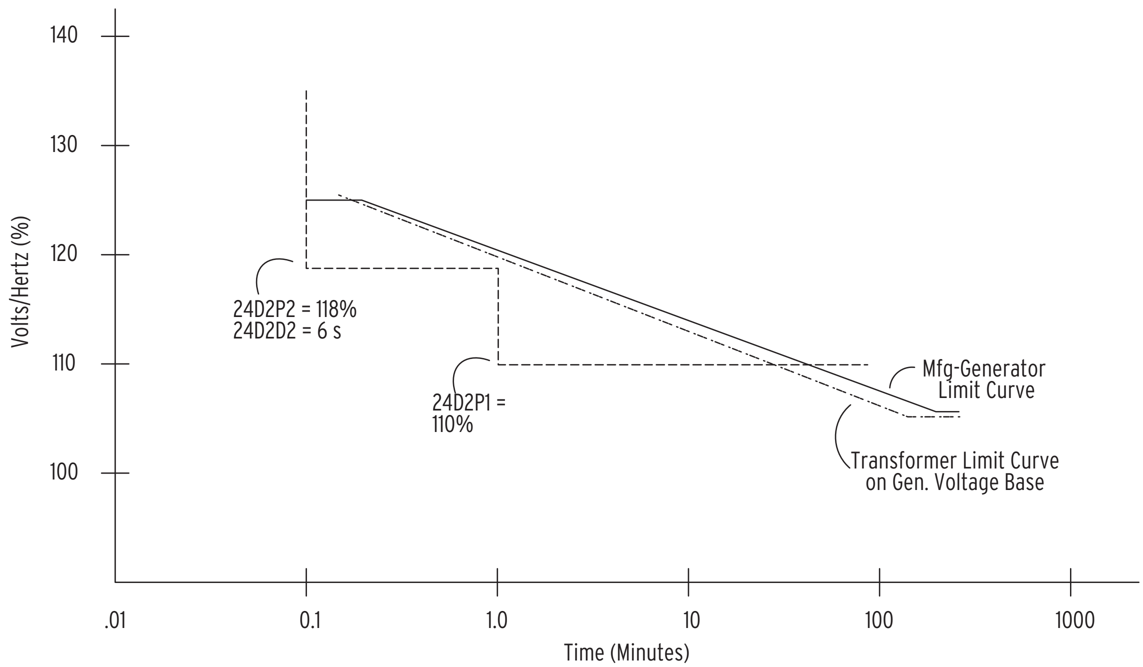


Figure 4.35 Dual-Level Volts/Hertz Time-Delay Characteristic, 24CCS = DD

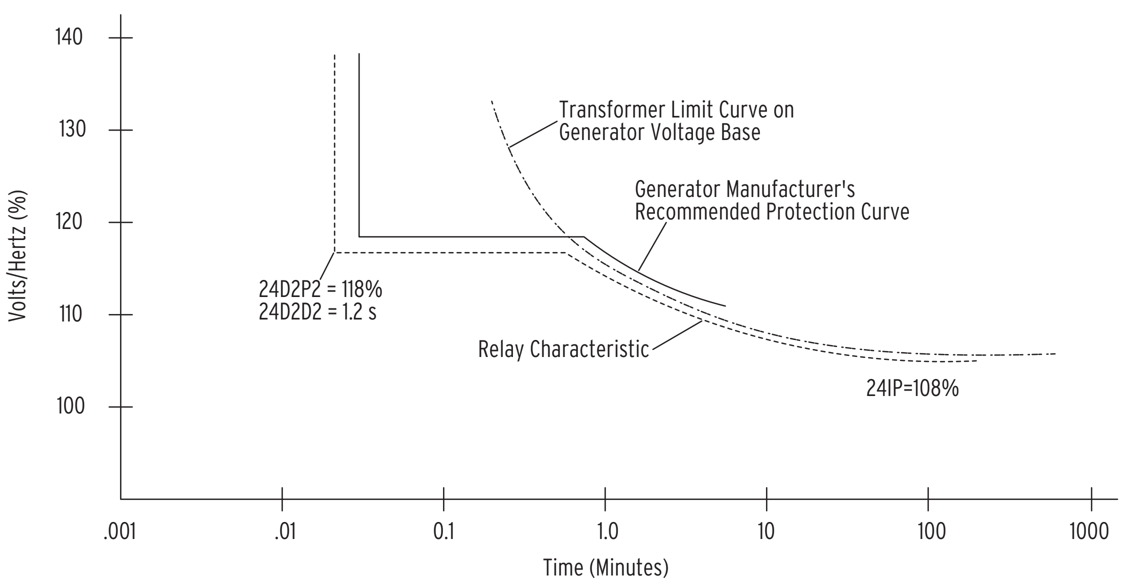


Figure 4.36 Composite Inverse/Definite-Time Overexcitation Characteristic, 24CCS = ID

Table 4.22 Volts Per Hertz Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE V/HZ PROT	Y, N	E24 := Y
XFMR WDG CONN	DELTA, WYE	24WDG := WYE
LVL1 V/HZ PICKUP	100%–200%	24D1P := 105
LVL1 TIME DLY	0.04–400.00 sec	24D1D := 1.00
LVL2 CURVE SHAPE	OFF, DD, ID, I, U	24CCS := ID
LVL2 INV-TM PU	100%–200%	24IP := 105
LVL2 INV-TM CURV	0.5, 1.0, 2.0	24IC := 2.0
LVL2 INV-TM FCTR	0.1–10.0 sec	24ITD := 0.1
LVL2 PICKUP 2	101%–200%	24D2P2 := 176
LVL2 TIME DLY 2	0.04–400.00 s	24D2D2 := 3.00
LVL2 RESET TIME	0.00–400.00 s	24CR := 240.00
24 ELEM TRQ-CNTRL	SELOGIC	24TC := 1

Collect this information before calculating volts/hertz element settings:

- ➤ Transformer manufacturer's overexcitation limit curve
- ➤ Transformer nominal phase-phase voltage

Select the transformer winding that is most likely to suffer overexcitation. The relay voltage input should be from a source that most reliably reflects that winding voltage.

Set E24 := Y to enable volts/hertz protection elements. If you do not need volts/hertz protection, set E24 := N. When E24 := N, the 24TC, 24D1, 24D1T, 24C2, 24C2T, and 24CR Relay Word bits are inactive. The relay hides corresponding settings; you do not need to enter these settings.

When three PTs are available, the most common PT winding connection is to connect both HV and LV sides in wye, leaving the power transformer winding connections as the only variable. For wye-connected power transformer windings, the power transformer phase-to-neutral voltage is readily measured through wye-wye connected PTs. Set 24WDG := WYE. When the power transformer windings are delta connected, the relay cannot measure the phase voltage directly, but needs to calculate the voltage values. The relay calculates the differences between the voltages presented to the relay from the wye-wye connected PTs and thus the voltage connected to the power transformer windings. Set 24WDG := DELTA. Thus, voltage values selection to calculate the volts/hertz protection and sequence components is based on the 24WDG selection; phase to phase for 24WDG := DELTA and phase-to-neutral for 24WDG = WYE.

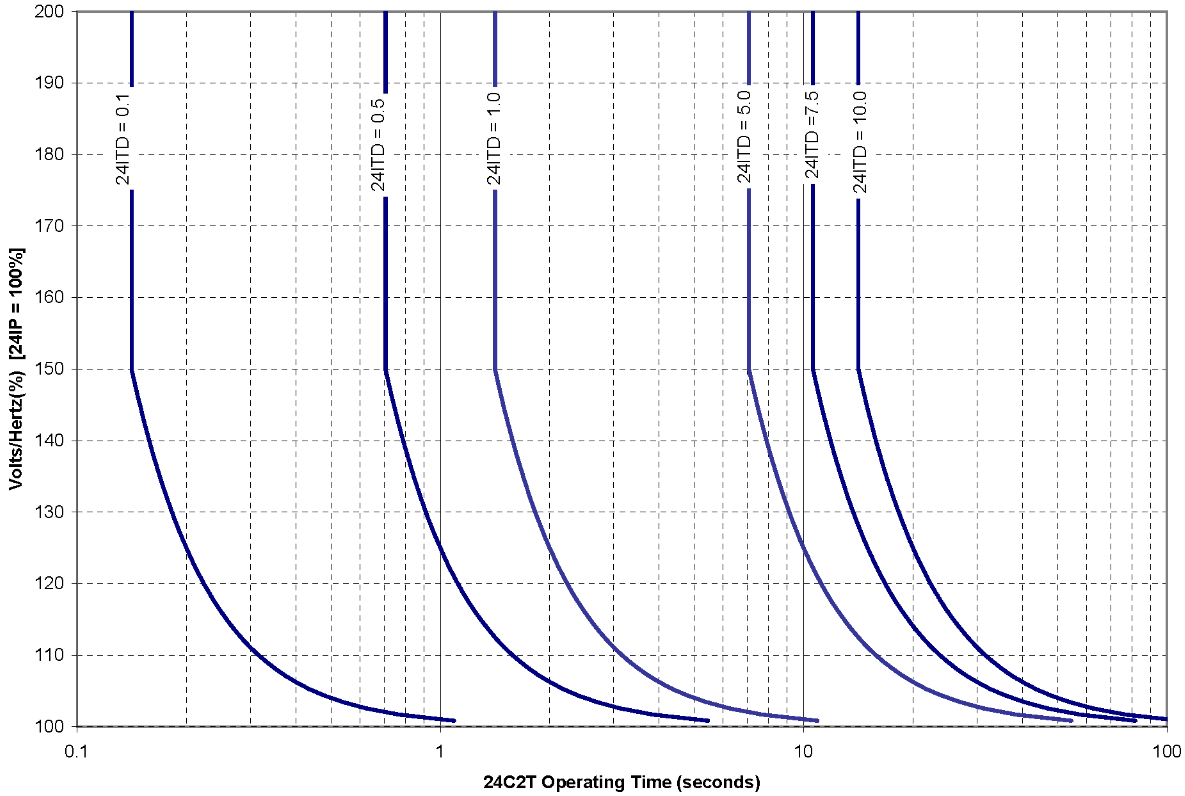
Use the Level 1 volts/hertz element as an overexcitation alarm. Set 24D1P equal to or greater than 105 percent, but less than the minimum pickup of the Level 2 element. Use a 24D1D time delay of 1.0 second to allow time for correction of an overexcitation condition prior to an alarm.

The 24CCS setting defines the overexcitation tripping element time-delay characteristic as shown in *Figure 4.32*. Set 24CCS := OFF if you do not require Level 2 volts/hertz protection. When 24CCS := OFF, the other Level 2 settings are hidden and do not need to be entered.

- When 24CCS := DD the element operates with a dual-level definite-time characteristic with pickup and delay of 24D2Pn and 24D2Dn (n = 1 or 2).
- When 24CCS := ID the element operates with a composite inverse-time and definite-time characteristic with pickup of 24IP (Inverse-time) and 24D2P2 (definite-time). The 24IC and 24ITD settings define the inverse-time curve shape (see *Table 4.35* through *Table 4.37*).
- When 24CCS := I the element operates with a simple inverse-time characteristic, defined by the 24IP, 24IC and 24ITD settings described above.
- When 24CCS := U the element operates with a user-defined inverse-time characteristic with a pickup of 24IP. The user curve should be set using SEL-5806 PC Software. This program handles individual mapping of points to make a curve that matches any transformer characteristic. It also handles all relay communication by either uploading the current curve or programming a new curve.

The 24CR setting defines the composite element reset time. When the element times out to trip, it will fully reset 24CR seconds after the applied volts/hertz drops below the element pickup setting. The reset characteristic is linear, so if the element times 60 percent toward a trip, it will fully reset (0.6 • 24CR) seconds after the applied volts/hertz drops below the element pickup setting. When the element is reset, the relay asserts the 24CR Relay Word bit.

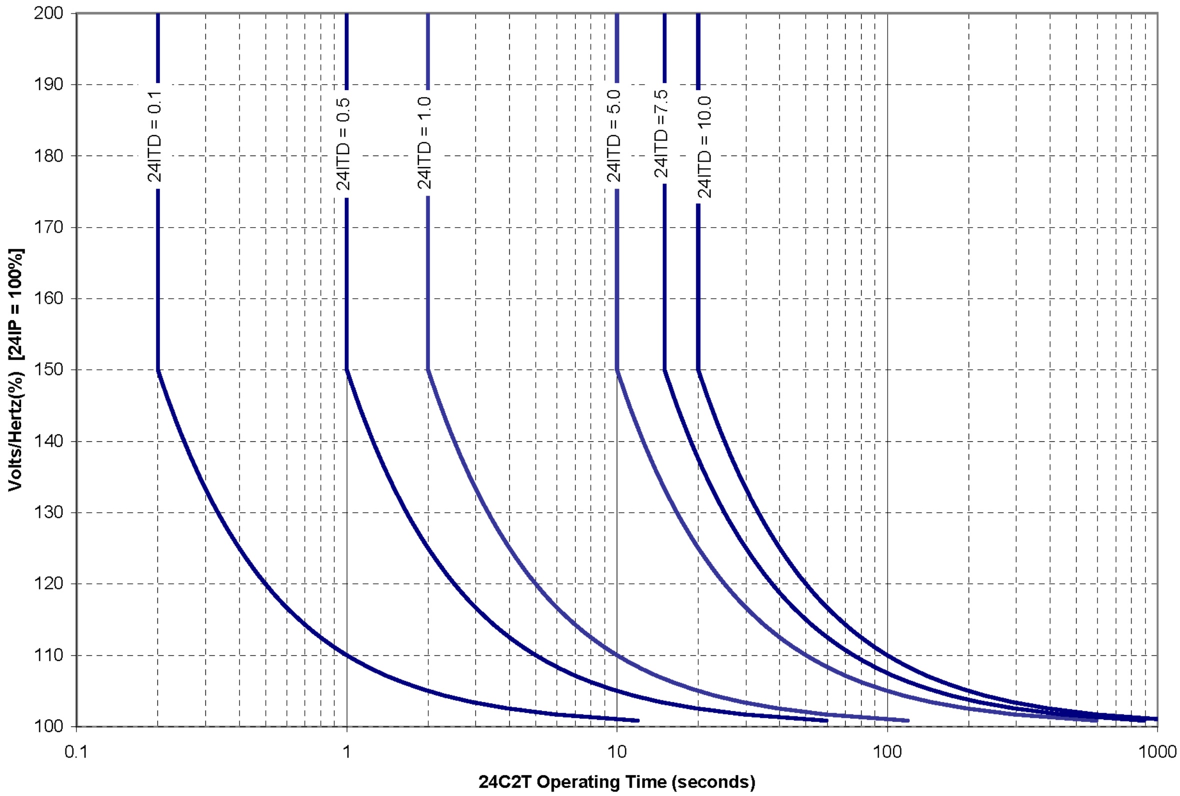
Both volts/hertz elements are disabled when the 24TC SELOGIC control equation equals logical 0. The elements are allowed to operate when the 24TC SELOGIC control equation equals logical 1, the default setting. You can add other supervisory conditions if you need these for your application.



$$t_p = \frac{24ITD}{\left(\left(\frac{\frac{VPP \bullet PTR}{freq} \bullet \frac{FNOM}{VNOM \bullet 10^3}}{\frac{24IP}{100}}\right) - 1\right)^{0.5}} \text{ seconds} \qquad \text{if V/Hz} \le 1.5 \bullet 24IP$$

$$t_p = 1.414 \bullet 24ITD \text{ seconds} \qquad \text{if V/Hz} > 1.5 \bullet 24IP$$

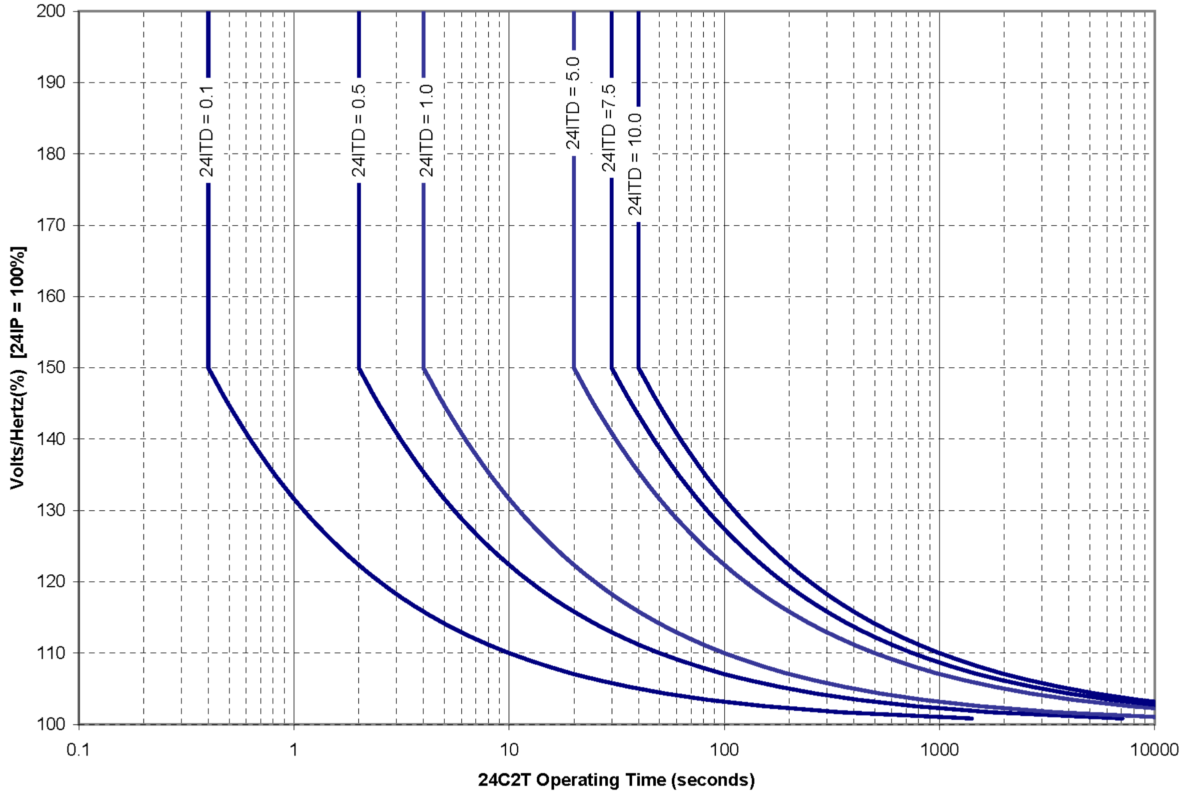
Figure 4.37 Volts/Hertz Inverse-Time Characteristic, 24IC = 0.5



$$t_p = \frac{24ITD}{\left(\left(\frac{\frac{VPP \bullet PTR}{freq} \bullet \frac{FNOM}{VNOM \bullet 10^3}}{\frac{24IP}{100}}\right) - 1\right)^{1.0}} \text{ seconds} \qquad \text{if V/Hz} \leq 1.5 \bullet 24IP$$

$$t_p = 2.0 \bullet 24ITD \text{ seconds} \qquad \text{if V/Hz} > 1.5 \bullet 24IP$$

Figure 4.38 Volts/Hertz Inverse-Time Characteristic, 24IC = 1



$$t_p = \frac{24ITD}{\left(\left(\frac{\frac{VPP \bullet PTR}{freq} \bullet \frac{FNOM}{VNOM \bullet 10^3}}{\frac{24IP}{100}}\right) - 1\right)^{2.0}} \text{ seconds} \qquad \text{if } V/Hz \le 1.5 \bullet 24IP$$

$$t_p = 4.0 \bullet 24ITD \text{ seconds} \qquad \text{if } V/Hz > 1.5 \bullet 24IP$$

Figure 4.39 Volts/Hertz Inverse-Time Characteristic, 24IC = 2

Power Elements

You can enable as many as two independent three-phase power elements in the SEL-787 relay. Each enabled element can be set to detect real power or reactive power. When voltage inputs to the relay are from delta connected PTs or when single voltage input is used, the relay cannot account for unbalance in the voltages in calculating the power. Take this into consideration in applying the power elements.

With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications are:

- ➤ Overpower and/or underpower protection/control
- ➤ Reverse power protection/control
- ➤ VAR control for capacitor banks

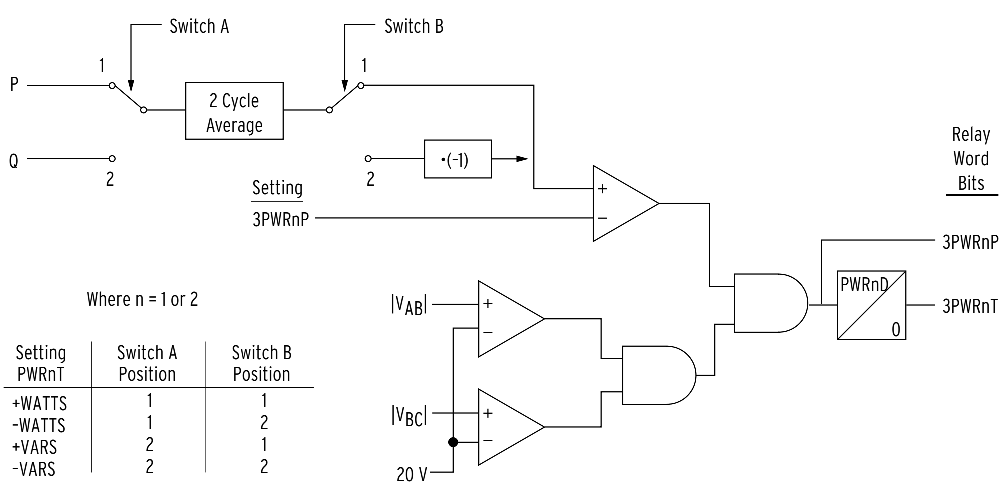
Table 4.23 Power Element Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PWR ELEM	N, 3P1, 3P2	EPWR := N
3PH PWR ELEM PU	OFF, 1.0–6500.0 VA (secondary)[a]	3PWR1P := OFF
PWR ELEM TYPE	+WATTS, –WATTS, +VARS, –VARS	PWR1T := +VARS
PWR ELEM DELAY	0.0–240.0 sec	PWR1D := 0.0
3PH PWR ELEM PU	OFF, 1.0–6500.0 VA (secondary)[a]	3PWR2P := OFF
PWR ELEM TYPE	+WATTS, –WATTS, +VARS, –VARS	PWR2T := +VARS
PWR ELEM DELAY	0.0–240.0 sec	PWR2D := 0.0

[a] The range shown is for 5 A input; range for 1 A input is OFF, 0.2–1300.0 VA.

EPWR := 3P1 enables one three-phase power element. Set EPWR := 3P2 if you want to use both elements.

Set the element pickup, 3PH PWR ELEM PU to desired values in secondary VA units. *Figure 4.40* shows the power element logic diagram and *Figure 4.41* shows the operation in the Real/Reactive power plane.



Setting PWRnT	Switch A Position	Switch B Position
+WATTS	1	1
-WATTS	1	2
+VARS	2	1
-VARS	2	2

Figure 4.40 Three-Phase Power Elements Logic

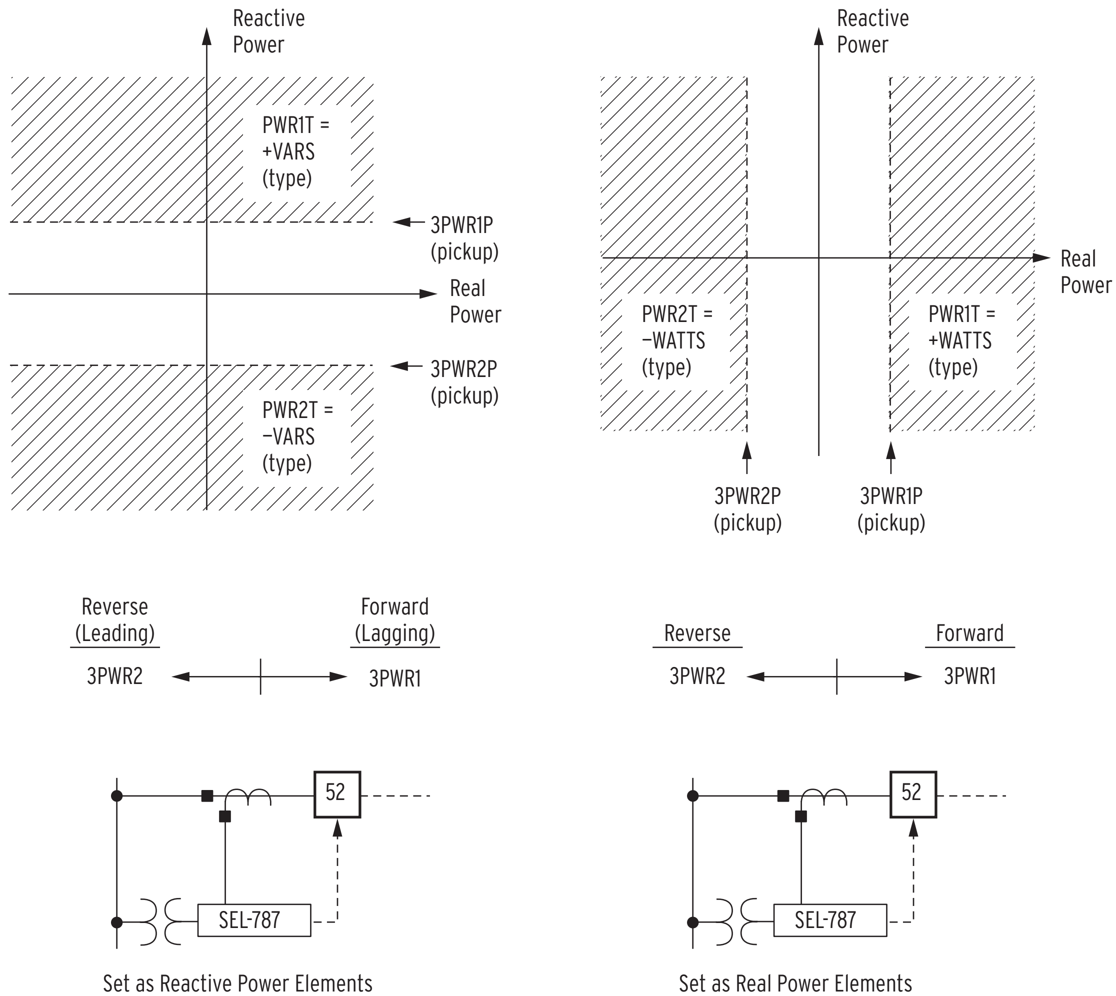


Figure 4.41 Power Elements Operation in the Real/Reactive Power Plane

The power element type settings are made in reference to the load convention:

- +WATTS: positive or forward real power
- –WATTS: negative or reverse real power
- +VARS: positive or forward reactive power (lagging)
- –VARS: negative or reverse reactive power (leading)

The two power element time delay settings (PWR1D and PWR2D) can be set to have no intentional delay for testing purposes. For protection applications involving the power element Relay Word bits, SEL recommends a minimum time delay setting of 0.1 second for general applications. The classical power calculation is a product of voltage and current, to determine the real and reactive power quantities. During a system disturbance, because of the high sensitivity of the power elements, the changing system phase angles and/or frequency shifts may cause transient errors in the power calculation.

The power elements are not supervised by any relay elements other than the minimum voltage check shown in *Figure 4.40*. If the protection application requires overcurrent protection in addition to the power elements, there may be a race condition, during a fault, between the overcurrent element(s) and the power element(s) if the power element(s) are still receiving sufficient operating quantities. Use the power element time delay setting to avoid such race conditions.

Frequency Elements

Table 4.24 Frequency Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
FREQ1 TRIP LEVEL	OFF, 20.0–70.0 Hz	81D1TP := OFF
FREQ1 TRIP DELAY	0.0–240.0 sec	81D1TD := 1.0
FREQ2 TRIP LEVEL	OFF, 20.0–70.0 Hz	81D2TP := OFF
FREQ2 TRIP DELAY	0.0–240.0 sec	81D2TD := 1.0
FREQ3 TRIP LEVEL	OFF, 20.0–70.0 Hz	81D3TP := OFF
FREQ3 TRIP DELAY	0.0–240.0 sec	81D3TD := 1.0
FREQ4 TRIP LEVEL	OFF, 20.0–70.0 Hz	81D4TP := OFF
FREQ4 TRIP DELAY	0.0–240.0 sec	81D4TD := 1.0

The SEL-787 provides four trip over- or underfrequency elements with independent level and time-delay settings. When an element level setting is less than the nominal frequency setting, the element operates as an underfrequency element. When the level setting is greater than the nominal frequency setting, the element operates as an overfrequency element. *Figure 4.42* shows the logic diagram for the frequency elements.

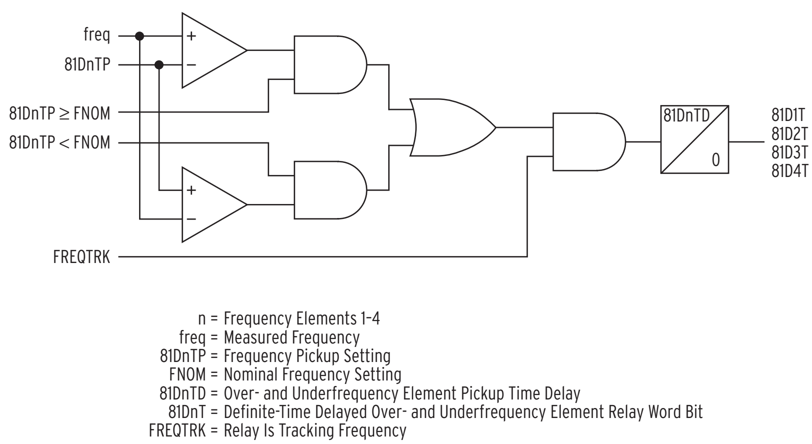


Figure 4.42 Over- and Underfrequency Element Logic

The SEL-787 tracks frequency only on the models with the voltage option. The relay uses the positive-sequence voltage (V1) to measure and track frequency. The frequency tracking bit (FREQTRK) asserts if the applied V1 magnitude is greater than 10 V rms for at least three cycles. The FREQTRK bit drops out if the V1 magnitude is less than 10 V for longer than 10 cycles. If no voltages are applied or the V1 magnitude is less than 10 V for longer than 10 cycles, the relay assumes the frequency is the same as the nominal frequency, or the FNOM setting.

Loss-of-Potential (LOP) Protection

The SEL-787 sets Relay Word bit LOP (loss-of-potential) upon detecting a loss of relay ac voltage input such as that caused by blown potential fuses or by the operation of molded-case circuit breakers. Because accurate relaying potentials are required by certain protection elements (undervoltage 27 elements, for example), you can use the LOP function to supervise these protection elements.

The relay declares an LOP when there is more than a 25 percent drop in the measured positive-sequence voltage (V1) with no corresponding magnitude or angle change (above a pre-determined threshold) in positive-sequence (I1), negative-sequence (I2), or zero-sequence currents (I0).

If this condition persists for 60 cycles, then the relay latches the LOP Relay Word bit at logical 1. The relay resets LOP when the positive-sequence voltage (V1) returns to a level greater than 0.43 • VNOM/PTR while negative-sequence voltage (V2) and zero-sequence voltage (V0) are both less than 5 V secondary (VNOM and PTR are relay settings).

Settings

The LOP function has no settings and is always active. You must incorporate the LOP function in a SELOGIC control equation to supervise relay protection elements (see *Example 4.3*).

LOP Impact on Other Protection Elements

Undervoltage and directional power elements require accurate relaying potentials for correct operation. It is critical that the relay detects an LOP condition and prevents operation of these elements. For example, when dropping a wrench on the phase-voltage input fuse holders, the relay LOP logic accurately determines that this loss of input voltages is an LOP condition and does not trip (if the LOP Relay Word bit supervises selected tripping elements, see *Example 4.3*). If you are using voltage-determined relay elements for tripping decisions, then blocking these elements is crucial when the voltage component is no longer valid.

EXAMPLE 4.3 Supervising Voltage-Element Tripping With LOP

To supervise undervoltage by LOP one of the trip equations can be set as follows:

TR2:= **. . . OR ((27P1T OR 27P2T) AND NOT LOP)**

Similarly, if you want the additional voltage-affected elements (e.g., 3PWR1T) to act only when there are correct relaying potentials voltage, use the following in the equation:

. . . OR ((27P1T OR 27P2T OR 3PWR1T) AND NOT LOP)

You can supervise each element separately or as a group when these elements occur in the trip equations, as shown in this example.

LOP Monitoring and Alarms

You should take steps to immediately correct an LOP problem so that normal protection is rapidly re-established. Include the LOP Relay Word bit in an output contact alarm to notify operation personnel of abnormal voltage input conditions and failures that can be detrimental to the protection system performance if not quickly corrected.

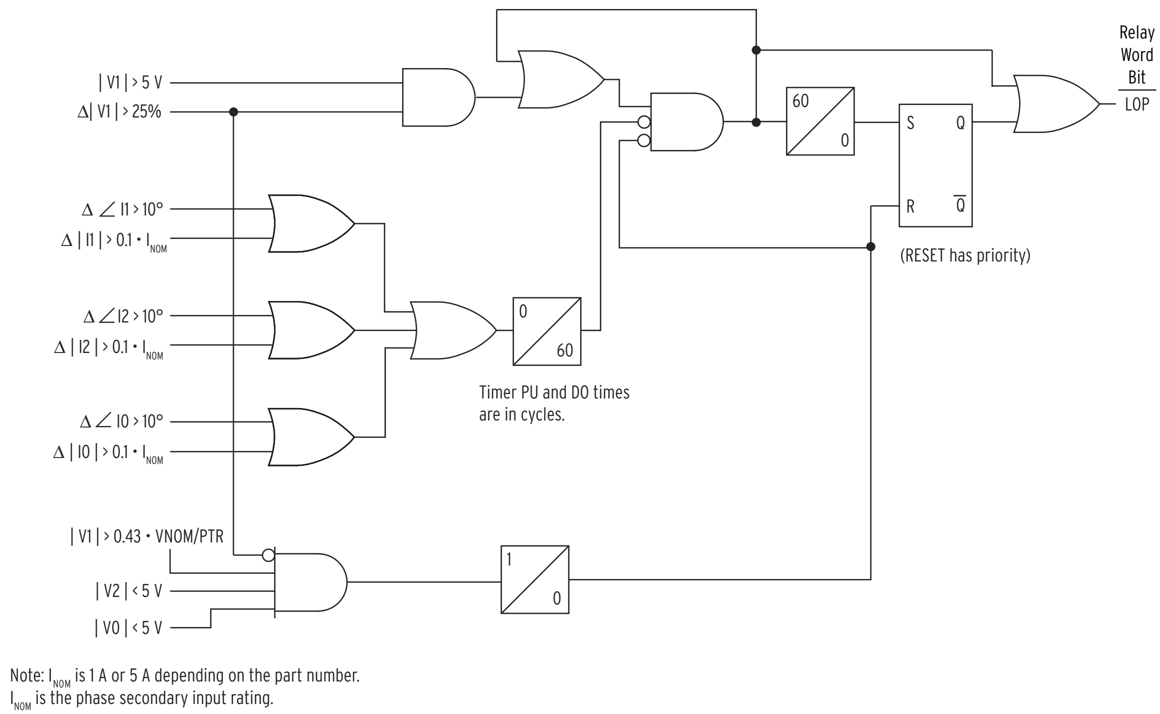


Figure 4.43 Loss-of-Potential (LOP) Logic

Demand Metering

The SEL-787 provides demand and peak demand metering, selectable between thermal and rolling demand types, for the following values for either Winding 1 or Winding 2 currents:

- ➤ IA, IB, IC, phase currents (A primary)
- ➤ IG Residual ground current (A primary; IG = 3I0 = IA + IB + IC)
- ➤ 3I2 Negative-sequence current (A primary)

Table 4.25 shows the demand metering settings. Also refer to *Section 5: Metering and Monitoring* and *Section 7: Communications* for other related information for the demand meter.

Table 4.25 Demand Meter Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE DEM MTR	OFF, W1, W2	EDEM := OFF
DEMAND MTR TYPE	THM, ROL	DEMTY := THM
DEM TIME CONSTNT	5, 10, 15, 30, 60 min	DMTC := 5
PH CURR DEM LVL	OFF, 0.50-16.00 A[a] OFF. 0.10-3.20 A [b]	PHDEMP := 5.00[a] PHDEMP := 1.00 b
RES CURR DEM LVL	OFF, 0.50-16.00 A[a] OFF, 0.10-3.2 A [b]	GNDEMP := 1.00[a] GNDEMP := 0.20[b]
3I2 CURR DEM LVL	OFF, 0.50-16.00 A[a] OFF, 0.10-3.2 A [b]	3I2DEMP := 1.00[a] 3I2DEMP := 0.20[b]

[a] For Inom = 5 A.
[b] For Inom = 1 A.

The demand current level settings are applied to demand current meter outputs as shown in *Figure 4.44*. For example, when residual ground demand current IGD goes above corresponding demand pickup GNDEMP, Relay Word bit GNDEM asserts to logical 1. Use these demand current logic outputs (PHDEM, GNDEM, and 3I2DEM) to alarm for high loading or unbalance conditions.

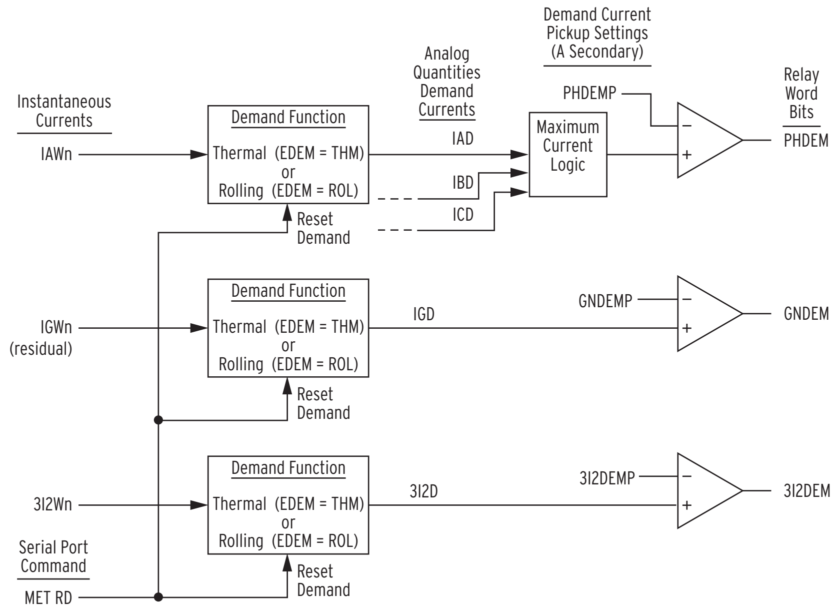


Figure 4.44 Demand Current Logic Outputs

The demand values are updated approximately once a second. The relay stores peak demand values to nonvolatile storage every six hours (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it will restore the peak demand values saved by the relay.

Demand metering peak recording is momentarily suspended when SELOGIC control equation setting FAULT is asserted (= logical 1).

The differences between thermal and rolling demand metering are explained in the following discussion.

Comparison of Thermal and Rolling Demand Meters

The example in *Figure 4.45* shows the response of thermal and rolling demand meters to a step current input. The current input is at a magnitude of zero and then suddenly goes to an instantaneous level of 1.0 per unit (a "step").

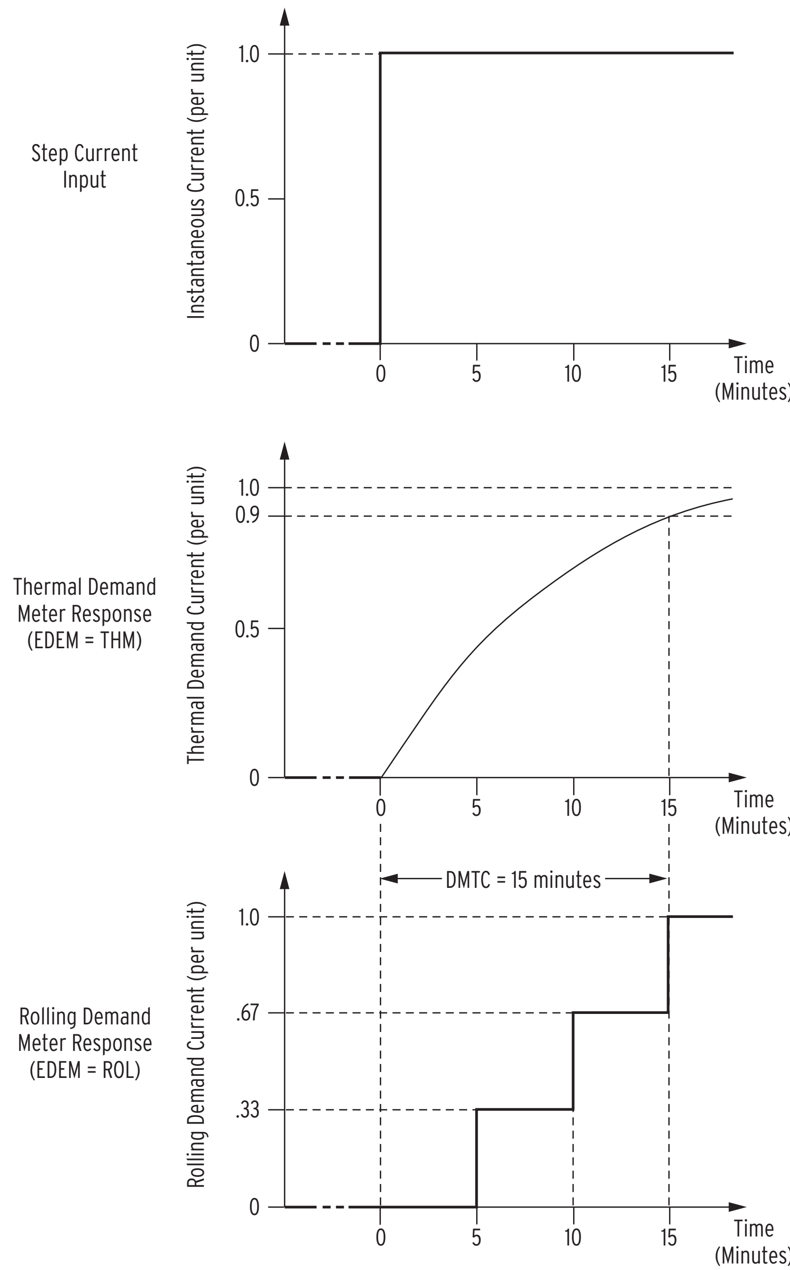


Figure 4.45 Response of Thermal and Rolling Demand Meters to a Step Input (Setting DMTC = 15 minutes)

Thermal Demand Meter Response

The response of the thermal demand meter in *Figure 4.45* (middle) to the step current input (top) is analogous to the series RC circuit in *Figure 4.46*.

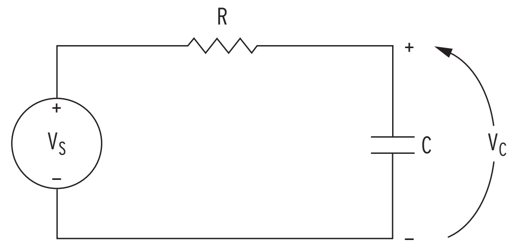


Figure 4.46 Voltage V_S Applied to Series RC Circuit

In the analogy:

Voltage V_S in *Figure 4.46* corresponds to the step current input in *Figure 4.45* (top).

Voltage V_C across the capacitor in *Figure 4.46* corresponds to the response of the thermal demand meter in *Figure 4.45* (middle).

If voltage V_S in *Figure 4.46* has been at zero (V_S = 0.0 per unit) for some time, voltage V_C across the capacitor in *Figure 4.46* is also at zero (V_C = 0.0 per unit). If voltage V_S is suddenly stepped up to some constant value (V_S = 1.0 per unit), voltage V_C across the capacitor starts to rise toward the 1.0 per unit value. This voltage rise across the capacitor is analogous to the response of the thermal demand meter in *Figure 4.45* (middle) to the step current input (top).

In general, as voltage V_C across the capacitor in *Figure 4.46* cannot change instantaneously, the thermal demand meter response is not immediate either for the increasing or decreasing applied instantaneous current. The thermal demand meter response time is based on the demand meter time constant setting DMTC (see *Table 4.25*). Note in *Figure 4.45*, the thermal demand meter response (middle) is at 90 percent (0.9 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The SEL-787 updates thermal demand values approximately every second.

Rolling Demand Meter Response

The response of the rolling demand meter in *Figure 4.45* (bottom) to the step current input (top) is calculated with a sliding time-window arithmetic average calculation. The width of the sliding time-window is equal to the demand meter time constant setting DMTC (see *Table 4.25*). Note in *Figure 4.45*, the rolling demand meter response (bottom) is at 100 percent (1.0 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The rolling demand meter integrates the applied signal (e.g., step current) input in five-minute intervals. The integration is performed approximately every second. The average value for an integrated five-minute interval is derived and stored as a five-minute total. The rolling demand meter then averages a number of the five-minute totals to produce the rolling demand meter response. In the *Figure 4.45* example, the rolling demand meter averages the three latest five-minute totals because setting DMTC = 15 (15/5 = 3). The rolling demand meter response is updated every five minutes, after a new five-minute total is calculated.

The following is a step-by-step calculation of the rolling demand response example in *Figure 4.45* (bottom).

Time = 0 Minutes

Presume that the instantaneous current has been at zero for quite some time before "Time = 0 minutes" (or the demand meters were reset). The three five-minute intervals in the sliding time-window at "Time = 0 minutes" each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–15 to –10 minutes
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to 0 minutes
0.0 per unit	

Rolling demand meter response at "Time = 0 minutes" = 0.0/3 = 0.0 per unit.

Time = 5 Minutes

The three five-minute intervals in the sliding time-window at "Time = 5 minutes" each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to 0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	

Rolling demand meter response at "Time = 5 minutes" = 1.0/3 = 0.33 per unit.

Time = 10 Minutes

The three five-minute intervals in the sliding time-window at "Time = 10 minutes" each integrate into the following five-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
0.0 per unit	–5 to 0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
2.0 per unit	

Rolling demand meter response at "Time = 10 minutes" = 2.0/3 = 0.67 per unit.

Time = 15 Minutes

The three five-minute intervals in the sliding time-window at "Time = 15 minutes" each integrate into the following 5-minute totals:

Five-Minute Totals	Corresponding Five-Minute Interval
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
1.0 per unit	10 to 15 minutes
3.0 per unit	

Rolling demand meter response at "Time = 15 minutes" = 3.0/3 = 1.0 per unit.

Trip/Close Logic

Trip/Close Logic Settings

Table 4.26 Trip/Close Logic Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
MIN TRIP TIME	0.0–400.0 sec	TDURD := 0.5
CLOSE 1 FAIL DLY	0.0–400.0 sec	CFD1 := 0.5
CLOSE 2 FAIL DLY	0.0–400.0 sec	CFD2 := 0.5
TRIP 1 EQUATION	SV	TR1 := 50P11T OR 51P1T OR 51Q1T OR NOT LT02 AND SV04T OR OC1
TRIP 2 EQUATION	SV	TR2 := 51P2T OR 51Q2T OR LT02 AND SV04T OR OC2
TRIP XFMR EQN	SV	TRXFMR := 87R OR 87U
REMOTE TRIP EQN	SV	REMTRIP := 0
UNLATCH TRIP 1	SV	ULTRIP1 := NOT (51P1P OR 51Q1P OR 52A1)
UNLATCH TRIP 2	SV	ULTRIP2 := NOT (51P2P OR 51Q2P OR 52A2)
UNLATCH TRP XFMR	SV	ULTRXFMR := NOT (87R OR 87U)
BREAKER1 STATUS	SV	52A1 := 0
CLOSE1 EQUATION	SV	CL1 := SV03T AND NOT LT02 OR CC1
UNLATCH CLOSE 1	SV	ULCL1 := TRIP1 OR TRIPXFMR
BREAKER 2 STATUS	SV	52A2 := 0
CLOSE 2 EQUATION	SV	CL2 := SV03T AND LT02 OR CC2
UNLATCH CLOSE 2	SV	ULCL2 := TRIP2 OR TRIPXFMR

The trip logic and close logic for the SEL-787 operate in a similar manner. Each has a SELogic control equation setting to set or latch the logic and another SELogic control equation setting to reset or unlatch the logic. Each also has other elements or functions that will unlatch the logic. The output of each logic is a Relay Word bit that can be assigned to operate output contacts, or in any other manner for which a Relay Word bit can be used. The specifics of each type of logic are discussed below.

TDURD Minimum Trip Time

This timer establishes the minimum time duration for which the TRIP Relay Word bits assert. This is a rising-edge initiated timer.

Trips initiated by TR*m* (*m* = 1, 2, XFMR) Relay Word bits (includes **OPEN** command from front-panel and serial ports) are maintained for at least the duration of the minimum trip duration time (TDURD) setting.

TR Trip Conditions SELOGIC Control Equations

NOTE: The outputs in the SEL-787 are not designed to interrupt the trip coil current. An auxiliary contact with adequate current interrupting capacity must clear the trip coil current before the output of the SEL-787 opens. Failure to observe this safeguard could result in damage to the SEL-787 output contacts. Avoid programming Relay Word bit TRm in the output equation to directly trip the breaker. Instead use Relay Word bit TRIPm, which stays asserted for at least the duration of the TDURD setting or until TRIPm is unlatched, whichever is longer.

There are three trip logic equations within the SEL-787. They are designed to operate when SELOGIC control equation trip variable setting TR*m* is asserted (*m* = 1, 2, XFMR), and to unlatch when SELOGIC control equation setting ULTR*m* is asserted. The TR1 and TR2 are intended for breaker 1 and 2 respectively and the TRXFMR for the transformer lockout relay. The output of the logic is Relay Word bit TRIP*m*.

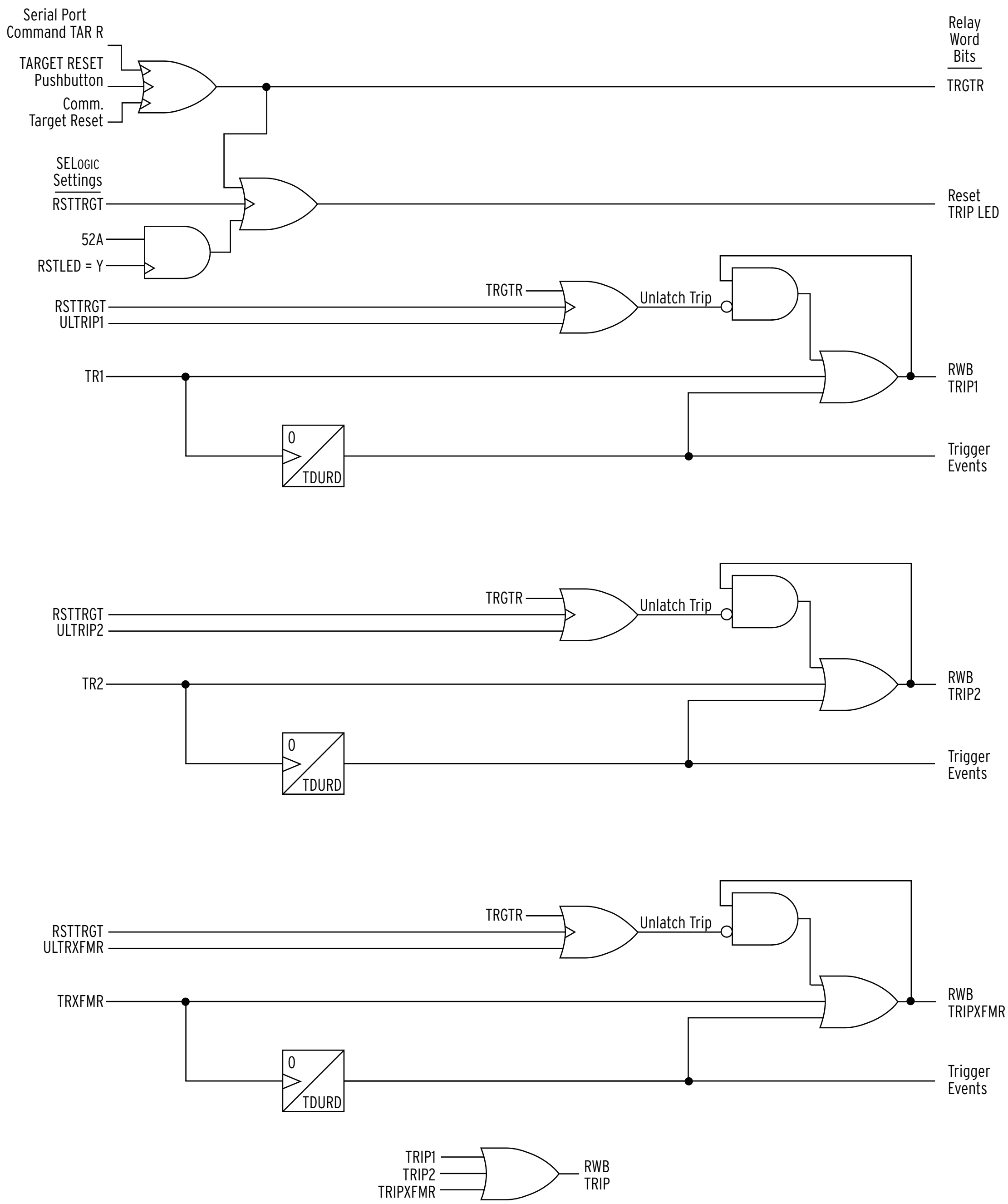


Figure 4.47 Trip Logic

The relay controls the tripping output contact(s) when the Relay Word bit TRIP*m* appears in an output contact SELOGIC control equation. Default relay settings have output **OUT103** set to TRIPXFMR (see *Table 4.34*). Assign Relay Word bits TRIP1 and TRIP2 to other available outputs as required by your application. See *Figure 2.24* for typical trip circuit connection.

NOTE: You can create your own custom logic using SELOGIC variables and map those variables to the TRm equations.

Set the TR*m* SELOGIC control equations to include an OR-combination of all the Relay Word bits that you want to cause the associated trip bits to assert. The factory-default setting already includes all commonly required Relay Word bits.

REMTRIP Remote Trip Conditions SELOGIC Control Equation

You can map any Relay Word bit or SELOGIC equation to the REMTRIP to trip a breaker or the transformer. For example, you can map a control input to REMTRIP and map the REMTRIP to appropriate TR*m* equation.

Unlatch Trip Logic

Each of the three trip logic equations has an associated unlatch trip SELOGIC equation. Following a fault, the appropriate trip signal is maintained until all of the following conditions are true:

NOTE: The factory-default setting of the ULTRIP provides an automatic reset of the trip when the breaker opens and selected 50/51 elements are not picked up.

- Minimum trip duration time (TDURD) passes.
- The TR*m* (*m* = 1, 2, XFMR) SELOGIC control equation result deasserts to logical 0.
- One of the following occurs:
  - Unlatch Trip SELOGIC control equation setting ULTRIP asserts to logical 1.
  - Target Reset SELOGIC control equation setting RSTTRGT asserts to logical 1.
  - Target Reset Relay Word TRGTR asserts. The TRGTR is asserted when the front-panel **TARGET RESET** pushbutton is pressed or a target reset serial port command is executed (ASCII, Modbus, or DeviceNet).

52A Breaker Status Conditions SELOGIC Control Equations

You can connect an auxiliary contact of the high and low side breaker to the relay. The SELOGIC control equations 52A1 and 52A2 allow you to configure the relay for either 52b or 52a contact input (or other contact that indicates a closed breaker). The factory-default setting assumes no auxiliary contact connection (both 52A1 and 52A2 := 0).

If you connect the breaker auxiliary contact to a digital input, you must change the factory-default logic equation. For example, set 52A1 := **IN101** if you connect the 52a contact of breaker 52-1 to input **IN101**.

Figure 4.48 shows a close logic diagram of breaker 52-1; the logic of breaker 52-2 is similar.

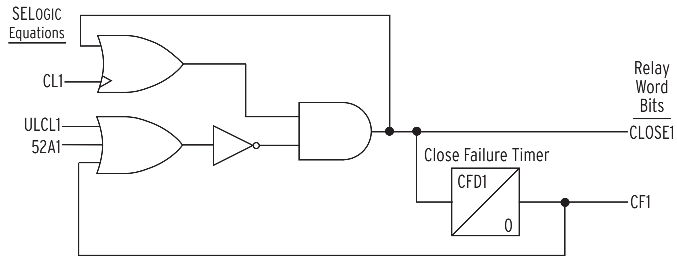


Figure 4.48 Close Logic

CL Close SELOGIC Control Equation

There are two close logic equations within the SEL-787. They are designed to operate when SELOGIC control equation close variable setting CL*m* is asserted (*m* = 1, 2) and to unlatch when SELOGIC control equation setting ULCL*m* is asserted. The output of the logic is Relay Word bits CLOSE*m*.

The relay controls the closing output contact(s) when the Relay Word bit CLOSE*m* appears in an output contact SELOGIC control equation. Assign the CLOSE bits to desired output relays as required by your application. See *Figure 2.20* for typical close circuit connection.

Set the CL*m* SELOGIC control equations to include an OR-combination of all Relay Word bits that you want to cause the associated close bits to assert. The factory-default setting already includes all commonly required Relay Word bits.

Unlatch Close Logic

Each of the two close logic equations has an associated unlatch close SELOGIC equation. Once a CLOSE bit is asserted it is sealed-in until one of the following conditions is true:

- Unlatch Close SELOGIC control equation setting ULCL1 (or ULCL2) asserts to logical 1.
- Relay Word 52A1 (or 52A2) asserts to logical 1.
- Close failure Relay Word bit asserts to logical 1.

Close Failure Logic

Each of the two close logic equations includes a close failure detection with an associated delay setting (CFD1 and CFD2). Set the close failure delay equal to the longest close time of the breaker plus a safety margin. If the breaker fails to close, the Relay Word CF1 (or CF2) will assert for 1/4 cycle. Use the CF bits as desired.

Logic Settings (SET L Command)

Settings associated with latches, timers, counters, math variables, and output contacts are listed below. Note that SELOGIC equations are processed every quarter cycle while math variable equations and analog quantities are updated every 100 ms.

SELOGIC Enables

Table 4.27 shows the enable settings for latch bits (ELAT), SELOGIC control equations (including timers) (ESV), Counters (ESC), and math variable equations (EMV). This helps limit the number of settings that you need to make. For example, if you need six timers, only enable six timers.

IMPORTANT: Upon relay initial power up or Port 1 setting changes or Logic setting changes, the user may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled, as soon as the ENABLED LED comes on (approximately 5–10 seconds from power up).

Table 4.27 Enable Settings

Setting Prompt	Setting Range	Default Setting
SELOGIC Latches	N, 1–32	ELAT := 4
SV/Timers	N, 1–32	ESV := 5
SELOGIC Counters	N, 1–32	ESC := N
Math Variables[a]	N, 1–32	EMV := N

[a] If a math variable is set equal to NA (e.g., MV01 := NA), it is treated as 0.

Latch Bits

Latch control switches (latch bits are the outputs of these switches) replace traditional latching devices. Traditional latching devices maintain output contact state. The SEL-787 latch control switch also retains state even when power to the device is lost. If the latch control switch is set to a programmable output contact and power to the device is lost, the state of the latch control switch is stored in nonvolatile memory, but the device de-energizes the output contact. When power to the device is restored, the programmable output contact will go back to the state of the latch control switch after device initialization. Traditional latching device output contact states are changed by pulsing the latching device inputs (see *Figure 4.49*). Pulse the set input to close (set) the latching device output contact. Pulse the reset input to open (reset) the latching device output contact. The external contacts wired to the latching device inputs are often from remote control equipment (e.g., SCADA, RTU).

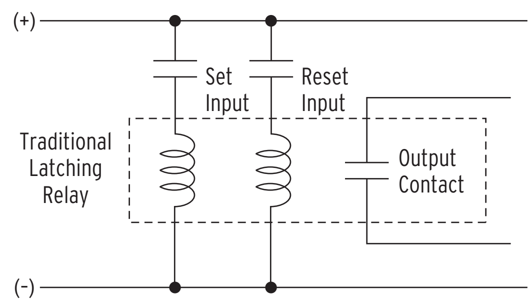


Figure 4.49 Schematic Diagram of a Traditional Latching Device

Thirty-two latch control switches in the SEL-787 provide latching device functionality. *Figure 4.50* shows the logic diagram of a latch switch. The output of the latch control switch is a Relay Word bit LT*n* (*n* = 01–32), called a latch bit.

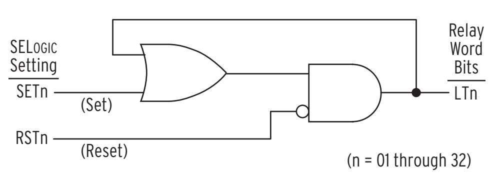


Figure 4.50 Logic Diagram of a Latch Switch

If setting SET*n* asserts to logical 1, latch bit LT*n* asserts to logical 1. If setting RST*n* asserts to logical 1, latch bit LT*n* deasserts to logical 0. If both settings SET*n* and RST*n* assert to logical 1, setting RST*n* has priority and latch bit LT*n* deasserts to logical 0. You can use these latch bits in SELOGIC control equations to create custom logic for your application.

The SEL-787 includes 32 latches. *Table 4.28* shows the **SET** and **RESET** default settings for Latch 1 through Latch 4. The remaining latches are all set to NA.

Table 4.28 Latch Bits Equation Settings

Settings Prompt	Setting Range	Setting Name := Factory Default
SET01	SELOGIC	SET01 := R_TRIG SV01T AND NOT LT01
RST01	SELOGIC	RST01 := R_TRIG SV01T AND LT01
SET02	SELOGIC	SET02 := R_TRIG SV02T AND NOT LT02 AND PB02
RST02	SELOGIC	RST02 := R_TRIG SV02T AND LT02 AND PB02
SET03	SELOGIC	SET03 := (PB03 AND R_TRIG SV02T) AND LT01 AND NOT (52A1 AND NOT LT02 OR 52A2 AND LT02)
RST03	SELOGIC	RST03 := (R_TRIG SV02T OR SV03T) AND LT03
SET04	SELOGIC	SET04 := (PB04 AND R_TRIG SV02T) AND (52A1 AND NOT LT02 OR 52A2 AND LT02)
RST04	SELOGIC	RST04 := (R_TRIG SV02T OR SV04T) AND LT04
• • •	• • •	• • •
SET32	SELOGIC	SET32 := NA
RST32	SELOGIC	RST32 := NA

Latch Bits: Nonvolatile State

Power Loss

The states of the latch bits (LT01–LT32) are retained if power to the device is lost and then restored. If a latch bit is asserted (e.g., LT02 := logical 1) when power is lost, it is asserted (LT02 := logical 1) when power is restored. If a latch bit is deasserted (e.g., LT03 := logical 0) when power is lost, it is deasserted (LT03 := logical 0) when power is restored.

Settings Change

If individual settings are changed, the states of the latch bits (Relay Word bits LT01 through LT32) are retained, as in the preceding *Power Loss on page 4.65* explanation. If the individual settings change causes a change in SELOGIC control equation settings SET*n* or RST*n* (*n* = 1 through 32), the retained states of the latch bits can be changed, subject to the newly enabled settings SET*n* or RST*n*.

Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss or settings change. The nonvolatile memory is rated for a finite number of writes for all cumulative latch bit state changes. Exceeding the limit can result in a flash self-test failure. *An average of 5000 cumulative latch bit state changes per day can be made for a 25-year device service life.*

Settings SET*n* and RST*n* cannot result in continuous cyclical operation of latch bit LT*n*. Use timers to qualify conditions set in settings SET*n* and RST*n*. If you use any optoisolated inputs in settings SET*n* and RST*n*, the inputs each have a separate debounce timer that can help in providing the necessary time qualification.

SELOGIC Control Equation Variables/Timers

Enable the number of SELOGIC control equations necessary for your application. Only the enabled SELOGIC control equations appear for settings. Each SELOGIC control equation variable/timer has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 4.51*. Timers SV01T through SV32T in *Figure 4.51* have a setting range of 0.00–3000.00 seconds. This timer setting range applies to both pickup and dropout times (SV*n*PU and SV*n*DO, *n* = 1 through 32).

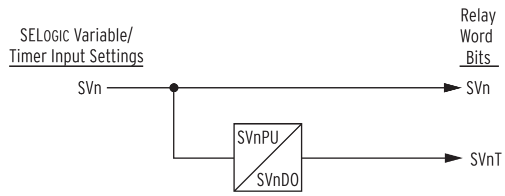


Figure 4.51 SELOGIC Control Equation Variable/Timers SV01/SV01T–SV32T

You can enter as many as 15 elements per SELOGIC equation, including a total of 14 elements in parentheses (see *Table 4.29* for more information).

SELOGIC Control Equation Operators

Use the Boolean operators to combine values with a resulting Boolean value. Edge trigger operators provide a pulse output. Combine the operators and operands to form statements that evaluate complex logic. SELOGIC control equations are either Boolean type or math type. Because the equals sign (=) is already used as an equality comparison, both Boolean type and math type of SELOGIC control equation settings begin with an “assignment” operator (:=) instead of with an equals sign.

Boolean SELOGIC control equation settings use logic similar to Boolean algebra logic, combining Relay Word bits together with one or more of the Boolean operators listed in *Table 4.29*. Math SELOGIC control equation settings operate on numerical values, using one or more of the Mathematical operators listed in *Table 4.29*. These numerical values can be mathematical variables or actual real numbers.

The relay converts variables from decimal to integer before performing math operations, i.e., scales it by multiplying by 128 followed by rounding. After the math operations, the relay converts the result back from integer to decimal by scaling the value down by 128 before reporting the results. This effectively means that math calculations are rounded. See *Example 4.4* for an explanation on improving the accuracy of the math operations by managing the processing order.

EXAMPLE 4.4 Improving the Accuracy of Math Operations

If MV01 := (60/4160) • 100,000, the relay performs the 60/4160 calculation and scales it by 128, then rounds this up to a 2. The relay then multiplies it by 100,000 and stores it as 200,000. When the number is reported it divides out the scale factor (128) and reports 1562.5.

Alternatively, if MV01 := (60 • 100,000)/4160, the relay multiplies (60 • 100,000) and then scales by 128 and then divides by 4160. This result is then rounded and stored as 184,615. The relay then divides 184,615 by 128 and reports 1442.3.

Example 4.4 illustrates how important it is to avoid calculations where a small number is divided by a larger number followed by multiplication. It will amplify the error significantly.

The executed result of a math SELOGIC control equation is stored in a math variable. The smallest and largest values a math variable can represent are –16777215.99 and +16777215.99, respectively. If the executed result exceeds these limits, it will be clipped at the limit value. For example, when the MV01:= executed result is –16777219.00, MV01 will be –16777215.99. Similarly, when the MV02 := executed result is +16777238.00, MV02 will be +16777215.99.

Comments can be added to both boolean and math SELOGIC control equations by inserting a # symbol. Everything following the # symbol in a SELOGIC control equation is treated as a comment. See *Table 4.30* for this and other Boolean and math operators and values.

Operator Precedence

When you combine several operators and operands within a single expression, the SEL-787 evaluates the operators from left to right, starting with the highest precedence operators and working down to the lowest precedence. This means that if you write an equation with three AND operators, for example SV01 AND SV02 AND SV03, each AND will be evaluated from the left to the right. If you substitute NOT SV04 for SV03 to make SV01 AND SV02 AND NOT SV04, the device evaluates the NOT operation of SV04 first and uses the result in subsequent evaluation of the expression.

Table 4.29 SELOGIC Control Equation Operators (Listed in Operator Precedence)

Operator	Function	Function Type (Boolean and/or Mathematical)
( )	parentheses	Boolean and Mathematical (highest precedence)
–	negation	Mathematical
NOT	NOT	Boolean
R_TRIG	rising-edge trigger/detect	Boolean
F_TRIG	falling-edge trigger/detect	Boolean
*	multiply	Mathematical
/	divide	Mathematical
+	add	Mathematical
-	subtract	Mathematical
<, >, <=, >=	comparison	Boolean
=	equality	Boolean
<>	inequality	Boolean
AND	AND	Boolean
OR	OR	Boolean (lowest precedence)

Parentheses Operator ( )

You can use more than one set of parentheses in a SELOGIC control equation setting. For example, the following Boolean SELOGIC control equation setting has two sets of parentheses:

SV04 := **(SV04 OR IN102) AND (PB01_LED OR RB01)**

In the above example, the logic within the parentheses is processed first and then the two parentheses resultants are ANDed together. Use as many as 14 sets of parentheses in a single SELOGIC control equation setting. The parentheses can be “nested” (parentheses within parentheses).

Math Negation Operator (–)

The negation operator – changes the sign of a numerical value. For example:

MV01 := **RB01**

When Remote bit RB01 asserts, Math variable MV01 has a value of 1, i.e., MV01 = 1. We can change the sign on MV01 with the following expression:

MV01 := **-1 * RB01**

Now, when Remote bit RB01 asserts, Math variable MV01 has a value of –1, i.e., MV01 = –1.

Boolean NOT Operator (NOT)

Apply the NOT operator to a single Relay Word bit and to multiple elements (within parentheses).

An example of a single Relay Word bit is as follows:

SV01 := **NOT RB01**

When Remote bit RB01 asserts from logical 0 to logical 1, the Boolean NOT operator, in turn, changes the logical 1 to a logical 0. In this example, SV01 deasserts when RB01 asserts.

Following is an example of the NOT operator applied to multiple elements within parentheses.

The Boolean SELOGIC control equation OUT101 setting could be set as follows:

OUT101 := **NOT(RB01 OR SV02)**

If both RB01 and SV02 are deasserted (= logical 0), output contact OUT101 asserts, i.e., OUT101 := NOT (logical 0 OR logical 0) = NOT (logical 0) = logical 1.

In a Math SELOGIC control equation, use the NOT operator with any Relay Word bits. This allows a simple if/else type equation, as shown in the example below.

MV01 := **12 * IN101 + (MV01 + 1) * NOT IN101**

The equation above sets MV01 to 12 whenever IN101 asserts, otherwise it increments MV01 by 1 each time the equation is executed.

Boolean Rising-Edge Operator (R_TRIG)

Apply the rising-edge operator, R_TRIG, to individual Relay Word bits only; you cannot apply R_TRIG to groups of elements within parentheses. When any Relay Word bit asserts (going from logical 0 to logical 1), R_TRIG interprets this logical 0 to logical 1 transition as a “rising edge” and asserts to logical 1 for one processing interval.

For example, the Boolean SELOGIC control equation event report generation setting uses rising-edge operators:

ER := **R_TRIG IN101 OR R_TRIG IN102**

The rising-edge operators detect a logical 0 to logical 1 transition each time one of IN101 or IN102 asserts. Using these settings, the device triggers a new event report each time IN101 or IN102 asserts anew, if the device is not already recording an event report. You can use the rising-edge operator with the NOT operator as long as the NOT operator precedes the R_TRIG operator. The NOT R_TRIG combination produces a logical 0 for one processing interval when it detects a rising edge on the specified element.

Boolean Falling-Edge Operator (F_TRIG)

Apply the falling-edge operator, F_TRIG, to individual Relay Word bits only; you cannot apply F_TRIG to groups of elements within parentheses. The falling-edge operator, F_TRIG, operates similarly to the rising-edge operator, but operates on Relay Word bit deassertion (elements going from logical 1 to logical 0) instead of Relay Word bit assertion. When the Relay Word bit deasserts, F_TRIG interprets this logical 1 to logical 0 transition as a "falling edge" and asserts to logical 1 for one processing interval, as shown in *Figure 4.52*.

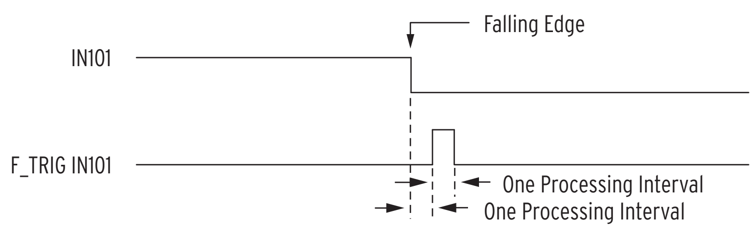


Figure 4.52 Result of Falling-Edge Operator on a Deasserting Input

You can use the falling-edge operator with the NOT operator as long as the NOT operator precedes the F_TRIG operator. The NOT F_TRIG combination produces a logical 0 for one processing interval when it detects a falling edge on the specified element.

Math Arithmetic Operators (*, /, +, and –)

If Relay Word bits (which are effectively Boolean resultants, equal to logical 1 or logical 0) are used in mathematical operations, they are treated as numerical values 0 and 1, depending on if the Relay Word bit is equal to logical 0 or logical 1, respectively.

Boolean Comparison Operators (<, >, <=, and >=)

Comparisons are mathematical operations that compare two numerical values, with the result being a logical 0 (if the comparison is not true) or logical 1 (if the comparison is true). Thus, what starts out as a mathematical comparison ends up as a Boolean resultant. For example, if the output of a math variable is above a certain value, an output contact is asserted:

OUT103 := **MV01 > 8**

If the math variable (MV01) is greater than 8 in value, output contact OUT103 asserts (OUT103 = logical 1). If the math variable (MV01) is less that or equal to 8 in value, output contact OUT103 deasserts (OUT103 = logical 0).

Boolean Equality (=) and Inequality (<>) Operators

Equality and inequality operators operate similar to the comparison operators. These are mathematical operations that compare two numerical values, with the result being a logical 0 (if the comparison is not true), or logical 1 (if the comparison is true). Thus, what starts out as a mathematical comparison, ends up as a Boolean resultant. For example, if the output of a math variable is not equal to a certain value, an output contact is asserted:

OUT102 := **MV01 <> 45**

If the math variable (MV01) is not equal to 45 in value, output contact OUT102 asserts (effectively OUT102 := logical 1). If the math variable (MV01) is equal to 45 in value, output contact OUT102 deasserts (effectively OUT102 := logical 0). *Table 4.30* shows other operators and values that you can use in writing SELOGIC control equations.

Table 4.30 Other SELOGIC Control Equation Operators/Values

Operator/ Value	Function	Function Type (Boolean and/or Mathematical)
0	Set SELOGIC control equation directly to logical 0 (XXX := 0)	Boolean
1	Set SELOGIC control equation directly to logical 1 (XXX := 1)	Boolean
#	Characters entered after the # operator are not processed and deemed as comments	Boolean and Mathematical
\	Indicates that the preceding logic should be continued on the next line ("\" is entered only at the end of a line)	Boolean and Mathematical

Timers Reset When Power Lost or Settings Changed

If the device loses power or settings change, the SELOGIC control equation variables/timers reset. Relay Word bits SV*n* and SV*n*T (*n* = 01–32) reset to logical 0 after power restoration or a settings change. *Figure 4.53* shows an effective seal-in logic circuit, created by the use of Relay Word bit SV07 (SELOGIC control equation variable SV07) in SELOGIC control equation SV07:

SV07 = **(SV07 OR OUT101) AND (OUT102 OR OUT401)**

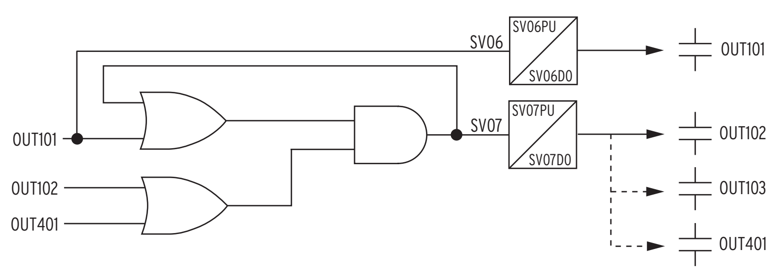


Figure 4.53 Example Use of SELOGIC Variables/Timers

SV/Timers Settings

The SEL-787 includes 32 SELOGIC variables. *Table 4.31* shows the pickup, dropout, and equation settings for SV01 through SV05. The remaining SELOGIC variables are not enabled (see *Table 4.27*).

Table 4.31 SELOGIC Variable Settings

Setting Prompt	Setting Range	Default Settings
SV TIMER PICKUP	0.00–3000.00 sec	SV01PU := 3.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV01DO := 0.00
SV INPUT	SELOGIC	SV01 := PB01
SV TIMER PICKUP	0.00–3000.00 sec	SV02PU := 0.25
SV TIMER DROPOUT	0.00–3000.00 sec	SV02DO := 0.00
SV INPUT	SELOGIC	SV02 := PB01 OR PB02 OR PB03 OR PB04
SV TIMER PICKUP	0.00–3000.00 sec	SV03PU := 0.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV03DO := 0.00
SV INPUT	SELOGIC	SV03 := LT03
SV TIMER PICKUP	0.00–3000.00 sec	SV04PU := 0.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV04DO := 0.00
SV INPUT	SELOGIC	SV04 := LT04
SV TIMER PICKUP	0.00–3000.00 sec	SV05PU := 0.25
SV TIMER DROPOUT	0.00–3000.00 sec	SV05DO := 0.25
SV INPUT	SELOGIC	SV05 := (PB01 OR PB02 OR LT03 OR LT04) AND NOT SV05T
• • •	• • •	• • •
SV TIMER PICKUP	0.00–3000.00 sec	SV32PU := 0.00
SV TIMER DROPOUT	0.00–3000.00 sec	SV32DO := 0.00
SV INPUT	SELOGIC	SV32 := NA

The pickup times of 0 for the SV03PU and SV04PU settings shown above provide an immediate Close and Trip actions from front-panel pushbuttons. For a delayed Close, set SV03PU to the desired delay. Similarly, set SV04PU for a delayed Trip action. See *Table 8.4* for more detail.

Counter Variables

NOTE: These counter elements conform to the standard counter function block #3 in IEC 1131-3 First Edition 1993-03 International Standard for Programmable controllers—Part 3: Programming languages.

NOTE: For device configurations that include voltage cards, the SEL-787 tracks the frequency. When tracking the frequency, the processing interval varies with the frequency.

NOTE: If setting SCnnCD is set to NA, the entire counter nn is disabled).

NOTE: SELOGIC counters are reset to zero if the relay loses power because the counters are stored in volatile memory.

SELOGIC counters are up- or down-counting elements, updated every processing interval. Each counter element consists of one count setting, four control inputs, two digital outputs, and one analog output. *Figure 4.54* shows Counter 01, the first of 32 counters available in the device.

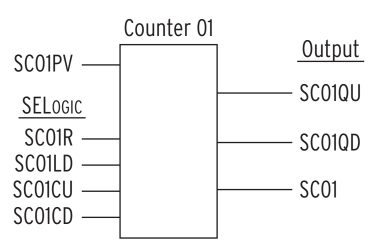


Figure 4.54 Counter 01

Digital output SC01QD asserts when the counter is at position zero, and digital output SC01QU asserts when the counter reaches the programmable count value. Use the reset input (SC01R) to force the count to zero, and the analog output (SC*nn*) with analog comparison operators. *Table 4.32* describes the counter inputs and outputs, and *Table 4.33* shows the order of precedence of the control inputs.

Table 4.32 Counter Input/Output Description

Name	Type	Description
SC*nn*LD	Active High Input	Load counter with the preset value to assert the output (SC*n*QU) (follows SELOGIC setting).
SC*nn*PV	Input Value	This Preset Value is loaded when SC*n*LD pulsed. This Preset Value is the number of counts before the output (SC*n*QU) asserts (follows SELOGIC setting).
SC*nn*CU	Rising-Edge Input	Count Up increments the counter (follows SELOGIC setting).
SC*nn*CD	Rising-Edge Input	Count Down decrements the counter (follows SELOGIC setting).
SC*nn*R	Active High Input	Reset counter to zero (follows SELOGIC setting)
SC*nn*QU	Active High Output	This Q Up output asserts when the Preset Value (maximum count) is reached (SC*n* = SC*n*PV, *n* = 01 to 32).
SC*nn*QD	Active High Output	This Q Down output asserts when the counter is equal to zero (SC*n* = 0, *n* = 01 to 32).
SC*nn*	Output Value	This counter output is an analog value that may be used with analog comparison operators in a SELOGIC control equation and viewed using the **COU** command.

Table 4.33 Order of Precedence of the Control Inputs

Order	Input
1	SC*nn*R
2	SC*nn*LD
3	SC*nn*CU
4	SC*nn*CD

Figure 4.55 shows an example of the effects of the input precedence, with SC01PV set to 7. The vertical dashed line indicates the relationship between SC01CU first being seen as a rising edge and the resultant outputs. This indicates that there is no intentional lag between the control input asserting and the count value changing. Most of the pulses in the diagram are on every second processing interval. The “one processing interval” valley is an example where the CD and CU pulses are only separated by one processing interval.

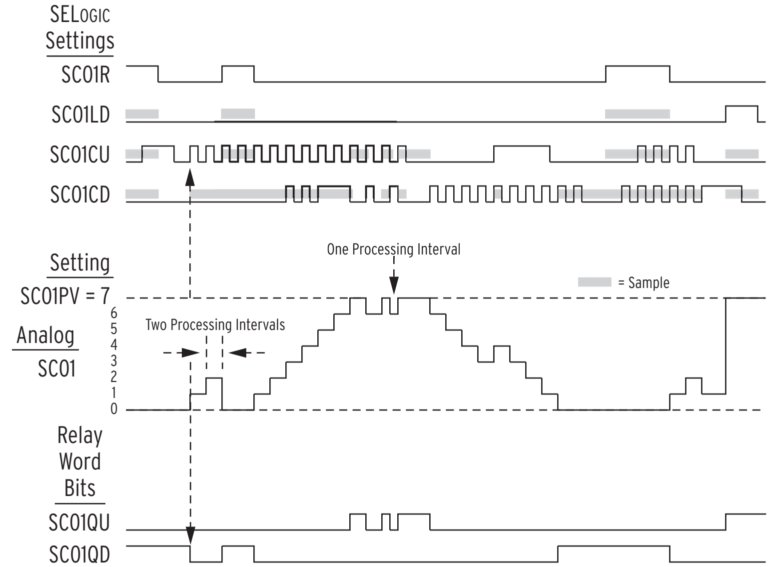


Figure 4.55 Example of the Effects of the Input Precedence

The shaded areas illustrate the precedence of the inputs:

- When SC01R is asserted, the SC01LD input is ignored.
- When SC01R or SC01LD is asserted, rising edges on the SC01CU or SC01CD inputs are ignored.
- When input SC01CU has a rising edge, a rising edge on SC01CD is ignored (unless SC01 is already at the maximum value SC01PV (= 7), in which case SC01CU is ignored, and the SC01CD is processed). An example of this exception appears in the above diagram, just before the "one processing interval" notation.

A maintained logical 1 state on the SC01CU or SC01CD inputs is ignored (after the rising edge is processed). A rising edge received on the SC01CU or SC01CD inputs is ignored when the SC01R or SC01LD inputs are asserted.

A maintained logical 1 on the SC01CU or SC01CD inputs does not get treated as a rising edge when the SC01R or SC01LD input deasserts.

The same operating principles apply for all of the counters: SC01–SC*mm*, where *mm* = the number of enabled counters. When a counter is disabled by setting, the present count value is forced to 0 (SC*nn* := 0), causing Relay Word bit SC*nn*QD to assert (SC*nn*QD := logical 1), and Relay Word bit SC*nn*QU to deassert (SC*nn*QU := logical 0).

Output Contacts

NOTE: When an output contact is not used for a specific function you must set the associated SELOGIC control equation to either 0 or 1.

Table 4.34 Control Output Equations and Contact Behavior Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
OUT101 FAIL-SAFE	Y, N	OUT101FS := Y
OUT101	SELOGIC	OUT101 := HALARM OR SALARM
OUT102 FAIL-SAFE	Y, N	OUT102FS := N
OUT102	SELOGIC	OUT102 := 0
OUT103 FAIL-SAFE	Y, N	OUT103FS := N
OUT103	SELOGIC	OUT103 := TRIPXFMR

Table 4.34 Control Output Equations and Contact Behavior Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
OUT301 FAIL-SAFE	Y, N	OUT301FS := N
OUT301	SELOGIC	OUT301 := 0
OUT302 FAIL-SAFE	Y, N	OUT302FS := N
OUT302	SELOGIC	OUT302 := 0
OUT303 FAIL-SAFE	Y, N	OUT303FS := N
OUT303	SELOGIC	OUT303 := 0
OUT304 FAIL-SAFE	Y, N	OUT304FS := N
OUT304	SELOGIC	OUT304 := 0

NOTE: Four digital outputs for Slot **C** are shown. The outputs for Slot **D** (OUT401–OUT404) and Slot **E** (OUT501–OUT504) have similar settings.

The SEL-787 provides the ability to use SELOGIC control equations to map protection (trip and warning) and general-purpose control elements to the outputs. In addition, you can enable fail-safe output contact operation for relay contacts on an individual basis.

If the contact fail-safe is enabled, the relay output is held in its energized position when relay control power is applied. The output falls to its de-energized position when control power is removed. Contact positions with de-energized output relays are indicated on the relay chassis and in *Figure 2.12* and *Figure 2.13*.

When TRIP output fail-safe is enabled and the **TRIP** contact is appropriately connected (see *Figure 2.16*), the breaker is automatically tripped when relay control power fails.

MIRRORED BITS Transmit SELOGIC Control Equations

See *Appendix H: MIRRORED BITS Communications* and *SEL-787 Settings Sheets* for details.

Global Settings (SET G Command)

General Settings

Table 4.35 General Global Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
PHASE ROTATION	ABC, ACB	PHROT := ABC
RATED FREQ.	50, 60 Hz	FNOM := 60
DATE FORMAT	MDY, YMD, DMY	DATE_F := MDY
FAULT CONDITION	SELOGIC	FAULT := 51P1P OR 51P2P OR 51G1P OR 51G2P OR 51N1P OR TRIP
EVE MSG PTS ENABL	N, 1–32	EMP := N
MESSENGER POINT MP01 TRIGGER	Off, 1 Relay Word bit	MPTR01 := OFF
MESSENGER POINT MP01 AQ	None, 1 analog quantity	MPAQ01 := NONE

Table 4.35 General Global Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
MESSENGER POINT MP01 TEXT	148 characters	MPTX01 := (blank)
• • •	• • •	• • •
MESSENGER POINT MP32 TRIGGER	Off, 1 Relay Word bit	MPTR32 := OFF
MESSENGER POINT MP32 AQ	None, 1 analog quantity	MPAQ32 := NONE
MESSENGER POINT MP32 TEXT	148 characters	MPTX32 := (blank)

The phase rotation setting tells the relay your phase labeling standard. Set PHROT equal to ABC when B-phase current lags A-phase current by 120 degrees. Set PHROT equal to ACB when B-phase current leads A-phase current by 120 degrees.

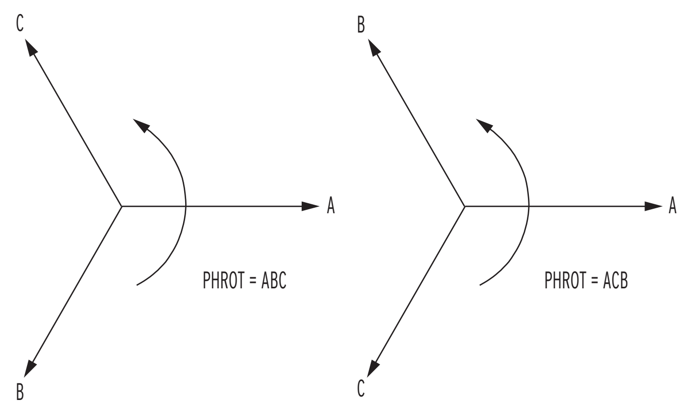


Figure 4.56 Phase Rotation Setting

Set the FNOM setting equal to your system nominal frequency. The DATE_F setting allows you to change the relay date presentation format to the North American standard (Month/Day/Year), the engineering standard (Year/Month/Day), or the European standard (Day/Month/Year).

Set the SELOGIC equation FAULT to temporarily block *Maximum and Minimum Metering*, *Energy Metering*, and *Demand Metering*.

Event Messenger Points

The SEL-787 can be configured to automatically send ASCII message on a communications port when trigger condition is satisfied. Use the **SET P** command to set PROTO := EVMSG on the desired port to select the port. This feature is designed to send messages to the SEL-3010 Event Messenger, however, any device capable of receiving ASCII messages can be used.

Set EMP to enable the desired number of message points.

Set each of MPTR*xx* (*xx* = 01–32) to the desired Relay Word bits, the rising edge of which defines the trigger condition.

MPAQ*xx* is an optional setting and can be used to specify an Analog Quantity to be formatted into a single message as described next.

Use MPTX*xx* to construct the desired message. Note that by default the analog quantity value, if specified, will be added at the end of the message, rounded to the nearest integer value (see *Example 4.5*).

EXAMPLE 4.5 Setting MPTXxx Using the Default Location of Analog Quantity

MPTX01 := THE LOAD CURRENT IS

MPAQ01 value = 157.44

Formatted message out when triggered: THE LOAD CURRENT IS 157

Location and resolution of the analog quantity value within the message can be specified by using "%.pf", where,

% defines location of the value

p defines number of digits (as many as 6, defaults to 6 if omitted)

f indicates floating point value (use %d if nearest whole number is desired)

EXAMPLE 4.6 Setting MPTXxx With a Specified Location of Analog Quantity

MPTX01 := THE LOAD CURRENT IS %.2f AMPERES

MPAQ01 value = 157.44

Formatted message out when triggered: THE LOAD CURRENT IS 157.44 AMPERES

MPTX01 := THE LOAD CURRENT IS %d AMPERES

MPAQ01 value = 157.44

Formatted message out when triggered: THE LOAD CURRENT IS 157 AMPERES

Multiple Settings Groups

SEL-787 Relays have four independent settings groups. Each settings group has complete relay settings and protection SELOGIC settings. The active settings group can be:

- Viewed on the front-panel LCD using the **MAIN** > **Set/Show** > **Active Group** menus, as shown in *Figure 8.20*.
- Viewed using the SEL ASCII serial port **GROUP** command, as described in *Table 7.17*.
- Selected using the SEL ASCII serial port **GROUP *n*** command described in *Table 7.17*.
- Selected using SELOGIC control equation settings SS1 through SS4, as shown in *Table 4.36*.

If SELOGIC control equations SS1–SS4 are defined and evaluate to logical 1, they have priority over the **GROUP *n*** command to select the active settings group. If SELOGIC control equations are defined but evaluate to logical 0, or if they are not defined, the **GROUP *n*** command can be used to select the active settings group.

Active Settings Group Indication

Only one settings group can be active at a time. Relay Word bits SG1 through SG4 indicate the active settings group. For example, if settings Group 3 is the active settings group, Relay Word bit SG3 is asserted to logical 1 and Relay Word bits SG1, SG2, and SG4 are deasserted to logical 0.

Active Settings Group Selection Via SELOGIC Control Equations

The Global settings class contains the SELOGIC control equation settings SS1 through SS4, as shown in *Table 4.36*.

Table 4.36 Setting Group Selection

Setting Prompt	Setting Range	Setting Name := Factory Default
GRP CHG DELAY	0–400 s	TGR := 3
SELECT GROUP1	SELOGIC	SS1 := 1
SELECT GROUP2	SELOGIC	SS2 := 0
SELECT GROUP3	SELOGIC	SS3 := 0
SELECT GROUP4	SELOGIC	SS4 := 0

As an example of how these settings operate, assume that the active settings group is settings Group 3. The corresponding Relay Word bit, SG3, is asserted to logical 1 to indicate that settings Group 3 is the active settings group.

When settings Group 3 is the active settings group, setting SS3 has priority. If setting SS3 is asserted to logical 1, settings Group 3 remains the active settings group, regardless of the activity of settings SS1, SS2, or SS4. If settings SS1 through SS4 all deassert to logical 0, settings Group 3 remains the active settings group.

If the active settings Group 3 SELOGIC control equation SS3 deasserts to logical 0 and one of the other settings (e.g., SS1) asserts to logical 1, the relay switches the active settings group from settings Group 3 to one of the other settings groups (e.g., settings Group 1) after the qualifying time setting TGR (Global setting).

In this example, if multiple SS*n* assert after SS3 deasserts to logical 0, the order of switching follows the first SS*n* that is set in a priority order of 1 through 4.

Active Settings Group Changes

The relay is disabled for less than one second while it processes the active settings group change. Relay elements, timers, and logic are reset, unless otherwise indicated in the specific logic description. For example, local bit (LB01–LB32), remote bit (RB01–RB32), and latch bit (LT01–LT32) states are retained during an active settings group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group. After a group change, an automatic message is shown on the front panel and sent to any serial port that has setting AUTO := Y.

Active Setting: Nonvolatile State

Power Loss

The active settings group is retained if power to the relay is lost and then restored. If a settings group is active when power is lost, the same settings group is active when power is restored.

Settings Change

If individual settings are changed for the active settings group or one of the other settings groups, the active settings group is retained. If individual settings are changed for a settings group other than the active settings group, there is no interruption of the active settings group, so the relay is not momentarily disabled. If the individual settings change causes a change in one or more SELOGIC control equation settings SS1–SS4, the active settings group can be changed, subject to the newly enabled SS1–SS4 settings.

Synchrophasor Measurement

The SEL-787 relay provides phasor measurement and control unit (PMCU) capabilities when connected to an IRIG-B time source. See *Appendix I: Synchrophasors* for description and *Table I.1* for the settings.

Time and Date Management Settings

The SEL-787 supports several methods of updating the relay time and date. For IRIG-B and phasor measurement unit (PMU) synchrophasor applications, refer to *Appendix I: Synchrophasors* for the description and *Table I.1* for the settings. For SNTP applications, refer to *Simple Network Time Protocol (SNTP) on page 7.12*. For time update from a DNP Master, see *Time Synchronization on page D.9*.

Table 4.37 shows the time and date management settings that are available in the Global settings.

Table 4.37 Time and Date Management Settings

Setting Description	Setting Range	Setting Name := Factory Default
IRIG-B Control Bits Definition	NONE, C37.118	IRIGC := NONE
Offset From UTC	–24.00 to 24.00 hours, rounds up to nearest 0.25 hour	UTC_OFF := 0.00
Month To begin DST	OFF, 1–12	DST_BEGM := OFF
Week Of The Month To Begin DST	1–3, L	DST_BEGW := 2
Day Of The Week To Begin DST	SUN, MON, TUE, WED, THU, FRI, SAT, SUN	DST_BEGD := SUN
Local Hour To Begin DST	0–23	DST_BEGH := 2
Month To End DST	1–12	DST_ENDM := 11
Week Of The Month To End DST	1–3, L	DST_ENDW := 1
Day Of The Week To End DST	SUN, MON, TUE, WED, THU, FRI, SAT, SUN	DST_ENDD := SUN
Local Hour To End DST	0–23	DST_ENDH := 2

IRIGC

IRIGC defines whether IEEE C37.118 control bit extensions are in use. Control bit extensions contain information such as Leap Second, UTC time, Daylight-Saving Time, and Time Quality. When your satellite-synchronized clock provides these extensions, your relay will be able adjust the synchrophasor time-stamp accordingly.

- IRIGC := NONE will ignore bit extensions
- IRIGC := C37.118 will extract bit extensions and correct synchrophasor time accordingly

Coordinated Universal Time (UTC) Offset Setting

The SEL-787 has a Global setting UTC_OFF, settable from –24.00 to 24.00 hours, in 0.25 hour increments.

The relay uses the UTC_OFF setting to calculate local (relay) time from the UTC source when configured for Simple Network Time Protocol (SNTP) updating via Ethernet. When a time source other than SNTP is updating the relay time, the UTC_OFF setting is not considered because the other time sources are defined as local time.

Automatic Daylight-Saving Time Settings

The SEL-787 can automatically switch to and from daylight-saving time, as specified by the eight Global settings DST_BEGM through DST_ENDH. The first four settings control the month, week, day, and time that daylight-saving time will begin, while the last four settings control the month, week, day, and time that daylight-saving time will end.

Once configured, the SEL-787 will change to and from daylight-saving time every year at the specified time. Device Word bit DST asserts when daylight-saving time is active.

The SEL-787 interprets the week number settings DST_BEGW and DST_ENDW (1–3, L = Last) as follows:

- ➤ The first seven days of the month are considered to be in week 1.
- ➤ The second seven days of the month are considered to be in week 2.
- ➤ The third seven days of the month are considered to be in week 3.
- ➤ The last seven days of the month are considered to be in week “L”.

This method of counting the weeks allows easy programming of statements like “the first Sunday”, “the second Saturday”, or “the last Tuesday” of a month.

As an example, consider the following settings:

DST_BEGM = 3
DST_BEGW = L
DST_BEGD = SUN
DST_BEGH = 2
DST_ENDM = 10
DST_ENDW = 3
DST_ENDD = WED
DST_ENDH = 3

With these example settings, the relay will enter daylight-saving time on the last Sunday in March at 0200 h, and leave daylight-saving time on the third Wednesday in October at 0300 h. The relay asserts Relay Word bit DST when DST is active.

When an IRIG-B time source is being used, the relay time follows the IRIG-B time, including daylight-saving time start and end, as commanded by the time source. If there is a discrepancy between the daylight-saving time settings and the received IRIG-B signal, the relay follows the IRIG-B signal.

When using IEEE C37.118 compliant IRIG-B signals (e.g., Global setting IRIGC = C37.118), the relay automatically populates the DST Relay Word bit, regardless of the daylight-saving time settings.

When using regular IRIG-B signals (e.g., Global setting IRIGC = NONE), the relay only populates the DST Relay Word bit of the daylight-saving time settings are properly configured.

Simple Network Time Protocol (SNTP)

The SEL-787 Port 1 (Ethernet Port) supports the SNTP Client protocol. See *Section 7: Communications*, *Simple Network Time Protocol (SNTP) on page 7.12* for a description and *Table 7.4* for the settings.

Breaker Failure Setting

Table 4.38 Breaker Failure Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
52A INTERLOCK	Y, N	52ABF := N
BRKR1 FAIL DELAY	0.00–2.00 sec	BFD1 := 0.50
BRKR1 FAIL INIT	SELOGIC	BFI1 := R_TRIG TRIP1 OR R_TRIG TRIPXFMR
BRKR2 FAIL DELAY	0.00-2.00 sec	BFD2 := 0.50
BRKR2 FAIL INIT	SELOGIC	BFI2 := R_TRIG TRIP2 OR R_TRIG TRIPXFMR

The SEL-787 provides flexible breaker failure logic (see *Figure 4.57*) for two breakers. In the default breaker failure logic, assertion of trip Relay Word bits associated with a breaker starts a BFD timer if the sum of positive and negative-sequence breaker current is above 0.02 • I_{NOM}. If the current remains above the threshold for BFD delay setting, Relay Word bit BFT will assert. Use the BFT to operate an output relay to trip appropriate backup breakers. Changing the BFI and/or 52ABF settings can modify the default breaker failure logic.

- Set BFI1 = R_TRIG TRIP1 OR R_TRIG TRIPXFMR AND NOT IN102 if input IN102 is manual trip only and breaker failure initiation is not desired when the tripping is caused by this input.
- Set 52ABF = Y if you want the breaker failure logic to detect failure of breaker/contactor auxiliary contact to operate during the trip operation as defined by the BFI setting.

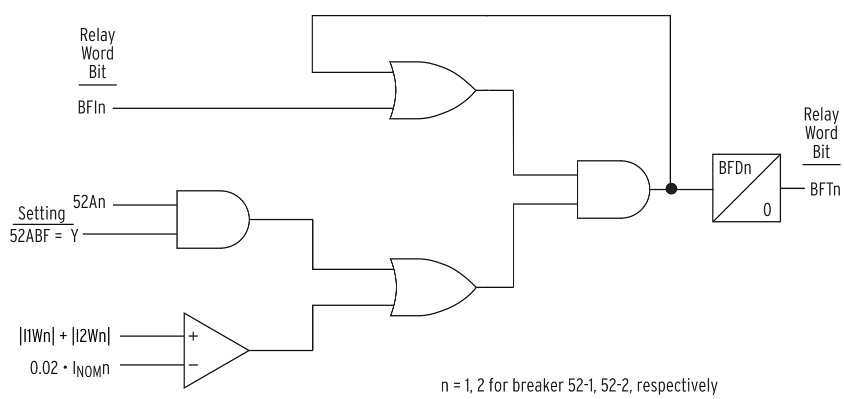


Figure 4.57 Breaker Failure Logic

Through-Fault Monitoring

The power transformers are subjected to heavy through currents for the system faults outside the transformer protection zone. The SEL-787 provides monitoring of the Through-Fault current. See *Section 5: Metering and Monitoring* for description and *Table 5.10* for the settings.

Analog Inputs

The SEL-787 samples the analog inputs four times per cycle. For analog inputs, set the following parameters for each input:

- ➤ Analog type
- ➤ High and low input levels
- ➤ Engineering units

Because of the flexibility to install different cards in the rear-panel slots on the device, the setting prompt adapts to the *x* and *y* variables shown in *Figure 4.58*. Variable *x* displays the slot position (**3** through **5**), and variable *y* displays the transducer (analog) input number (1 through 4).

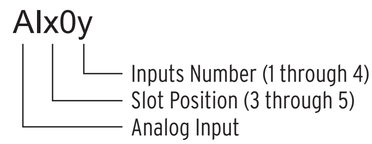


Figure 4.58 Analog Input Card Adaptive Name

Analog Input Calibration Process

In the analog input circuit, the dominant error is signal offset. To minimize the signal offset, we adjust each of the device analog input channels by a compensation factor. These compensation factors correct the signal offset errors to within ±1 µA or ±1 mV.

Signal offset compensation factor calculation procedure:

Step 1. Turn the SEL-787 on and allow it to warm up for a few minutes.

Step 2. Set the analog inputs for each analog channel to the desired range using the AI*xxx*TYP, AI*xxx*L, AI*xxx*H, AI*xxx*EL, and AI*xxx*EH settings (for example, ±1 mA).

Step 3. Short each analog input in turn at the device terminals using short, low resistance leads with solid connections.

Step 4. Issue the command **MET AI 10** to obtain 10 measurements for each channel.

Step 5. Record these 10 measurements, then calculate the average of the 10 measurements by adding the 10 values algebraically, and dividing the sum by 10. This is the average offset error in engineering units at zero input (for example, –0.014 mA).

Step 6. Negate this value (flip the sign) and add the result to each of the AI*xxx*EL and AI*xxx*EH quantities. For this example, the new AI*xxx*EL and AI*xxx*EH values are –0.986 mA and 1.014 mA.

Analog Input Setting Example

Assume we installed an analog card in Slot **3**. On Input 1 of this analog card, we connect a 4–20 mA transducer driven from a device that measures temperature on a transformer load tap changer mechanism. For this temperature transducer, 4 mA corresponds to –50°C, and 20 mA corresponds to 150°C. You have already installed the correct hardware jumper (see *Figure 2.3* for more information) for Input 1 to operate as a current input.

Table 4.39 summarizes the steps and describes the settings we will carry out in this example.

Table 4.39 Summary of Steps

	Step	Activity	Terse Description
General	1	SET G AI301NAM	Access settings for INPUT 1
	2	TX_TEMP	Enter a Tag name
	3	I	Select type of analog input; "I" for current
Transducer High/Low Output	4	4	Enter transducer low output (LOW IN VAL)
	5	20	Enter transducer high output (HI IN VAL)
Level	6	Degrees C	Enter Engineering unit
	7	–50	Enter Engineering unit value LOW
	8	150	Enter Engineering unit value HIGH
Low Warning/ Alarm	9	OFF	Enter LOW WARNING 1 value
	10	OFF	Enter LOW WARNING 2 value
	11	OFF	Enter LOW ALARM value
High Warning/ Alarm	12	65	Enter HIGH WARNING 1 value
	13	95	Enter HIGH WARNING 2 value
	14	105	Enter HIGH ALARM value

NOTE: The AIxOyNAM setting cannot accept the following and will issue the Invalid Element message:
- Analog Quantities
- Duplicate Names
- Other AI Names

Because the analog card is in Slot **3**, type **SET G AI301NAM <Enter>** to go directly to the setting for Slot **3**, Input 1. Although the device accepts alphanumeric characters, the name AI*x*0*y*NAM setting must begin with an alpha character (A through Z) and not a number. The device displays the following prompt:

```
AI301 TAG NAME (8 Characters)   AI301NAM:= AI301 ?
```

Use the Instrument Tag Name to give the analog quantity a more descriptive name. This tag name appears in reports (EVENT, METER, and SUMMARY) instead of the default name of AI301. SELOGIC control equations, Signal Profiles, and Fast Message Read use the default names. Use as many as eight valid tag name characters to name the analog quantity. Valid tag name characters are: 0–9, A–Z, and the underscore (_). For this example, we assign TX_TEMP as the tag name.

Because this is a 4–20 mA transducer, enter **I <Enter>** (for current driven device) at AI301TYP, the next prompt (enter **V** if this is a voltage-driven device). The next two settings define the lower level (AI301L) and the upper level (AI301H) of the transducer. In this example, the low level is 4 mA and the high level is 20 mA.

```
AI301 TYPE  (I,V)              AI301TYP:= I  ?
```

NOTE: Because the SEL-787 accepts current values ranging from –20.48 to +20.48 mA, be sure to enter the correct range values.

The next three settings define the applicable engineering unit (AI301EU), the lower level in engineering units (AI301EL) and the upper level in engineering units (AI301EH). Engineering units refer to actual measured quantities, i.e., temperature, pressure, etc. Use the 16 available characters to assign descriptive names for engineering units. Because we measure temperature in this example, enter “degrees C” (without quotation marks) as engineering units. Enter **–50 <Enter>** for the lower level and **150 <Enter>** for the upper level.

With the levels defined, the next six settings provide two warning settings and one alarm setting for low temperature values, as well as two warning settings and one alarm setting for high temperature values. State the values in engineering units, not the setting range of the transducer. Note the difference between low warnings and alarm functions and high warnings and alarm functions: low warnings and alarm functions assert when the measured value falls below the setting; high warnings and alarm functions assert when the measured values rise above the setting.

In this example, we measure the oil temperature of a power transformer, and we want the following three actions to take place at three different temperature values:

- At 65°C, start the cooling fans
- At 95°C, send an alarm
- At 105°C, trip the transformer

Because we are only interested in cases when the temperature values exceed their respective temperature settings (high warnings and alarm functions), we do not use the low warnings and alarm functions. Therefore, set the lower values (AI301LW1, AI301LW2, AI301LAL) to OFF, and the three higher values as shown in *Figure 4.59*. Set inputs connected to voltage driven transducers in a similar way.

```
=>>SET G AI301NAM TERSE <Enter>
Global
AI 301 Settings
AI301 TAG NAME (8 characters)
AI301NAM:= AI301
? TX_TEMP <Enter>
AI301 TYPE (I,V)                              AI301TYP:= I        ? <Enter>
AI301 LOW IN VAL (-20.480 to 20.480 mA)       AI301L  := 4.000    ? <Enter>
AI301 HI IN VAL (-20.480 to 20.480 mA)        AI301H  := 20.000   ? <Enter>
AI301 ENG UNITS (16 characters)
AI301EU := mA
? degrees C <Enter>
AI301 EU LOW (-99999.000 to 99999.000)        AI301EL := 4.000    ? -50 <Enter>
AI301 EU HI (-99999.000 to 99999.000)         AI301EH := 20.000   ? 150 <Enter>
AI301 LO WARN L1 (OFF,-99999.000 to 99999.000) AI301LW1:= OFF     ? <Enter>
AI301 LO WARN L2 (OFF,-99999.000 to 99999.000) AI301LW2:= OFF     ? <Enter>
AI301 LO ALARM (OFF,-99999.000 to 99999.000)  AI301LAL:= OFF      ? <Enter>
AI301 HI WARN L1 (OFF,-99999.000 to 99999.000) AI301HW1:= OFF     ? 65 <Enter>
AI301 HI WARN L2 (OFF,-99999.000 to 99999.000) AI301HW2:= OFF     ? 95 <Enter>
AI301 HI ALARM (OFF,-99999.000 to 99999.000)  AI301HAL:= OFF      ? 115 <Enter>
AI 302 Settings
AI302 TAG NAME (8 characters)
AI302NAM:= AI302
? END  <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.59 Settings to Configure Input 1 as a 4–20 mA Transducer Measuring Temperatures Between –50°C and 150°C

Analog (DC Transducer) Input Board

Table 4.40 shows the setting prompt, setting range, and factory-default settings for an analog input card in Slot **3**. For the name setting (AI301NAM, for example), enter only alphanumeric and underscore characters. Characters are not case sensitive, but the device converts all lowercase characters to uppercase. Although the device accepts alphanumeric characters, the name AI301NAM setting must begin with an alpha character (A–Z) and not a number.

Table 4.40 Analog Input Card in Slot 3

Setting Prompt	Setting Range	Setting Name := Factory Default
AI301 TAG NAME	8 characters 0–9, A–Z, _	AI301NAM := AI301
AI301 TYPE	I, V	AI301TYP := I
AI301 LOW IN VAL	–20.480 to +20.480 mA	AI301L := 4.000
AI301 HI IN VAL	–20.480 to +20.480 mA	AI301H := 20.000
AI301 LOW IN VAL	–10.240 to +10.240 V	AI301L := 0.000[a]
AI301 HI IN VAL	–10.240 to +10.240 V	AI301H := 10.000[a]
AI301 ENG UNITS	16 characters	AI301EU := mA
AI301 EU LOW	–99999.000 to +99999.000	AI301EL := 4.000
AI301 EU HI	–99999.000 to +99999.000	AI301EH := 20.000
AI301 LO WARN 1	OFF, –99999.000 to +99999.000	AI301LW1 := OFF
AI301 LO WARN 2	OFF, –99999.000 to +99999.000	AI301LW1 := OFF
AI301 LO ALARM	OFF, –99999.000 to +99999.000	AI301LAL := OFF
AI301 HI WARN 1	OFF, –99999.000 to +99999.000	AI301HW1 := OFF
AI301 HI WARN 2	OFF, –99999.000 to +99999.000	AI301HW2 := OFF
AI301 HI ALARM	OFF, –99999.000 to +99999.000	AI301HAL := OFF

[a] Voltage setting range for a voltage transducer, i.e., when AI301TYP := V.

Analog Outputs

If an SEL-787 configuration includes the four analog inputs and four analog outputs (4 AI/4 AO) card, the analog outputs are allocated to output numbers 1-4. *Figure 4.60* shows the *x* and *y* variable allocation for the analog output card.

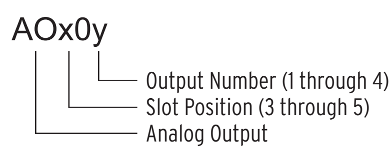


Figure 4.60 Analog Output Number Allocation

For an analog input/output card in Slot **3**, setting AO301AQ identifies the analog quantity we assign to Analog Output 1 (when set to OFF, the device hides all associated AO*x*0*y* settings and no value appears on the output). You can assign any of the analog quantities listed in *Appendix K: Analog Quantities*.

Table 4.41 shows the setting prompt, setting range, and factory-default settings for an analog card in Slot **3**.

Table 4.41 Output Setting for a Card in Slot 3

NOTE: The SEL-787 hides the following settings with default values when you use a 3 DI/4 DO/1 AO card:
AOxx1TYP := I
AOxx1L := 4.000
AOxx1H := 20.000

Setting Prompt	Setting Range	Setting Name := Factory Default
AO301 ANALOG QTY	Off, 1 analog quantity	AO301AQ := OFF
AO301 TYPE	I, V	AO301TYP := I
AO301 AQTY LO	–2147483647.000 to +2147483647.000	AO301AQL := 4.000
AO301 AQTY HI	–2147483647.000 to +2147483647.000	AO301AQH := 20.000
AO301 LO OUT VAL	–20.480 to +20.480 mA	AO301L := 4.000
AO301 HI OUT VAL	–20.480 to +20.480 mA	AO301H := 20.000
AO301 LO OUT VAL	–10.240 to +10.240 V	AO301L := 0.000[a]
AO301 HI OUT VAL	–10.240 to +10.240 V	AO301H := 10.000[a]

[a] Voltage setting range for a voltage transducer, i.e., when AO301TYP := V.

Example

In this example, assume we want to display in the station control room the analog quantity (refer to *Appendix K: Analog Quantities*) IAW1_MAG, Phase A Current Magnitude in Primary Amps (0 to 3000 Amps range) using a –20 to +20 mA Analog Output channel. We install an analog input/output card in Slot C (SELECT 4 AI/4 AO) and set the card channel AO301 as shown in *Figure 4.60* below. Note that the AO301 channel has to be configured as a "current analog output" channel (refer to *Figure 2.5*).

The display instrument expects –20 mA when the IAW1_MAG current is 0 amperes primary and +20 mA when it is 3000 amperes primary.

```
=>>SET G AO301AQ TERSE <Enter>
Global
AO 301 Settings
AO301 ANALOG QTY (OFF, 1 analog quantity)
AO301AQ := OFF
? IAW1_MAG <Enter>
AO301 TYPE (I,V)                               AO301TYP:= I          ? <Enter>
AO301 AQTY LO (-2147483647.000 to 2147483647.000)
                                               AO301AQL:= 4.000      ? 0 <Enter>
AO301 AQTY HI (-2147483647.000 to 2147483647.000)
                                               AO301AQH:= 20.000     ? 3000 <Enter>
AO301 LO OUT VAL (-20.480 to 20.480 mA)        AO301L  := 4.000      ? –20 <Enter>
AO301 HI OUT VAL (-20.480 to 20.480 mA)        AO301H  := 20.000     ? 20 <Enter>
AO 302 Settings
AO302 ANALOG QTY (OFF, 1 analog quantity)
AO302AQ := OFF
? END <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.61 Analog Output Settings

Digital Input Debounce

To comply with different control voltages, the SEL-787 offers dc debounce as well as ac debounce modes. Therefore, if the control voltage is dc, select the dc mode of operation, and if the control voltage is ac, select the ac mode of operation. In general, debounce refers to a qualifying time delay before processing the change of state of a digital input. Normally, this delay applies to both the processing of the debounced input when used in device logic, as well as to the time stamping in the SER. Following is a description of the two modes.

DC Mode Processing (DC Control Voltage)

Figure 4.62 shows the logic for the dc debounce mode of operation. To select the dc mode of debounce, set IN101D to any number between 0 and 65000 ms. In the figure, Input IN101 becomes IN101R (internal variable), after analog-to-digital conversion. On assertion, IN101R starts Debounce Timer, producing Relay Word bit IN101 after the debounce time delay. The debounce timer is a pickup/dropout combination timer, with debounce setting IN101D applying to both pickup (pu) and dropout (do) timers, i.e., you cannot set any timer individually. For example, a setting of IN101D = 20 ms delays processing of the input signal by 20 ms (pu) and maintains the output of the timer (do) for 20 ms. Relay Word bit IN101 is the output of the debounce timer. If you do not want to debounce a particular input, still use Relay Word bit IN101 in logic programming, but set the debounce time delay to 0 (IN101D = 0).

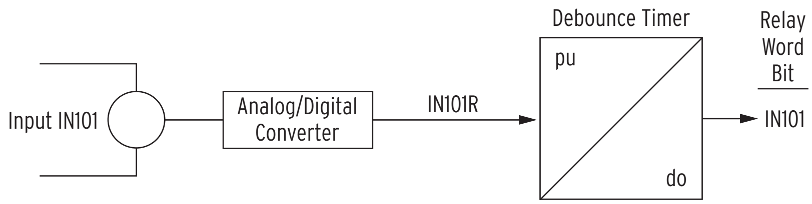


Figure 4.62 DC Mode Processing

AC Mode Processing (AC Control Voltage)

Figure 4.63 shows IN101R from Input IN101 applied to a pickup/dropout timer. Different from the dc mode, there are no time settings for the debounce timer in the ac mode: the pickup time delay is fixed at 2 ms, and the dropout time is fixed at 16 ms. Relay Word bit IN101 is the output of the debounce timer. To select the ac mode of debounce, set IN101D = AC.

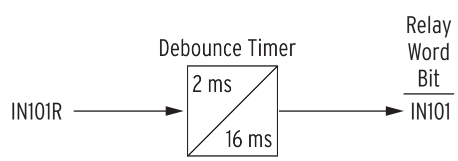


Figure 4.63 AC Mode Processing

Figure 4.64 shows a timing diagram for the ac mode of operation. On the rising edge of IN101R, the pickup timer starts timing (points marked 1 in *Figure 4.64*). If IN101R deasserts (points marked 2 in *Figure 4.64*) before expiration of the pickup time setting, Relay Word bit IN101 does not assert, and remains at logical 0. If, however, IN101R remains asserted for a period longer than the pickup timer setting, then Relay Word bit IN101 asserts to a logical 1.

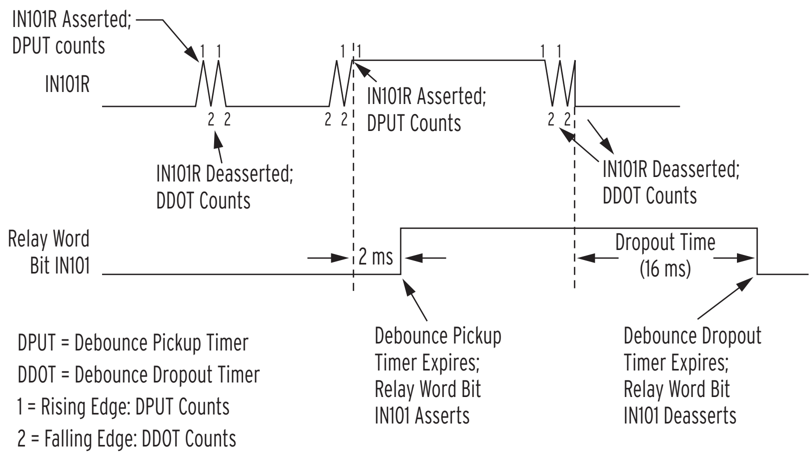


Figure 4.64 Timing Diagram for Debounce Timer Operation When Operating in AC Mode

Deassertion follows the same logic. On the falling edge of IN101R, the dropout timer starts timing. If IN101R remains deasserted for a period longer than the dropout timer setting, then Relay Word bit IN101 deasserts to a logical 0.

Table 4.42 shows the settings prompt, setting range, and factory-default settings for a card in Slot C. See the *SEL-787 Settings Sheets* for a complete list of input debounce settings.

Table 4.42 Slot C Input Debounce Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
IN301 Debounce	AC, 0–65000 ms	IN301D := 10
IN302 Debounce	AC, 0–65000 ms	IN302D := 10
IN303 Debounce	AC, 0–65000 ms	IN303D := 10
IN304 Debounce	AC, 0–65000 ms	IN304D := 10
IN305 Debounce	AC, 0–65000 ms	IN305D := 10
IN306 Debounce	AC, 0–65000 ms	IN306D := 10
IN307 Debounce	AC, 0–65000 ms	IN307D := 10
IN308 Debounce	AC, 0–65000 ms	IN308D := 10

Data Reset

Table 4.43 Data Reset Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
RESET TARGETS	SELogic	RSTTRGT := 0
RESET ENERGY	SELogic	RSTENRGY := 0
RESET MAX/MIN	SELogic	RSTMXMN := 0
RESET DEMAND	SELogic	RSTDEM := 0
RESET PK DEMAND	SELogic	RSTPKDEM := 0

The RSTTRGT setting resets the trip output and front-panel **TRIP** LED, provided there is no trip condition present. See *Figure 4.47* for more details. The RSTENRGY and RSTMXMN settings reset the Energy and Max/Min Metering values respectively. You should assign a contact input (for example, RSTTRGT := IN401) to each of these settings if you want remote reset. The

RSTDEM and RSTPKDEM settings reset demand and peak-demand. See *Figure 4.44* for the demand current logic diagram.

Access Control

NOTE: DISABLSET does not disable the setting changes from the serial ports.

The DSABLSET setting defines conditions for disabling all setting changes from the front-panel interface. To disable setting changes from the front-panel interface, assign, for example, a contact input (e.g., DSABLSET := IN402) to the DSABLSET setting. When Relay Word bit DSABLSET asserts, you can view the device settings from the front-panel interface, but you can only change settings using serial port commands. *Table 4.44* shows the settings prompt, setting range, and factory-default settings.

The BLOCK MODBUS SET setting is used to block relay settings changes via Modbus or DeviceNet protocols. The factory-default setting, BLKMBSET := NONE, allows all setting changes via Modbus or DeviceNet communications. The BLKMBSET := R_S setting prevents Modbus or DeviceNet communications from resetting to the factory-default settings. The BLKMBSET := ALL setting blocks all changes to the settings via the Modbus or the DeviceNet protocol.

Table 4.44 Setting Change Disable Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
DISABLE SETTINGS	SELOGIC	DSABLSET := 0
BLOCK MODBUS SET	NONE, R_S, ALL	BLKMBSET := NONE

Time-Synchronization Source

The SEL-787 accepts a demodulated IRIG-B time signal. *Table 4.45* shows the setting to identify the input for the signal. Set TIME_SRC := IRIG1 when you use relay terminals B01/B02 or EIA-232 serial Port 3 for the time signal input. When you use fiber-optic Port 2 for the signal, set the TIME_SRC := IRIG2. Refer to *IRIG-B Time-Code Input on page 2.20* and *IRIG-B on page 7.5* for additional information.

Table 4.45 Time-Synchronization Source Setting

Setting Prompt	Setting Range	Setting Name := Factory Default
IRIG TIME SOURCE	IRIG1, IRIG2	TIME_SRC := IRIG1

Port Settings (SET P Command)

The SEL-787 provides settings that allow you to configure the parameters for the communications ports. See *Section 2: Installation* for a detailed description of port connections. On the base unit: **Port F** (front panel) is an EIA-232 port; **Port 1** is an optional Ethernet port(s); **Port 2** is a fiber-optic serial port; and **Port 3** (rear) is optionally an EIA-232 or EIA-485 port. On the optional communications card, you can select **Port 4** as either EIA-485 or EIA-232 (not both) with the COMMINF setting. See *Table 4.46* through *Table 4.51* for the serial port settings. See the appropriate appendix for additional information on communication protocols (DNP, Modbus, IEC 61850, DeviceNet, Synchrophasors, and MIRRORED BITS).

The EPORT setting provides you with access control for the corresponding port. Setting EPORT := N disables the port and hides the remaining port settings.

PORT F

Table 4.46 Front-Panel Serial Port Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, MOD, EVMSG, PMU	PROTO := SEL
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
HDWR HANDSHAKING	Y, N	RTSCTS := N
PORT TIME-OUT	0–30 min	T_OUT := 5
SEND AUTOMESSAGE	Y, N	AUTO := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

PORT 1

Table 4.47 Ethernet Port[a] Settings (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
IP ADDRESS	zzz.yyy.xxx.www	IPADDR := 192.168.1.2
SUBNET MASK	15 characters	SUBNETM := 255.255.255.0
DEFAULT ROUTER	15 characters	DEFRTR := 192.168.1.1
Enable TCP Keep-Alive	Y, N	ETCPKA := Y
TCP Keep-Alive Idle Range	1–20 sec	KAIDLE := 10
TCP Keep-Alive Interval Range	1–20 sec	KAINTV := 1
TCP Keep-Alive Count Range	1–20 sec	KACNT := 6
FAST OP MESSAGES	Y, N	FASTOP := N
OPERATING MODE	FIXED, FAILOVER, SWITCHED	NETMODE := FAILOVER
FAILOVER TIMEOUT	0.10–65.00 sec	FTIME := 1.00
PRIMARY NETPORT	A, B, D	NETPORT := A
NETWRK PORTA SPD	AUTO, 10, 100 Mbps	NETASPD := AUTO
NETWRK PORTB SPD	AUTO, 10, 100 Mbps	NETBSPD := AUTO
ENABLE TELNET	Y, N	ETELNET := Y
TELNET PORT	23, 1025–65534	TPORT := 23
TELNET TIME OUT	1–30 min	TIDLE := 15
ENABLE FTP	Y, N	EFTPSERV := Y
FTP USER NAME	20 characters	FTPUSER := FTPUSER
Enable IEC 61850 Protocol	Y, N	E61850 := N
Enable IEC 61850 GSE	Y, N	EGSE := N
Enable DNP Sessions[b]	0–3	EDNP := 0
Enable Modbus Sessions	0–2	EMOD := 0
MODBUS TCP PORT 1	(1–65534)	MODNUM1 := 502

IMPORTANT: Upon relay initial power up or Port 1 setting changes or Logic setting changes, the user may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled, as soon as the ENABLED LED comes ON (about 5–10 seconds from power up).

Table 4.47 Ethernet Port[a] Settings (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
MODBUS TCP PORT 2	(1–65534)	MODNUM2 := 502
Modbus Timeout 1	(15–900 sec)	MTIMEO1 := 15
Modbus Timeout 2	(15–900 sec)	MTIMEO2 := 15

[a] The SEL-787 Port 1 (Ethernet Port) supports SNTP Client protocol. See Section 7: Communications, Simple Network Time Protocol (SNTP) for the description and Table 7.4 for the settings.
[b] See Table D.7 for a complete list of the DNP3 session settings.

Port Number Settings Must be Unique

When making the SEL-787 Port 1 settings, port number settings cannot be used for more than one protocol. The relay checks all of the settings shown in *Table 4.48* before saving changes. If a port number is used more than once, or if it matches any of the fixed port numbers (20, 21, 23, 102, 502), the relay displays an error message and returns to the first setting that is in error or contains a duplicate value.

Table 4.48 Port Number Settings That Must be Unique

Setting	Name	Setting Required When
TPORT	Telnet Port	Always
MODNUM1[a]	Modbus TCP Port 1	EMOD > 0
MODNUM2[a]	Modbus TCP Port 2	EMOD > 1
DNPNUM	DNPTCP and UDP Port	EDNP > 0
SNTPPORT	SNTPIP (Local) Port Number	ESNTP ≠ OFF

[a] MODNUM1 and MODNUM2 can have the same port number. The relay displays an error message if this number matches with the port numbers of the other protocols.

PORT 2

NOTE: For additional settings when PROTO := MBxx, see Table H.5 as well as MIRRORED BITS Transmit SELOGIC Equations on page SET.25. For additional settings when PROTO := DNP, see Table D.7 for a complete list of the DNP3 session settings.

Table 4.49 Fiber-Optic Serial Port Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, DNP, MOD, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB	PROTO := SEL
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
PORT TIME-OUT	0–30 min	T_OUT := 5
SEND AUTOMESSAGE	Y, N	AUTO := N
FAST OP MESSAGES	Y, N	FASTOP := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

PORT 3

NOTE: For additional settings when PROTO := MBxx, see Table H.5 as well as MIRRORED BITS Transmit SELOGIC Equations on page SET.25. For additional settings when PROTO := DNP, see Table D.7 for a complete list of the DNP3 session settings.

Table 4.50 Rear-Panel Serial Port Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, DNP, MOD, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB	PROTO := SEL
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
PORT TIMEOUT	0–30 min	T_OUT := 5
SEND AUTOMESSAGE	Y, N	AUTO := N
HDWR HANDSHAKING	Y, N	RTSCTS := N
FAST OP MESSAGES	Y, N	FASTOP := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

PORT 4

NOTE: For additional settings when PROTO := MBxx, see Table H.5 as well as MIRRORED BITS Transmit SELOGIC Equations on page SET.25.For additional settings when PROTO := DNP, see Table D.7 for a complete list of the DNP3 session settings.

Table 4.51 Rear-Panel Serial Port (EIA-232/EIA-485) Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
ENABLE PORT	Y, N	EPORT := Y
PROTOCOL	SEL, MOD, DNET, DNP, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB	PROTO := SEL
COMM INTERFACE	232, 485	COMMINF := 232
SPEED	300–38400 bps	SPEED := 9600
DATA BITS	7, 8 bits	BITS := 8
PARITY	O, E, N	PARITY := N
STOP BITS	1, 2 bits	STOP := 1
PORT TIMEOUT	0–30 min	T_OUT := 5
SEND AUTOMESSAGE	Y, N	AUTO := N
HDWR HANDSHAKING	Y, N	RTSCTS := N
FAST OP MESSAGES	Y, N	FASTOP := N
MODBUS SLAVE ID	1–247	SLAVEID := 1

Set the speed, data bits, parity, and stop bits settings to match the serial port configuration of the equipment that is communicating with the serial port.

After Port Timeout minutes of inactivity on a serial port at Access Level 2, the port automatically returns to Access Level 0. This security feature helps prevent unauthorized access to the relay settings if the relay is accidentally left in Access Level 2. If you do not want the port to time out, set Port Timeout equal to 0 minutes.

Set PROTO := SEL (standard SEL ASCII protocol), MOD (Modbus RTU protocol), or one of the MIRRORED BITS protocols, as needed for your application. For detailed information, refer to *Appendix C: SEL Communications Processors*, *Appendix E: Modbus Communications*, and *Appendix H: MIRRORED BITS Communications*.

Use the MBT option if you are using a Pulsar MBT9600 bps modem (see *Appendix H: MIRRORED BITS Communications* for more information). With this option set, the relay transmits a message every second processing interval and the device deasserts the RTS signal on the EIA-232 connector. Also, the device monitors the CTS signal on the EIA-232 connector, which the modem deasserts if the channel has too many errors. The modem uses the device RTS signal to determine whether the MB or MB8 MIRRORED BITS protocol is in use.

Set the AUTO := Y to allow automatic messages at a serial port.

The relay EIA-232 serial ports support software (XON/XOFF) flow control. If you want to enable support for hardware (RTS/CTS) flow control, set the RTSCTS setting equal to Y.

Set FASTOP := Y to enable binary Fast Operate messages at the serial port. Set FASTOP := N to block binary Fast Operate messages. Refer to *Appendix C: SEL Communications Processors* for the description of the SEL-787 Fast Operate commands.

Set PROTO := DNET to establish communications when the DeviceNet card is used. *Table 4.52* shows the additional settings, which can be set only at the rear on the DeviceNet card. Once the relay detects the DeviceNet card, all **Port 4** settings are hidden. Refer to *Appendix G: DeviceNet Communications* for details on DeviceNet.

Table 4.52 Rear-Panel DeviceNet Port Settings

Setting Name	Setting Range
MAC_ID	0–63
ASA	8 Hex characters assigned by factory
DN_Rate	125, 250, 500 kbps

Front-Panel Settings (SET F Command)

General Settings

Local bits provide control from the front panel (local bits), and display points display selected information on the LCD display. However, you need to first enable the appropriate number of local bits and display points necessary for your application. When your SEL-787 arrives, four display points are already enabled, but no local bits are enabled. If more display points are necessary for your application, use the EDP setting to enable as many as 32 display points. Use the ELB setting to enable as many as 32 local bits.

Table 4.53 Display Point and Local Bit Default Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
DISPLAY PTS ENABL	N, 1–32	EDP := 4
LOCAL BITS ENABL	N, 1–32	ELB := N

To optimize the time you spend on setting the device, only the number of enabled display points and enabled local bits become available for use. Use the front-panel LCD timeout setting (FP_TO) as a security measure. If the display is within an Access Level 2 function when a timeout occurs, such as the device setting entry, the function is automatically terminated (without saving changes) after inactivity for this length of time. After terminating the function, the front-panel display returns to the default display. If you prefer to disable the front-panel timeout function during device testing, set the LCD timeout equal to OFF. Use the front-panel LCD contrast setting (FP_CONT) to adjust the contrast of the liquid crystal display.

Use the front-panel automessage setting FP_AUTO to define displaying of Trip/Warning messages. Set FP_AUTO either to Override or add to the Rotating display when the relay triggers a Trip/Warning message. Set RSTLED := Y to reset the latched LEDs automatically when the breaker or the contactor closes.

Table 4.54 Front-Panel General Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
LCD TIMEOUT	OFF, 1–30 min	FP_TO := 15
LCD CONTRAST	1–8	FP_CONT := 5
FP AUTOMESSAGES	OVERRIDE, ROTATING	FP_AUTO := OVERRIDE
CLOSE RESET LEDS	Y, N	RSTLED := Y

Display Points

NOTE: The rotating display is updated approximately every two seconds.

Use display points to view either the state of internal relay elements (Boolean information) or analog information on the LCD display. Although the LCD screen displays a maximum of 16 characters at a time, you can enter as many as 60 valid characters. Valid characters are 0–9, A–Z, -, /, ", {, }, space. For text exceeding 16 characters, the LCD displays the first 16 characters, then scrolls through the remaining text not initially displayed on the screen.

Table 4.55 LCD Display Point Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
DISPLAY POINT DP01	60 characters	DP01 := RID,"{16}"
DISPLAY POINT DP02	60 characters	DP02 := TID,"{16}"
DISPLAY POINT DP03	60 characters	DP03 := IAVW1MAG, "W1 AVE I {5} A"
DISPLAY POINT DP04	60 characters	DP04 := IAVW2MAG, "W2 AVE I {5} A"
DISPLAY POINT DP05	60 characters	DP05 :=
• • •	• • •	• • •
DISPLAY POINT DP32	60 characters	DP32 :=

Boolean Display Point Entry Composition

Boolean information is the status of Relay Word bits (see *Appendix J: Relay Word Bits*). In general, the legal syntax for Boolean display points consists of the following four fields or strings, separated by commas:

Relay Word Bit Name, “Alias”, “Set String”, “Clear String”.

where:

Name = Relay Word bit name (IN101, for example). All binary quantities occupy one line on the front-panel display (all analog quantities occupy two lines).

Alias = A more descriptive name for the Relay Word bit (such as TRANSFORMER 3), or the analog quantity (such as TEMPERATURE).

Set String = State what should be displayed on the LCD when the Relay Word bit is asserted (CLOSED, for example)

Clear String = State what should be displayed on the LCD when the Relay Word bit is deasserted (OPEN, for example)

Any or all of Alias, Set String, or Clear String can be empty. Although the relay accepts an empty setting Name as valid, a display point with an empty Name setting is always hidden (see below). Commas are significant in identifying and separating the four strings. Use quotation marks only if the text you enter for Alias, Set String, or Clear String contains commas or spaces. For example, DP01 = Name,Text is valid, but Name, Alias 3 is not valid (contains a space). Correct the Alias name by using the quotation marks: Name, "Text 3". You can customize the data display format by entering data in selected strings only. *Table 4.56* shows the various display appearances resulting from entering data in selected strings.

Hidden (No Display)

A display point is hidden when settings are entered (DP*n* = XX, where *n* = 01 through 32 and XX = any valid setting), but nothing shows on the front-panel display. *Table 4.56* shows examples of settings that always, never, or conditionally hide a display point.

Table 4.56 Settings That Always, Never, or Conditionally Hide a Display Point

Programmable Automation Controller Setting	Name	Alias	Set String	Clear String	Comment
DP01 := IN101,TRFR1,CLOSED,OPEN	IN101	TRFR1	CLOSED	OPEN	Never hidden
DP01 := IN101,TRFR1	IN101	TRFR1	—	—	Never hidden
DP01 := NA	—	—	—	—	Always hidden
DP01 := IN101,,,	IN101	—	—	—	Always hidden
DP01 := IN101,TRFR1,,	IN101	TRFR1	—	—	Always hidden
DP01 := IN101,TRFR1,CLOSED,	IN101	TRFR1	CLOSED	—	Hidden when IN101 is deasserted
DP01 := IN101,"TRFR 1",,OPEN	IN101	TRFR 1	—	OPEN	Hidden when IN101 is asserted

Following are examples of selected display point settings, showing the resulting front-panel displays. For example, at a certain station we want to display the status of both HV and LV circuit breakers of Transformer 1. When the HV circuit breaker is open, we want the LCD display to show: `TRFR 1 HV BRKR: OPEN`, and when the HV circuit breaker is closed, we want the display to show: `TRFR 1 HV BRKR: CLOSED`. We also want similar displays for the LV breaker.

After connecting a form a (normally open) auxiliary contact from the HV circuit breaker to Input **IN101** and a similar contact from the LV circuit breaker to Input **IN102** of the SEL-787, we are ready to program the display points, using the following information for the HV breaker (LV breaker similar):

- ➤ Relay Word bit—IN101
- ➤ Alias—TRFR 1 HV BRKR:
- ➤ Set String—CLOSED (the form a [normally open] contact asserts or sets Relay Word bit IN101 when the circuit breaker is closed)
- ➤ Clear String—OPEN (the form a [normally open] contact deasserts or clears Relay Word bit IN101 when the circuit breaker is open)

Name, Alias, Set String, and Clear String

When all four strings have entries, the relay reports all states.

Table 4.57 Entries for the Four Strings

Name	Alias	Set String	Clear String
IN101	TRFR 1 HV BRKR	CLOSED	OPEN

Figure 4.65 shows the settings for the example, using the **SET F** command. Use the **>** character to move to the next settings category.

```
=>>SET F TERSE <Enter>
Front Panel
General Settings
DISPLY PTS ENABL (N,1-32)                    EDP     := 4        ? > <Enter>
.
.
.
Target LED Set
TRIP LATCH T_LED (Y,N)                       T01LEDL := Y        ? > <Enter>
Display Point Settings (maximum 60 characters):
(Boolean): Relay Word Bit Name, "Alias", "Set String", "Clear String"
(Analog) : Analog Quantity Name, "User Text and Formatting"
DISPLAY POINT DP01 (60 characters)
DP01    := RID,"{16}"
? IN101,"TRFR 1 HV BRKR:",CLOSED,OPEN <Enter>
DISPLAY POINT DP02 (60 characters)
DP02    := TID,"{16}"
? IN102,"TRFR 1 LV BRKR:",CLOSED,OPEN <Enter>
DISPLAY POINT DP03 (60 characters)
DP03    := IAV, "IAV CURR {5} A"
? END <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.65 Display Point Settings

Figure 4.66 shows the display when both HV and LV breakers are open (both IN101 and IN102 deasserted). *Figure 4.67* shows the display when the HV breaker is closed, and the LV breaker is open (IN101 asserted, but IN102 still deasserted).

Figure 4.66 Front-Panel Display—Both HV and LV Breakers Open

Figure 4.67 Front-Panel Display—HV Breaker Closed, LV Breaker Open

Name String, Alias String, and Either Set String or Clear String Only

The following discusses omission of the Clear String; omission of the Set String gives similar results. Omitting the Clear String causes the relay to only show display points in the set state, using the **SET F** command as follows:

```
DP01    := RID, “{16}”
 ? IN101,"TRFR 1 HV BRKR:",CLOSED <Enter>
```

When the Relay Word bit IN101 deasserts, the relay removes the complete line with the omitted Clear String (TRFR 1 HV BRKR). When both breakers are closed, the relay has the set state information for both HV and LV breakers, and the relay displays the information as shown in *Figure 4.68*. When the HV breaker opens (LV breaker is still closed), the relay removes the line containing the HV breaker information because the Clear String information was omitted. Because the line containing the HV breaker information is removed, the relay now displays the LV breaker information on the top line, as shown in *Figure 4.69*.

Figure 4.68 Front-Panel Display—Both HV and LV Breakers Closed

Figure 4.69 Front-Panel Display—HV Breaker Open, LV Breaker Closed

If you want the relay to display a blank state when IN101 deasserts instead of removing the line altogether, use the curly brackets { } for the Clear String, as follows:

```
DP01    := RID, “{16}”
 ? IN101,"TRFR 1 HV BRKR:",CLOSED,{} <Enter>
```

When Input IN101 now deasserts, the relay still displays the line with the HV breaker information, but the state is left blank, as shown in *Figure 4.70*.

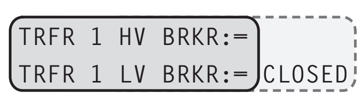


Figure 4.70 Front-Panel Display—HV Breaker Open, LV Breaker Closed

Name Only

Table 4.58 shows an entry in the Name String only (leaving the Alias string, Set String, and Clear String void), using the **SET F** command as follows:

```
DP01    := RID, “{16}”
 ? IN101 <Enter>
```

Table 4.58 Binary Entry in the Name String Only

Name	Alias	Set String	Clear String
IN101	—	—	—

Figure 4.71 shows the front-panel display for the entry in *Table 4.58*. Input IN101 is deasserted in this display (`IN101=0`), but changes to `IN101=1` when Input IN101 asserts.

```
IN101=0
```

Figure 4.71 Front-Panel Display for a Binary Entry in the Name String Only

Analog Display Point Entry Composition

In general, the legal syntax for analog display points consists of the following two fields or strings:

Name, "User Text and Formatting."

where:

Name	=	Analog quantity name (AI301 for example). All analog quantities occupy two lines on the front-panel display (all binary quantities occupy one line on the display).
User text and numerical formatting	=	Display the user text, replacing the numerical formatting {width.dec,scale} with the value of Name, scaled by "scale", formatted with total width "width" and "dec" decimal places. Name can be either an analog quantity or a Relay Word bit. The width value includes the decimal point and sign character, if applicable. The "scale" value is optional; if omitted, the scale factor is 1. If the numeric value is smaller than the string size requested, the string is padded with spaces to the left of the number. If the numeric value does not fit within the string width given, the string grows (to the left of the decimal point) to accommodate the number.

Unlike binary quantities, the relay displays analog quantities on both display lines. *Table 4.59* shows an entry in the Name string only (leaving the User Text and Formatting string void) with the following syntax:

Table 4.59 Analog Entry in the Name String Only

Name	Alias	Set String	Clear String
AI301	—	—	—

Figure 4.72 shows the front-panel display for the entry in *Table 4.59*, using the **SET F** command as follows:

```
DP01    := RID, "{16}"
 ? AI301 <Enter>
```

Figure 4.72 Front-Panel Display for an Analog Entry in the Name String Only

Name and Alias

For a more descriptive name of the Relay Word bit, enter the Relay Word bit in the Name String, and an alias name in User Text and Formatting String. *Table 4.60* shows a Boolean entry in the Name and Alias Strings (DP01) and an entry in the Name and User Text and Formatting Strings (DP02), using the **SET F** command as follows:

```
DP01    := RID, “{16}”
 ? IN101,"INPUT IN101:" <Enter>
DP02    := TID, “{16}”
 ? AI301,TEMPERATURE: <Enter>
```

Table 4.60 Entry in the Name String and the Alias Strings

Name	Alias	Set String	Clear String
IN101	INPUT IN101	—	—
AI301	TEMPERATURE	—	—

Figure 4.73 shows the front-panel display for the entry in *Table 4.60*. Input IN101 is deasserted in this display (0), and the display changes to `INPUT IN101=1` when Input IN101 asserts.

Figure 4.73 Front-Panel Display for an Entry in (a) Boolean Name and Alias Strings and (b) Analog Name and User Text and Formatting Strings

If the engineering units are set, then the front-panel display shows the engineering units. For example, in the Group setting example, we set AI301EU to degrees C. With this setting, the front-panel display looks as shown in *Figure 4.74*.

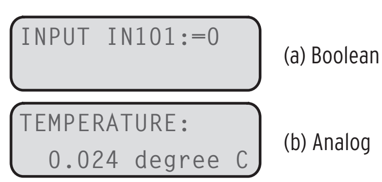


Figure 4.74 Front-Panel Display for an Entry in (a) Boolean Name and Alias Strings and (b) Analog Name, User Text and Formatting Strings, and Engineering Units

For fixed text, enter a 1 in the Name String, then enter the fixed text as the alias text. For example, to display the word DEFAULT and SETTINGS on two different lines, use a display point for each word, i.e., DP01 = 1,“DEFAULT” and DP02 = 1,“SETTINGS.” *Table 4.61* shows other options and front-panel displays for the User Text and Formatting settings.

Table 4.61 Example Settings and Displays

Example Display Point Setting Value	Example Display
AI301,"TEMP {4}deg C"	TEMP 1234 deg C
AI301,"TEMP = {4.1}"	TEMP = xx.x
AI301,"TEMP = {5}"	TEMP = 1230
AI301,"TEMP={4.2,0.001} C"	TEMP = 1.23 C
AI301,"TEMP HV HS1={4,1000}"	TEMP HV HS1 = 1234
1,{}	Empty line
1,"Fixed Text"	Fixed text
0	Hides the display point

Following is an example of an application of analog settings. Assume we also want to know the hot-spot temperature, oil temperature, and winding temperature of the transformer at a certain installation. To measure these temperatures, we have installed an analog card in relay Slot **C**, and connected 4–20 mA transducers inputs to analog inputs AI301 (hot-spot temperature), AI302 (oil temperature), and AI303 (winding temperature).

First enable enough display points for the analog measurements (e.g. EDP = 5). *Figure 4.75* shows the settings to add the three transducer measurements. (Use the **>** character to move to the next settings category).

```
=>>SET F TERSE <Enter>
Front Panel
General Settings
DISPLY PTS ENABL (N,1-32)                        EDP     := 4        ? 5 <Enter>
LOCAL BITS ENABL (N,1-32)                        ELB     := 1        ? > <Enter>
.
.
.
Target LED Set
TRIP LATCH T_LED (Y,N)                           T01LEDL := Y        ? > <Enter>
Display Point Settings (maximum 60 characters):
(Boolean): Relay Word Bit Name, "Alias", "Set String", "Clear String"
(Analog) : Analog Quantity Name, "User Text and Formatting"
DISPLAY POINT DP01 (60 characters)
DP01    := IN101,"TRFR 1 HV BRKR:",CLOSED,OPEN
? <Enter>
DISPLAY POINT DP02 (60 characters)
DP02    := IN102,"TRFR 1 LV BRKR:",CLOSED,OPEN
? <Enter>
DISPLAY POINT DP03 (60 characters)
DP03    := IAV, "IAV CURR {5} A"
? AI301,"HOT SPOT TEMP" <Enter>
DISPLAY POINT DP04 (60 characters)
DP04    := IG_MAG, "GND CURR {5} %"
? AI302,"OIL TEMPERATURE" <Enter>
DISPLAY POINT DP05 (60 characters)
DP05    := IA_MAG, "IA {7.1} A pri"
? AI303,"WINDING TEMP" <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.75 Adding Temperature Measurement Display Points

Rotating Display

With more than two display points enabled, the relay scrolls through all enabled display points, thereby forming a rotating display, as shown in *Figure 4.76*.

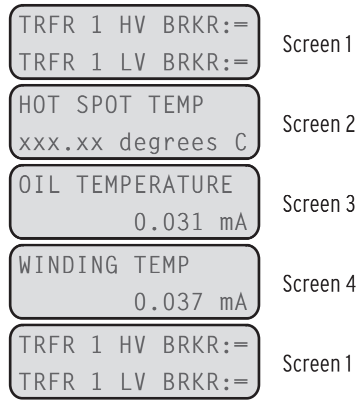


Figure 4.76 Rotating Display

To change the temperature units to more descriptive engineering units, enter the desired units with the AI*xxx*EU (e.g., AI302EU) setting.

Local Bits

Local bits are variables (LB*nn*, where *nn* means 01 through 32) that are controlled from front-panel pushbuttons. Use local bits to replace traditional panel switches. The state of the local bits is stored in nonvolatile memory every second. When power to the device is restored, the local bits will go back to their states after the device initialization.

Each local bit requires three of the following four settings, using a maximum of 14 valid characters for the NLB*nn* setting, and a maximum seven valid characters (0–9, A–Z, -, /, ., space) for the remainder:

- NLB*nn*: Name the switch (normally the function that the switch performs, such as SUPERV SW) that will appear on the LCD display.
- CLB*nn*: Clear local bit. Enter the text that describes the intended operation of the switch (this text appears on the display) when LB*nn* deasserts (OPEN, for example).
- SLB*nn*: Set local bit. Enter the text that describes the intended operation of the switch (this text appears on the display) when LB*nn* asserts (CLOSE, for example).
- PLB*nn*: Pulse local bit. When selecting the pulse operation, LB*nn* asserts for only one processing interval before deasserting again. Enter the text that describes the intended operation when LB*nn* asserts (START, for example).
- Omit either SLB*nn* or PLB*nn* (never CLB*nn*) by setting the omitted setting to NA.

For the transformer in our example, configure two local bits: one to replace a supervisory switch, and the other to start a fan motor. Local bit 1 replaces a supervisory switch (SUPERV SW) and we use the clear/set combination. Local bit 2 starts a fan motor (START) that only needs a short pulse to seal itself in, and we use the clear/pulse combination. *Figure 4.77* shows the settings to program the two local bits.

```
=>>SET F TERSE <Enter>
Front Panel
General Settings
DISPLY PTS ENABL (N,1-32)                     EDP     := 5        ? <Enter>
LOCAL BITS ENABL (N,1-32)                     ELB     := N        ? 2 <Enter>
LCD TIMEOUT (OFF,1-30 min)                    FP_TO   := 15       ? > <Enter>
  .
  .
  .
Target LED Set
TRIP LATCH T_LED (Y,N)                        T01LEDL := Y        ? > <Enter>
Display Point Settings (maximum 60 characters):
(Boolean): Relay Word Bit Name, "Alias", "Set String", "Clear String"
(Analog) : Analog Quantity Name, "User Text and Formatting"
DISPLAY POINT DP01 (60 characters)
DP01    := IN101,"TRFR 1 HV BRKR:",CLOSED,OPEN
? > <Enter>
Local Bits Labels:
LB_ NAME (14 characters; Enter NA to null)
NLB01   :=
? SPERV SW <Enter>
CLEAR LB_ LABEL (7 characters; Enter NA to null)
CLB01   :=
? OPEN <Enter>
SET LB_ LABEL (7 characters; Enter NA to null)
SLB01   :=
? CLOSE <Enter>
PULSE LB_ LABEL (7 characters; Enter NA to null)
PLB01   :=
? NA <Enter>
LB_ NAME (14 characters; Enter NA to null)
NLB02   :=
? FAN START <Enter>
CLEAR LB_ LABEL (7 characters; Enter NA to null)
CLB02   :=
? OFF <Enter>
SET LB_ LABEL (7 characters; Enter NA to null)
SLB02   :=
? NA <Enter>

PULSE LB_ LABEL (7 characters; Enter NA to null)
PLB02   :=
? START <Enter>
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Figure 4.77 Adding Two Local Bits

Target LED Settings

The SEL-787 offers the following two types of LEDs. See *Figure 8.1* and *Figure 8.25* for the programmable LED locations:

➤ Six Target LEDs

➤ Eight Pushbutton LEDs

You can program all 14 LEDs using SELOGIC control equations, the only difference being that the target LEDs also include a latch function.

Target LEDs

NOTE: If the LED latch setting (TnLEDL) is set to Y, and TRIP asserts, the LED latches to the state at TRIP assertion. The latched LED targets can be reset with TARGET RESET if the target conditions are absent.

Settings T*n*LEDL (*n* = 01 through 06) and T*n*_LED (*n* = 01 through 06) control the six front-panel LEDs. With T*n*LEDL set to Y, the LEDs latch the LED state at TRIP assertion. To reset these latched LEDs, the trip condition should no longer exist and one of the following must occur:

➤ Pressing **TARGET RESET** on the front panel.

➤ Issuing the serial port command **TAR R**.

➤ The assertion of the SELOGIC equation RSTTRGT.

With T*n*LEDL settings set to N, the LEDs do not latch and directly follow the state of the associated SELOGIC control equation setting.

Enter any of the Relay Word bits (or combinations of Relay Word bits) as conditions in the T*n*_LED SELOGIC control equation settings. When these Relay Word bits assert, the corresponding LED also asserts.

Table 4.62 Target LED Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
TRIP LATCH T_LED	Y, N	T01LEDL := Y
LED1 EQUATION	SELOGIC	T01_LED := 87U OR 87R
TRIP LATCH T_LED	Y, N	T02LEDL := Y
LED2 EQUATION	SELOGIC	T02_LED := ORED50T
TRIP LATCH T_LED	Y, N	T03LEDL := Y
LED3 EQUATION	SELOGIC	T03_LED := ORED51T
TRIP LATCH T_LED	Y, N	T04LEDL := Y
LED4 EQUATION	SELOGIC	T04_LED := 27P1T OR 27P2T OR 59P1T OR 59P2T OR 59Q1T OR 59Q2T
TRIP LATCH T_LED	Y, N	T05LEDL := Y
LED5 EQUATION	SELOGIC	T05_LED := 81D1T OR 81D2T OR 81D3T OR 81D4T
TRIP LATCH T_LED	Y, N	T06LEDL := Y
LED6 EQUATION	SELOGIC	T06_LED := 24D1T OR 24C2T

Pushbutton LEDs

Enter any of the Relay Word bits (or combinations of Relay Word bits) as conditions in the PB*p*_LED (*p* = 1A, 1B,…4A, 4B) SELOGIC control equation settings. When these Relay Word bits assert, the corresponding LED also asserts. *Table 4.63* shows the setting prompts, settings ranges, and default settings for the LEDs.

Table 4.63 Pushbutton LED Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
PB1A_LED EQUATION	SELOGIC	PB1A_LED := NOT LT01 OR SV01 AND NOT SV01T AND SV05T
PB1B_LED EQUATION	SELOGIC	PB1B_LED := LT01 OR SV01 AND NOT SV01T AND SV05T
PB2A_LED EQUATION	SELOGIC	PB2A_LED := NOT LT02 OR SV02 AND NOT SV02T AND SV05T AND PB02
PB2B_LED EQUATION	SELOGIC	PB2B_LED := LT02 OR SV02 AND NOT SV02T AND SV05T AND PB02
PB3A_LED EQUATION	SELOGIC	PB3A_LED := 52A1 OR (SV03 AND SV05T AND NOT SV03T AND NOT LT02)
PB3B_LED EQUATION	SELOGIC	PB3B_LED := 52A2 OR (SV03 AND SV05T AND NOT SV03T AND LT02)
PB4A_LED EQUATION	SELOGIC	PB4A_LED := NOT 52A1 OR (SV04 AND SV05T AND NOT SV04T AND NOT LT02)
PB4B_LED EQUATION	SELOGIC	PB4B_LED := NOT 52A2 OR (SV04 AND SV05T AND NOT SV04T AND LT02)

Report Settings (SET R Command)

The report settings use Relay Word bits for the SER trigger as shown in *Table 4.65* (see *Appendix J: Relay Word Bits* for more information).

SER Chatter Criteria

The SER includes an automatic deletion and reinsertion function to prevent overfilling of the SER buffer with chattering information. Each processing interval the relay checks the Relay Word bits in the four SER reports for any changes of state. When detecting a change of state, the relay adds a record to the SER report containing the Relay Word bit(s), new state, time stamp, and checksum (see *Section 9: Analyzing Events* for more information).

When detecting oscillating SER items, the relay automatically deletes these oscillating items from SER recording. *Table 4.64* shows the auto-removal settings.

Table 4.64 Auto-Removal Settings

Settings Prompt	Setting Range	Setting Name := Factory Default
Auto-Removal Enable	Y, N	ESERDEL := N
Number of Counts	2–20 counts	SRDLCNT := 5
Removal Time	0.1–90.0 seconds	SRDLTIM := 1.0

To use the automatic deletion and reinsertion function, proceed with the following steps:

Step 1. Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function.

Step 2. Select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element.

Setting SRDLTIM declares a time interval during which the relay qualifies an input by comparing the changes of state of each input against the SRDLCNT setting. When an item changes state more than SRDLCNT times in an SRDLTIM interval, the relay automatically removes these Relay Word bits from SER recording. Once deleted from recording, the item(s) will be ignored for the next nine intervals. At the ninth interval, the chatter criteria will again be checked and, if the point does not exceed the criteria, it will be automatically reinserted into recording at the starting of the tenth interval. The user can enable or disable the auto-deletion function via the SER settings. Any auto-deletion notice entry will be lost during changes of settings. The deleted items can be viewed in the SER Delete Report (Command **SER D**—refer to *Section 7: Communications* for additional information).

SER Trigger Lists

To capture element state changes in the SER report, enter the Relay Word bit into one of the four SER (SER1 through SER4) trigger equations. Each of the four programmable trigger equations allows entry of as many as 24 Relay Word bits separated by spaces or commas; the SER report accepts a total of 96 Relay Word bits. *Table 4.65* shows the settings prompt and default settings for the four SER trigger equations.

Table 4.65 SER[a] Trigger Settings

Setting Prompt	Setting Name := Factory Default
SER1	SER1 := IN101 IN102 PB01 PB02 PB03 PB04 52A1 52A2 TRIP1 TRIP2 TRIPXFMR
SER2	SER2 := ORED51T ORED50T 87U 87R 27P1T 27P2T 59P1T 59P2T 59Q1T 59Q2T 3PWR1T 3PWR2T REF1F 24D1T 24C2T RTDT
SER3	SER3 := 81D1T 81D2T 81D3T 81D4T
SER4	SER4 := SALARM

[a] Use as many as 24 Relay Word elements separated by spaces or commas for each setting.

Relay Word Bit Aliases

Table 4.66 Enable Alias Settings

Setting Prompt	Setting Range	Setting Name = Factory Default
Enable ALIAS Settings (N, 1–20)	N, 1–20	EALIAS = 4

To simplify your review of the information displayed in the SER record, the relay provides the Alias setting function. Using the Alias settings, you can change the way relay elements listed in the SER settings above are displayed in the SER report. In addition, the Alias settings allow you to change the text displayed when a particular element is asserted and deasserted. The relay permits as many as 20 unique aliases, as defined by the Enable Alias Settings (EALIAS) setting. Factory-default alias settings are shown in *Table 4.67*.

Define the enabled alias settings by entering the Relay Word bit name, a space, the desired alias, a space, the text to display when the condition asserts, a space, and the text to display when the condition deasserts.

```
ALIAS1 = PB01 FP_AUX1 PICKUP DROPOUT
```

See *Table J.1* for the complete list of Relay Word bits. Use as many as 15 characters to define the alias, asserted text, and deasserted text strings. You can use capital letters (A–Z), numbers (0–9), and the underscore character (_) within each string. Do not attempt to use a space within a string because the relay will interpret a space as the break between two strings. If you wish to clear a string, simply type **NA**.

Table 4.67 SET R SER Alias Settings

Setting Prompt	Relay Word Bit	Alias	Asserted Text	Deasserted Text
ALIAS1 :=	PB01	FP_LOCK	PICKUP	DROPOUT
ALIAS2 :=	PB02	FP_BRKR_SELECT	PICKUP	DROPOUT
ALIAS3 :=	PB03	FP_CLOSE	PICKUP	DROPOUT
ALIAS4 :=	PB04	FP_TRIP	PICKUP	DROPOUT
ALIAS5–ALIAS20	NA			

Event Report Settings

Table 4.68 Event Report Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
EVENT TRIGGER	SELOGIC	ER := 0
EVENT LENGTH	15, 64 cyc	LER := 15
PREFAULT LENGTH	1–59 cyc	PRE := 5

NOTE: Event report data stored in the relay will be lost when you change the LER setting, You must save the data before changing the setting.

Event reports can be either 15 cycles or 64 cycles in length as determined by the LER setting. For LER of 15, the prefault length, PRE, must be in the range 1–10. The relay can hold at least seventy-seven 15-cycle event reports or nineteen 64-cycle event reports.

Load Profile Settings

Use the LDLIST setting to declare the analog quantities you want included in the Load Profile Report. Enter as many as 17 analog quantities, separated by spaces or commas, into LDLIST setting. See *Appendix K: Analog Quantities* for a list of the available Analog Quantities. Also set the LDAR to the desired acquisition rate for the report.

IMPORTANT: All stored load data are lost when changing the LDLIST.

Table 4.69 Load Profile Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
LDP LIST	NA, as many as 17 analog quantities	LDLIST := NA
LDP ACQ RATE	5, 10, 15, 30, 60 min	LDAR := 15

DNP Map Settings (SET DNP n Command, n = 1, 2, or 3)

Table 4.70 shows the available settings. See *Appendix D: DNP3 Communications* for additional details.

Table 4.70 DNP Map Settings[a] (Sheet 1 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
DNP Binary Input Label Name	10 characters	BI_00 := ENABLED
DNP Binary Input Label Name	10 characters	BI_01 := TRIPXFMR
DNP Binary Input Label Name	10 characters	BI_02 := TRIP1
DNP Binary Input Label Name	10 characters	BI_03 := TRIP2
•	•	•
•	•	•
•	•	•
DNP Binary Input Label Name	10 characters	BI_99 := NA
DNP Binary Output Label Name	10 characters	BO_00 := RB01
•	•	•
•	•	•
•	•	•
DNP Binary Output Label Name	10 characters	BO_31 := RB32

Table 4.70 DNP Map Settings[a] (Sheet 2 of 2)

Setting Prompt	Setting Range	Setting Name := Factory Default
DNP Analog Input Label Name	24 characters	AI_00 := IAW1_MAG
DNP Analog Input Label Name	24 characters	AI_01 := IBW1_MAG
• • •	• • •	• • •
DNP Analog Input Label Name	24 characters	AI_99 := NA
DNP Analog Output Label Name	6 characters	AO_00 := NA
• • •	• • •	• • •
DNP Analog Output Label Name	6 characters	AO_31 := NA
DNP Counter Label Name	11 characters	CO_00 := NA
• • •	• • •	• • •
DNP Counter Label Name	11 characters	CO_31 := NA

[a] See Appendix D: DNP3 Communications for complete list of the DNP Map Labels and factory-default settings.

Modbus Map Settings (SET M Command)

Modbus User Map

Table 4.71 shows the available settings. See *Appendix E: Modbus Communications* for additional details.

Table 4.71 User Map Register Settings[a]

Setting Prompt	Setting Range	Setting Name := Factory Default
USER REG#001	NA, 1 Modbus Register Label	MOD_001 := IAW1_MAG
• • •	• • •	• • •
USER REG#125	NA, 1 Modbus Register Label	MOD_125 := NA

[a] See Appendix E: Modbus Communications for a complete list of the Modbus Register Labels and factory-default settings.

Section 5
Metering and Monitoring

Overview

The SEL-787 Transformer Protection Relay includes metering functions to display the present values of current, voltage (if included), analog inputs (if included), and RTD measurements (with the external SEL-2600 RTD Module or an internal RTD card).

The relay provides the following methods to read the present meter values:

- ➤ Front-panel rotating display
- ➤ Front-panel menu
- ➤ EIA-232 serial ports (using SEL ASCII text commands or ACSELERATOR QuickSet SEL-5030 Software)
- ➤ Telnet via Ethernet port
- ➤ Modbus via EIA-485 port or EIA-232 port
- ➤ Modbus TCP via Ethernet port
- ➤ DNP3 Serial via EIA-232 port or EIA-485 port
- ➤ DNP3 LAN/WAN via Ethernet port
- ➤ DeviceNet port
- ➤ Analog outputs
- ➤ IEC 61850 via Ethernet port
- ➤ C37.118 Synchrophasor Protocol via serial port

Load monitoring and trending are possible using the Load Profile function. The relay automatically configures itself to save as many as 17 quantities (selected from the Analog Quantities) every 5, 10, 15, 30, or 60 minutes. The data are stored in nonvolatile memory. As many as 6500 time samples are stored.

The SEL-787 has a through-fault event monitoring function that gathers current level, duration and date/time for each through fault experienced by the transformer. The function calculates and tracks accumulated I^2t through fault and alarms excess I^2t over time. This monitor function can be used to schedule proactive transformer bank maintenance.

Power Measurement Conventions

The SEL-787 uses the IEEE convention for power measurement. The implications of this convention are depicted in *Figure 5.1*.

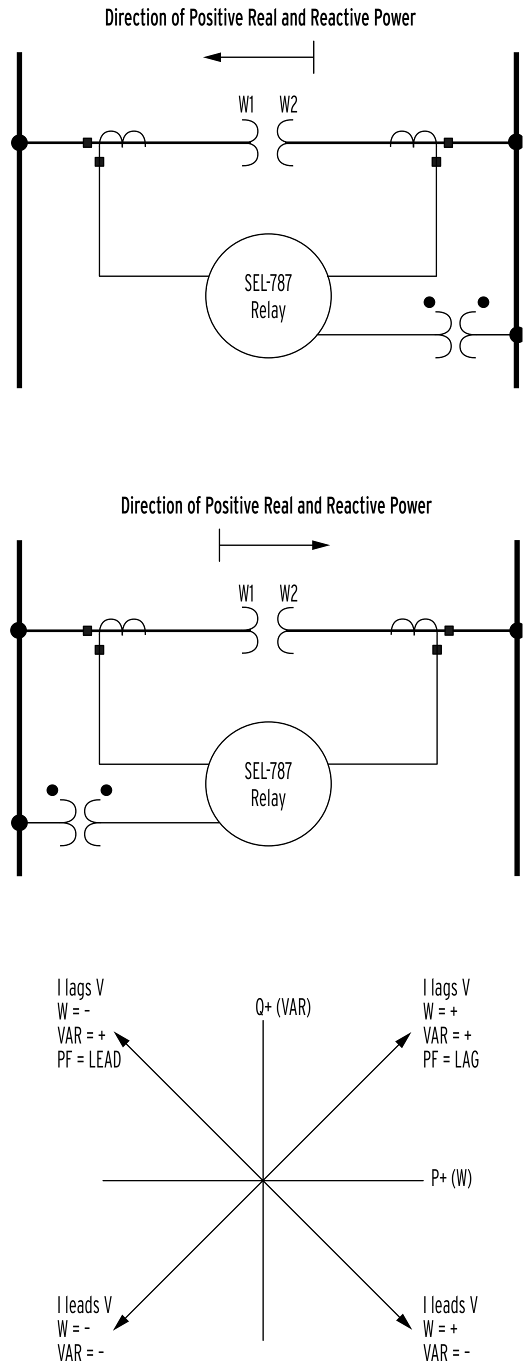


Figure 5.1 Complex Power Measurement Conventions

Delta-Connected CTs

The relay displays currents, voltages, and power in primary values as part of most metering and monitoring reports. If the winding phase CTs are wye connected, the relay can accurately derive the primary currents from the secondary values through multiplying them by the corresponding CT ratio.

Delta-connected CTs, in general, remove zero-sequence current and introduce a phase shift. They also increase magnitude by $\sqrt{3}$ under balanced system conditions and as high as two times under unbalanced conditions. As a result, the relay cannot derive the primary current/quantities accurately. The relay performs the following under all system conditions in the case of delta-connected CTs. The primary currents displayed are derived from the secondary values through multiplying them by the corresponding CT ratio and dividing them by $\sqrt{3}$. The phase angles are not compensated and reflect the same values as measured on the secondary.

Metering

The SEL-787 meter data fall into the following categories:

- Fundamental metering
- Differential metering
- Thermal metering: RTD metering (with the external SEL-2600 RTD Module or an internal RTD option)
- Energy metering
- Maximum and minimum metering
- Math variable metering (analog quantities metering)
- RMS metering
- Analog transducer input metering
- Demand and peak demand metering
- Harmonic metering
- Synchrophasor metering

Fundamental Metering

Table 5.1 details each of the fundamental meter data types in the SEL-787. *Section 8: Front-Panel Operations* and *Section 7: Communications* describe how to access the various types of meter data using the relay front panel and communications ports.

If the winding phase CTs are delta connected, the primary currents displayed are derived from the secondary values by multiplying them with CTR (CT ratio) and dividing them by the square root of 3. The phase angles shown are the same as the secondary values. If the CT connection type is known (DAB or DAC), the user can correct the phase angles. The MET response is meant to show steady-state primary values. During unbalanced conditions the primary line currents cannot be reproduced accurately because the delta-connected CTs filter out the zero-sequence component of the line current. Wye-connected CTs do not have any such issue.

Table 5.1 Measured Fundamental Meter Values

Relay Option	Meter Values
All Models	Line Currents: IAW1, IBW1, ICW1 and IAW2, IBW2, ICW2 magnitudes (A primary) and phase angles (deg) IGW1, IGW2 (Residual Ground Fault Current) magnitude (A primary) and phase angle (deg) for Winding 1 and 2 IAVW1, IAVW2 (Average Current Magnitude for Winding 1 and 2) (A primary) Negative-Sequence Currents (3I2W1 and 3I2W2) (A primary)
With Neutral Current Option (REF)	IN magnitude (A primary) phase angle (deg)
With Voltage Option	VAB, VBC, VCA or VAN, VBN, VCN, VG magnitudes (V primary) and phase angles (deg) Average Voltage (L-L or L-N) (V primary) Negative-Sequence (3V2) (V primary) Real Power (kW) Reactive Power (kVAR) Apparent Power (kVA) Power Factor Volts/Hertz (%), System frequency (Hz)

All angles are displayed between –180 and +180 degrees. The angles are referenced to VAB or VAN (for delta- or wye-connected PT, respectively) or IAW1. If the voltage channels are not supported, or if VAB < 13 V (for delta-connected PT) or VAN < 13 V (for wye-connected PT), the angles are referenced to IAW1 current. *Figure 5.2* shows an example of the **METER** command report.

NOTE: Calculated phase-to-phase voltages for wye-connected PTs are available in the analog quantities and can be selected as display points. See Appendix K: Analog Quantities.

```
=>>MET <Enter>

SEL-787                                    Date: 01/23/2008   Time: 13:46:49
TRNSFRMR RELAY                             Time Source: Internal

                    IAW1     IBW1     ICW1     IGW1     3I2W1    IAVW1
Wdg1 Mag (A pri.)    118.4    122.5    120.6      4.1      3.1    120.5
Wdg1 Angle (deg)      -2.4   -122.3    117.9   -151.2    154.3      0.0

                    IAW2     IBW2     ICW2     IGW2     3I2W2    IAVW2
Wdg2 Mag (A pri.)   2357.6   2457.8   2402.2     97.3     76.8   2405.9
Wdg2 Angle (deg)      -2.2   -122.3    118.0   -150.4    141.9      0.0

                        IN
Neutral Mag (A pri.)    147.0
Neutral Angle (deg)      -1.0

                     VA       VB       VC       VG       3V2     VAVE
Volt Mag (V pri.)  12094.5  12268.1  11894.3   1037.3    752.4  12085.6
Volt Angle (deg)       0.0   -120.0    124.0   -131.9     -5.6      0.0

Real Power (kW)             87032
Reactive Power (kVAR)        5360
Apparent Power (kVA)        87197
Power Factor (LAG)              1.00

Frequency (Hz)   60.0
V/Hz (%)        153.9

=>>
```

Figure 5.2 METER Command Report With Voltage Option

Differential Metering

The differential metering function in the SEL-787 reports the fundamental frequency operate and restraint currents for each differential element (87) in multiples of TAP. *Table 5.2* shows the value reported. *Figure 5.3* shows an example of the **METER DIF** (differential) command report.

Table 5.2 Measured Differential Meter Values

Relay Option	Differential Values
All	Operate currents IOP1, IOP2, IOP3 in pu of TAP value for elements 87-1, 87-2, and 87-3, respectively Restraint currents IRT1, IRT2, IRT3 in pu of TAP value for elements 87-1, 87-2, and 87-3, respectively IOP1F2, IOP2F2, and IOP3F2 are 2nd harmonic currents as a percentage of IOP1, IOP2, and IOP3, respectively. IOP1F4, IOP2F4, IOP3F4 are 4th harmonic currents as a percentage of IOP1, IOP2, and IOP3, respectively. IOP1F5, IOP2F5, and IOP3F5 are 5th harmonic currents as a percentage of IOP1, IOP2, and IOP3, respectively.

```
=>>MET DIF <Enter>

SEL-787                                 Date: 01/23/2008   Time: 13:44:35
TRNSFRMR RELAY                          Time Source: Internal

                        IOP1     IOP2     IOP3
Operate      (pu)       0.59     0.62     0.60

                        IRT1     IRT2     IRT3
Restraint    (pu)       0.29     0.31     0.30

                      IOP1F2   IOP2F2   IOP3F2
2nd Harmonic (%)        0.33     0.16     0.16

                      IOP1F4   IOP2F4   IOP3F4
4th Harmonic (%)        0.50     0.32     0.33

                      IOP1F5   IOP2F5   IOP3F5
5th Harmonic (%)        0.50     0.63     0.49

=>>
```

Figure 5.3 METER DIF (Differential) Command Report

Thermal Metering

The thermal metering function reports the RTD meter values (see *Table 5.3* for details) and also reports the state of connected RTDs if any have failed (see *Table 5.4* for details).

Table 5.3 Thermal Meter Values

Relay Option	Thermal Values
With External SEL-2600 RTD Module or Internal RTD Option	All RTD Temperatures

Table 5.4 RTD Input Status Messages

Message	Status
Open	RTD leads open
Short	RTD leads shorted
Comm Fail	Fiber-optic communications to SEL-2600 RTD Module have failed
Stat Fail	SEL-2600 RTD Module self-test status failure

Figure 5.4 provides an example of the **METER T** command report.

```
=>>MET T <Enter>

SEL-787                                    Date: 11/12/2007   Time: 12:34:14
TRNSFRMR RELAY                             Time Source: Internal

Ambient RTD       70 C
Max Other RTD    95 C

 RTD2  AMB        70 C
 RTD3  TEST3     -30 C
 RTD5  TEST5      75 C
 RTD6  TEST6      90 C
 RTD8  TEST8     -10 C
RTD10  TEST10     95 C
RTD11  TEST11     65 C
RTD12  TEST12     open

=>>
```

Figure 5.4 METER T Command Report With RTDs

Energy Metering

The SEL-787 with the voltage option includes energy metering. Use this form of metering to quantify real and reactive energy supplied by the transformer. Refer to *Figure 5.1* for the definitions of positive real power, negative real power, positive reactive power, and negative reactive power. Below are the energy meter values:

- MWhP—Positive real three-phase energy
- MWhN—Negative real three-phase energy
- MVARhP—Positive reactive three-phase energy
- MVARhN—Negative reactive three-phase energy
- Last date and time energy meter quantities were reset

NOTE: Energy values roll over after 99,999.999 MVAh and reset to 0.

Figure 5.5 shows the device response to the **METER E** command.

```
=>MET E <Enter>

SEL-787                                    Date: 02/23/2009 Time: 13:48:27
TRNSFRMR RELAY                             Time Source: Internal

Energy
Positive MWH (MWh)           5.300
Negative MWH (MWh)           0.000
Positive MVARH (MVArh)       0.000
Negative MVARH (MVArh)       0.411

LAST RESET = 02/20/2009 10:55:52
=>
```

Figure 5.5 METER E Command Report

To reset energy meter values, issue the **MET RE** command as shown in *Figure 5.6*.

```
=>>MET RE <Enter>
Reset Metering Quantities (Y,N)? Y <Enter>
Reset Complete
=>>
```

Figure 5.6 METER RE Command Report

Energy metering values are stored to nonvolatile memory four times per day and within one minute of the energy metering values being reset.

Maximum and Minimum Metering

Maximum and minimum metering allows you to determine maximum and minimum operating quantities such as currents, voltages, power, analog input quantities, RTD quantities and frequency. *Table 5.5* lists the max/min metering quantities.

Table 5.5 Maximum/Minimum Meter Values

Relay Option	Max/Min Meter Values
Base Model	Maximum and minimum line currents IAW1, IBW1, ICW1, IAW2, IBW2, ICW2 (A primary) Maximum and minimum IG (residual ground fault current) magnitude (A primary)
With Neutral Current Option (REF)	Maximum and minimum neutral current IN magnitudes (A primary)
With Voltage Option	VAB, VBC, VCA or VAN, VBN, VCN magnitudes (V primary) Maximum and minimum real, reactive and apparent three-phase power (kW, kVAR, kVA) Maximum and minimum system frequency (Hz)
With RTD option or SEL-2600 RTD Module	Maximum and minimum RTD temperatures (°C)
With analog input option	Maximum and minimum analog input values (engineering units)

All maximum and minimum metering values will have the date and time that they occurred. The analog quantities from *Table 5.5* are checked approximately every 1.0 seconds and, if a new maximum or minimum value occurs, this value is saved along with the date and time that the maximum or minimum value occurred. Maximum and minimum values are only checked if relay element FAULT is deasserted (no fault condition exists) for at least one second. Additionally, the following minimum thresholds must also be met:

- Current magnitudes of IAW*n*, IBW*n*, and ICW*n*: 3% of the nominal current (INOM • CTR*n*). (*n* = 1 or 2 depending on the winding)
- Current magnitude of IGW*n*: IAW*n*, IBW*n*, and ICW*n* all must be above their thresholds (*n* =1 or 2 depending on the winding)
- Current magnitude of IN: 3% of the nominal IN rating (INOM • CTRN)
- Voltage values (phase-neutral and phase-to-phase): 7.5 • PTR V and 13 • PTR V, respectively.
- Power values (real, reactive, and apparent): All three currents (IAW*n*, IBW*n*, ICW*n*) and all three voltages (VA, VB, VC or VAB, VBC, VCA) must be above their thresholds.

Figure 5.7 shows an example device response to the **METER M** command.

```
=>>MET M <Enter>

SEL-787                                  Date: 11/01/2007   Time: 14:32:32
TRNSFRMR RELAY                           Time Source: Internal

                  MAX       DATE       TIME       MIN        DATE       TIME
IAW1 (A)         607.5    11/01/2007  10:57:48    485.9    11/01/2007    10:56:20
IBW1 (A)         608.3    11/01/2007  11:02:09    604.8    11/01/2007    10:56:35
ICW1 (A)         733.7    11/01/2007  10:56:13    609.7    11/01/2007    11:02:44
IGW1 (A)        1411.5    11/01/2007  10:57:57      2.1    11/01/2007    11:02:57
IN (A)          3002.3    11/01/2007  11:03:07    177.7    11/01/2007    10:55:58
IAW2 (A)         607.8    11/01/2007  10:57:48    116.2    11/01/2007    10:56:20
IBW2 (A)         606.8    11/01/2007  11:02:09    235.8    11/01/2007    10:56:35
ICW2 (A)         608.4    11/01/2007  10:56:13    364.5    11/01/2007    11:02:44
IGW2 (A)        1200.5    11/01/2007  10:58:04    158.8    11/01/2007    11:03:33
VA (V)         10004      11/01/2007  10:57:41   6701.4    11/01/2007    11:03:30
VB (V)         10006      11/01/2007  10:58:02   6704.9    11/01/2007    11:02:32
VC (V)         10025      11/01/2007  10:56:55   6714.7    11/01/2007    11:00:30
KW3P (kW)       9626.1    11/01/2007  11:02:03  -1561.9    11/01/2007    10:56:21
KVAR3P (kVAR)   1814.3    11/01/2007  10:57:42  -7408.9    11/01/2007    11:01:17
KVA3P (kVA)    12133      11/01/2007  11:02:57   2330.7    11/01/2007    10:56:07
FREQ (Hz)         60.0    11/01/2007  11:01:18     60.0    11/01/2007    10:58:05

LAST RESET = LAST RESET = 11/01/2007 10:55:52

=>>
```

Figure 5.7 METER M Command Report

To reset maximum/minimum meter values, issue the **MET RM** command as shown in *Figure 5.8*. The max/min meter values can be reset from the serial port, the front panel, or assertion of the RSTMXMN relay element. The date and time of the reset are preserved and shown in the max/min meter report.

```
=>>MET RM <Enter>
Reset Metering Quantities (Y,N)? Y <Enter>
Reset Complete
=>>
```

Figure 5.8 METER RM Command Response

All maximum and minimum metering values are stored to nonvolatile memory four times per day and within one minute of the maximum and minimum metering values being reset.

Math Variable Metering

The SEL-787 includes 32 math variables. When you receive your SEL-787, no math variables are enabled. To use math variables, enable the number of math variables (between 1 and 32) you require, using the EMV setting in the Logic setting category. *Figure 5.9* shows the device response to the **METER MV M**(ath) **V**(ariable) command with 8 of the 32 math variables enabled.

```
=>>MET MV <Enter>

SEL-787                                 Date: 03/11/2008    Time: 12:32:10
TRNSFRMR RELAY                          Time Source: Internal

MV01       1.00
MV02   -32767.00
MV03      -1.00
MV04       0.00
MV05    1000.59
MV06   -1000.61
MV07    2411.01
MV08    2410.99

=>>
```

Figure 5.9 MET MV Command Report

RMS Metering

The SEL-787 includes root mean squared (rms) metering. Use rms metering to measure the entire signal (including harmonics). You can measure the rms quantities shown in *Table 5.6*.

Table 5.6 RMS Meter Values

Relay Option	RMS Meter Values
Base Model	RMS current IAW1, IBW1, ICW1, IAW2, IBW2, and ICW2 magnitudes (A primary)
With Neutral Current (IN) Option	RMS current IN magnitude (A primary)
With Voltage Option	VAB, VBC, VCA or VAN, VBN, VCN, and VG magnitudes (V primary)

RMS quantities contain the total signal, including harmonics. This differs from the fundamental meter (**METER** command) in that the fundamental meter quantities only contain the fundamental frequency (60 Hz for a 60-Hz system). *Figure 5.10* shows the **METER RMS** command report.

```
=>MET RMS <Enter>

SEL-787                                   Date: 01/23/2008   Time: 13:44:57
TRNSFRMR RELAY                            Time Source: Internal

               IAW1     IBW1     ICW1
RMS (A pri.)    118.0    122.5    120.7

               IAW2     IBW2     ICW2
RMS (A pri.)   2351.7   2461.3   2401.1

                IN
RMS (A pri.)    146.6

                VAB      VBC      VCA
RMS (V pri.)    12090    11893    21180

=>
```

Figure 5.10 METER RMS Command Report

Analog Input Metering

The SEL-787 can monitor analog (transducer) quantities that it is measuring if equipped with optional analog inputs. Analog input metering shows transducer values from standard voltage and current transducers. These values can then be used for monitoring automation and control applications.

Through the global settings, you can set each type of analog input to the type of transducer that drives that analog input. You also set the range of the transducer output. Analog inputs can accept both current and voltage transducer outputs. Ranges for the current transducers are ±20 mA and ranges for the voltage transducers are ±10 V. You also set the corresponding output of the analog inputs in engineering units. See *Section 4: Protection and Logic Functions* for an explanation of how to set up analog inputs for reading transducers. *Figure 5.11* shows an example of analog input metering.

```
=>MET AI <Enter>

SEL-787                                 Date: 01/23/2008   Time: 13:44:44
TRNSFRMR RELAY                          Time Source: Internal

Input Card 3
AI301 (mA)   -0.008
AI302 (mA)   -0.007
AI303 (mA)   -0.001
AI304 (mA)   -0.006

=>
```

Figure 5.11 METER AI Command Report

Demand Metering

The SEL-787 offers the choice between two types of demand metering, settable with the enable setting:

EDEM = THM (Thermal Demand Metering)

or

EDEM = ROL (Rolling Demand Metering)

The relay provides demand (**METER DE** command) and peak demand (**METER PE** command) metering for the winding selected (Winding 1 or Winding 2). *Table 5.7* shows the values reported. *Figure 5.12* provides an example of the **METER DE** (Demand) command report and *Figure 5.13* provides an example of the **METER PE** (Peak Demand) command report. Refer to *Demand Metering on page 4.55* for detailed descriptions and settings selection.

Table 5.7 Demand Values

Relay Option	Demand/Peak Demand Values
All	Demand/Peak Demand values of line currents IAW*n*, IBW*n*, and ICW*n* magnitudes (A primary) Demand/Peak Demand Value of IGWn (residual ground fault current) magnitude (A primary) Demand/peak demand value of negative-sequence current (3I2W*n*) magnitude (A primary), where *n* = 1 or 2 depending on the winding selected.

```
=>MET DEM <Enter>

SEL-787                                 Date: 01/23/2008   Time: 13:46:56
TRNSFRMR RELAY                          Time Source: Internal

                   IAD      IBD      ICD      IGD     3I2D
DEMAND (A pri.)     53.9     55.9     54.8      2.1      1.4

LAST RESET = 01/23/2008 13:45:38
=>
```

Figure 5.12 METER DEM Command Report

```
=>MET P <Enter>

SEL-787                                    Date: 01/23/2008   Time: 13:47:00
TRNSFRMR RELAY                             Time Source: Internal

                  IAPD     IBPD     ICPD     IGPD     3I2PD
DEMAND (A pri.)     55.8     57.8     56.7      2.1      1.4

LAST RESET = 01/23/2008 13:45:37
=>
```

Figure 5.13 METER P Command Report

Peak demand metering values are stored to nonvolatile memory four times per day and within one minute of the peak demand metering values being reset. Demand metering is stored in volatile memory only, and the data will be lost when power to the relay is removed.

Harmonic Metering

The harmonic metering function in the SEL-787 reports the current and voltage harmonics through the fifth harmonic and the total harmonic distortion percentage (THD %). *Table 5.8* shows the harmonic values reported. *Figure 5.14* provides an example of the **METER H** (Harmonic) command report.

Table 5.8 Measured Harmonic Meter Values

Relay Option	Harmonic Values
All	Fundamental magnitude (secondary A) and 2nd, 3rd, 4th, harmonic % values and THD % of line currents IAW1, IBW1, ICW1, IAW2, IBW2, and ICW2
With Neutral Current (IN) option	Fundamental magnitude (secondary A), 2nd, 3rd, 4th, 5th harmonic % values, and THD % of neutral current IN
With Voltage Option	Fundamental magnitude (secondary V), 2nd, 3rd, 4th, and 5th harmonic % values and THD % of voltages VAB, VBC, VCA or VAN, VBN, VCN

```
=>MET H <Enter>

SEL-787                                    Date: 01/23/2008   Time: 13:44:27
TRNSFRMR RELAY                             Time Source: Internal

            IAW1   IBW1   ICW1   IAW2   IBW2   ICW2    IN     VAB    VBC    VCA
Fund (sec)    1.0    1.0    1.0    2.0    2.0    2.0    1.2   67.2   66.1  117.7
2nd (%)       0.3    0.4    0.5    0.2    0.3    0.3    0.4    0.0    0.0    0.0
3rd (%)       0.5    0.6    0.6    0.2    0.3    0.2    0.3    0.0    0.0    0.0
4th (%)       0.4    0.4    0.5    0.2    0.2    0.3    0.2    0.0    0.0    0.0
5th (%)       0.6    0.6    0.9    0.3    0.3    0.2    0.4    0.0    0.0    0.0
THD (%)       0.9    1.0    1.2    0.5    0.5    0.5    0.7    0.0    0.0    0.0

=>
```

Figure 5.14 METER H Command Report

Synchrophasor Metering

The **MET PM** serial port ASCII command may be used to view the SEL-787 synchrophasor measurements. There are multiple ways to use the **MET PM** command:

- As a test tool, to verify connections, phase rotation, and scaling
- As an analytical tool, to capture synchrophasor data at an exact time, in order to compare it with similar data captured in other phasor measurement unit(s) at the same time. As a method of periodically gathering synchrophasor data through a communications processor.

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings PHDATAV, PHDATAI, and PHCURR. The **MET PM** command can function even when no serial ports are sending synchrophasor data. It is unaffected by serial port setting PROTO.

The **MET PM** command will only operate when the SEL-787 is in the IRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1. *Table 5.9* below, shows the measured values for the **MET PM** Command. *Figure I.4* in *Appendix I: Synchrophasors*, shows a sample **MET PM** command response. The **MET PM TIME** command can be used to direct the SEL-787 to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM** 14:14:12 will result in a response similar to *Figure I.4*, occurring just after 14:14:12, with the time stamp 14:14:12.000. Refer to *Appendix I: Synchrophasors*, for further details on synchrophasor measurements, settings, C37.118 Protocol etc.

Table 5.9 Synchrophasor Measured Values

Relay Option	Meter Values
All Models	Currents: IAW1, IBW1, ICW1, I1W1 (Winding 1 positive-sequence current) and IAW2, IBW2, ICW2, I1W2 (Winding 2 positive-sequence current), magnitudes (A primary) and phase angles (deg)
Digitals	TSOK and SV17–SV32 Relay Word Bit status
Analogs	MV29–MV32 Math Variables[a]
	System Frequency (Hz) = 50 or 60 Hz
	Rate of change of Frequency = 0
With Voltage Option	Voltage phasors: VAB, VBC, VCA or VAN, VBN, VCN, and V1 (positive-sequence voltage), magnitudes (V or kV) and phase angles (deg)
	System Frequency (Hz)
	Rate of change of Frequency (Hz/s)

[a] These data are calculated every 100 ms. Only the data that occurs at the "Top of the Second" will be used for MET PM responses.

Small Signal Cutoff for Metering

The relay applies a threshold to the secondary voltage and current magnitude metering quantities to force a reading to zero when the measurement is near zero. The threshold for fundamental metering current values is 0.01 • INOM A (secondary) and for voltage values is 0.1 V (secondary). The threshold for RMS metering current values is 0.03 • INOM A (secondary) and for voltage values is 0.3 V (secondary).

Load Profiling

The SEL-787 includes a load profiling function. The relay automatically records selected quantities into nonvolatile memory every 5, 10, 15, 30, or 60 minutes, depending on the LDAR load profile report setting (see *Load Profile Settings on page 4.105*). Choose which analog quantities you want to monitor from the analog quantities listed in *Appendix K: Analog Quantities*. Set these quantities into the LDLIST load profile list report setting.

The relay memory can hold data for 6500 time-stamped entries. For example, if you chose to monitor 10 values at a rate of every 15 minutes, you could store 66 days worth of data.

Download the load rate profile data using the serial port **LDP** command described in *LDP Command (Load Profile Report) on page 7.30*. *Figure 5.15* shows an example **LDP** serial port command response.

```
=>LDP <Enter>

SEL-787                              Date: 2008/01/17 Time: 18:07:05
TRNSFRMR RELAY                         Time Source: Internal

#    DATE      TIME       IAW1_MAG IAW1_ANG IBW1_MAG IBW1_ANG ICW1_MAG ICW1_ANG
23 2008/01/14 16:16:40.992   0.099 0.000     0.225    -52.125    0.344 -108.435
22 2008/01/14 16:21:40.270 124.580 0.000   124.853   -119.627  123.668  120.426
21 2008/01/14 16:26:40.157 124.346 0.000   124.902   -119.358  123.626  120.711
20 2008/01/14 16:31:40.019 124.309 0.000   124.886   -119.598  123.973  120.577
19 2008/01/14 16:36:40.024 124.293 0.000   124.836   -119.361  123.403  120.631
18 2008/01/14 16:41:40.056 124.559 0.000   124.813   -119.709  123.970  120.493
17 2008/01/14 16:46:40.275 124.249 0.000   124.774   -119.646  123.907  120.574
16 2008/01/14 16:51:40.333 124.589 0.000   124.671   -119.569  123.603  120.483
15 2008/01/14 16:56:40.908   0.088 0.000     0.188     45.000    0.395  -26.565
14 2008/01/15 17:01:40.934 124.293 0.000   124.842   -119.504  123.485  120.619
13 2008/01/15 17:06:40.972 124.490 0.000   124.758   -119.463  123.546  120.518
12 2008/01/15 17:11:40.038 124.341 0.000   124.741   -119.297  123.424  120.779
11 2008/01/16 17:16:40.045 124.320 0.000   125.130   -119.517  123.630  120.623
10 2008/01/16 17:21:40.295 124.476 0.000   124.687   -119.537  123.518  120.455
9  2008/01/16 17:26:40.070 124.284 0.000   124.874   -119.413  123.649  120.818
8  2008/01/16 17:31:40.168   0.129 0.000     0.182    106.928    0.210   49.399
7  2008/01/17 17:36:40.215 124.313 0.000   125.154   -119.530  123.752  120.662
6  2008/01/17 17:41:40.803 124.383 0.000   124.992   -119.613  123.796  120.550
5  2008/01/17 17:46:40.282 124.446 0.000   124.799   -119.464  123.600  120.444
4  2008/01/17 17:51:40.077 124.432 0.000   124.710   -119.774  123.728  120.379
3  2008/01/17 17:56:40.114 124.288 0.000   125.274   -119.590  123.905  120.605
2  2008/01/17 18:01:41.047 124.392 0.000   124.730   -119.483  123.404  120.576
1  2008/01/17 18:06:41.020   0.210 0.000     0.099     -8.130    0.182  -57.529

=>
```

Figure 5.15 LDP Command Report

Through-Fault Event Monitoring

Figure 5.16 shows a fault that occurs outside the area of unit protection of the transformer. Such through faults can last for several cycles, subjecting the transformer windings to mechanical stress and the transformer winding insulation to thermal stress. Monitor and document this through-fault activity with the through-fault element in the SEL-787. The through-fault element also calculates the cumulative mechanical stress on the transformer windings.

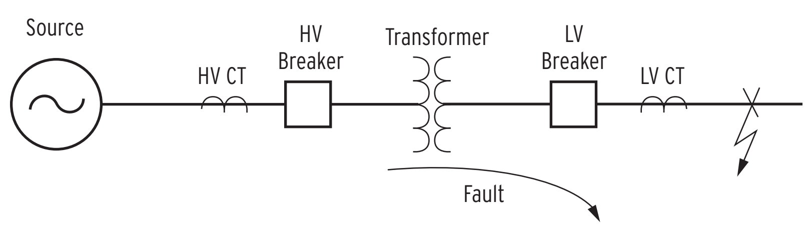


Figure 5.16 Transformer Bank Subjected to Through Fault

Figure 5.17 shows through-fault curves for Category IV transformers as published in IEEE Standard C57.109-1993. These curves apply to transformers that are covered by the IEEE standard or, in general, to transformers that were built beginning in the early 1970s. For transformers built prior to 1970, consult the manufacturer to obtain the transformer short-circuit withstand capabilities.

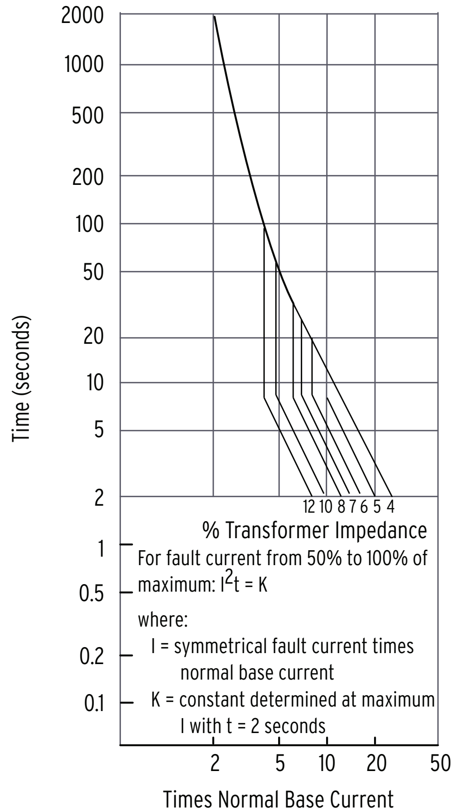


Figure 5.17 Category IV Transformers Through-Fault Protection Curves

The curves in *Figure 5.17* are a function of the transformer short-circuit impedance, and is keyed to the maximum I^2t of the worst-case mechanical duty (maximum fault current for 2 seconds). *Equation 5.1* through *Equation 5.3* show the three equations that the element uses to evaluate the thermal curve each processing interval. Note that the calculated currents are in primary values. To convert the secondary current to primary current, the element multiplies the secondary current by the CT ratio of the particular winding.

$$I_{PU} = \frac{I \bullet \sqrt{3} \bullet kV_{LL}}{1000 \bullet S}$$

Equation 5.1

$$I_{MAX\_PU} = \frac{1}{Z_{PU}}$$

Equation 5.2

$$t(I_{PU}) = \frac{K}{(I_{PU})^2}$$

Equation 5.3

where:

I = Measured current
S = Transformer MVA rating (MVA)
kV_{LL} = Line-to-line voltage (kV)
Z_{PU} = Transformer impedance (per unit)
K = 1250 if $(4.5 \le I_{PU} \le 0.5 \bullet I_{MAX\_PU})$ or $2 \bullet (I_{MAX\_PU})^2$ if $I_{PU} > 0.5 \bullet I_{MAX\_PU}$

There are only four settings to set the through-fault event monitor, all under the Through Fault category in Global Settings (**SET G** command) (see *Table 5.10*). Enable the through fault element by setting the SELOGIC equation ETHRFLT for the conditions that you want the element to run. The default setting for ETHRFLT := NOT TRXFMR disables Through-Fault Monitor for all transformer internal faults (Relay Word Bit TRFXMR := 1).Use Setting THFLTD to select the winding that you want the element to use when calculating the through-fault current. Switch S1 in *Figure 5.18* selects OFF or one of windings 1 or 2. Set the through-fault alarm pickup (THFLTPU) to the desired value, and enter the transformer percentage impedance at the XFMRZ setting.

NOTE: When you change the ETHRFLT setting, the relay also clears the data and records, i.e., it has the same effect as the **TFE C** or **TFE R** command.

Table 5.10 Through-Fault Element Settings

Setting Prompt	Setting Range	Setting Name := Factory Default
THR FLT WDG	OFF, 1, 2	THFLTD := OFF
ENABLE THR FLT	SELOGIC	ETHRFLT := NOT TRXFMR
THR FLT ALARM PU	50.0%–900.0%	THFLTPU := 100.0
XFMR IMPEDANCE	2.0%–40.0%	XFMRZ := 10.0

NOTE: The MVA setting must be set to the transformer MVA rating when the THFLTD setting is set to 1 or 2.

On the basis that mechanical stress takes effect only at high current values, the through-fault element runs only if the selected phase current is greater than 4.75 times full load current. Allowing a hysteresis of 0.25 of full load, the through-fault element resets when the current falls below 4.5 times the full load current.

Figure 5.18 shows a functional diagram of the through-fault element for the A-phase of Winding 1 (THFLTD = 1), the B-phase and C-phase elements have identical diagrams. When SELOGIC equation ETHRFLT asserts and the A-phase current exceeds 4.75 times the transformer full-load current, Enable asserts and the 1-minute Timer starts.

When Enable asserts, the following occurs:

- ➤ The thermal element advances the A-phase fault counter by 1 count.
- ➤ The thermal element advances the total fault counter by 1 count.
- ➤ The thermal element records the time when the fault starts (rising edge of Enable).
- ➤ The process to determine the maximum through-fault current for the fault duration starts.
- ➤ The integration process starts, whereby the element sums the values (*Equation 5.3*) calculated each processing interval (1/4 of a power system cycle).

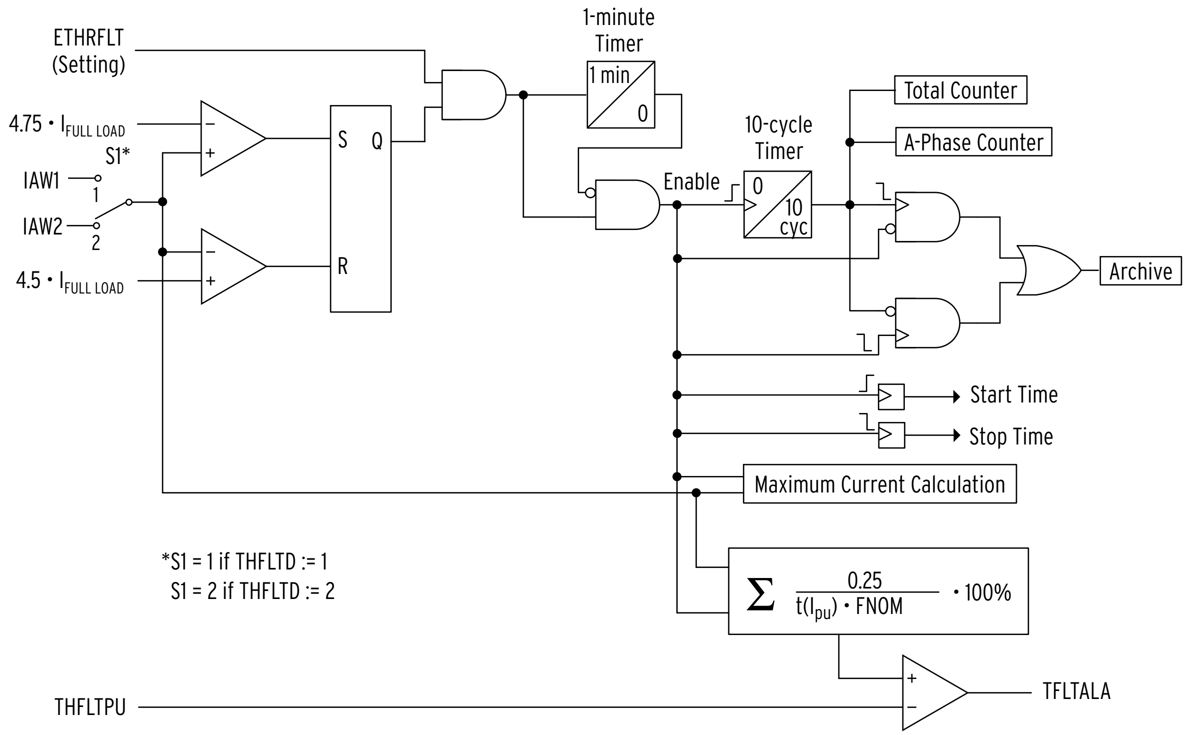


Figure 5.18 Through-Fault Diagram

The 10-cycle Timer avoids the inadvertent increment of the counters or archiving of the data if the fault current momentarily drops below the lower threshold level.

Setting threshold THFLTPU would usually be set to alarm for excessive, cumulative transformer bank stress. When the integration exceeds the value as specified by the THFLTPU setting, Relay Word bit TFLTALA asserts. Assign output Relay Word bit TFLTALA to an output for annunciation or control action such as to modify distribution feeder auto-reclosing (e.g., reduce the number of reclosures from 3 to 2).

When the fault current falls below 4.5 times the full load level, the element deasserts, and the following occurs:

- ➤ The thermal element records the stop time; then calculates (and records) the fault duration.
- ➤ The thermal element records the maximum value of the fault current during the fault.
- ➤ The integration process stops.

The relay can store (archive) the data of 500 through faults in a first-in-first-out (FIFO) buffer. The element automatically archives the data when one of the following conditions is true:

- ➤ The 10-cycle Timer deasserts and the enable signal is already de-asserted.
- ➤ The 10-cycle Timer is already de-asserted and the enable signal de-asserts.

Through-Fault Element (TFE) Serial Command

The format of the **TFE** command is as follows:

TFE [*nnn* **A**|**P**|**C**|**R**]

where:

nnn	Specifies number of through faults to display.
A	The relay displays all the Through Fault Records in the memory.
P	Use to specify pre-loading
C or R	Sets the accumulated values to 0 and deletes the history.

Figure 5.19 displays the relay response to the **TFE** (no other parameters) command. Notice that Winding 1 is the winding whose current inputs the element uses in the calculations (THFLTD = 1). The **TFE** command lists as many as 20 of the most recent through-faults. "Total Number of Transformer Through Faults:" is the sum of the detected through faults of all three phases since the last reset, with a maximum of 65,535 counts. "Number of n Phase Through Faults:" (n = A, B, C) refers to the through faults detected for that particular phase since the last reset, also with a maximum of 65,535 counts. The "Total Accumulated Percentage of Through Fault Capability" shows the per phase value. The value represents the percent amount of through fault capability used up based on the per unitized capability from the curve of *Figure 5.17*. The through-fault alarm state is either a 1 (indicating an alarm state), or a 0 (indicating a normal state).

```
=>>TFE <Enter>

SEL-787                                 Date: 04/03/2008   Time: 15:24:02
TRNSFRMR RELAY                          Time Source: Internal

Winding 1
Total Number of Transformer Through Faults: 4
Total Number of A Phase Through Faults:     2
Total Number of B Phase Through Faults:     1
Total Number of C Phase Through Faults:     1

Total Accumulated Percentage of Through Fault Capability:
                     A-Phase    B-Phase    C-Phase
                     95.97      60.00      60.00
Through Fault Alarm: 0          0          0

Last Reset: 04/03/2008 15:16:27

#   DATE       TIME         Duration   IA     IB     IC    A     B     C   Alarm
                           (seconds)   (max primary kA)    (Increment %)
1   04/03/2008 15:23:37.102 19.983    1.99   0.00   0.00 35.97  0.00  0.00
2   04/03/2008 15:20:23.256  1.663    0.00   0.00   3.28  0.00  0.00 50.94 ABC
3   04/03/2008 15:20:19.918  1.675    0.00   6.37   0.00  0.00 99.99  0.00 AB
4   04/03/2008 15:20:16.596  1.650    1.99   0.00   0.00  2.97  0.00  0.00 A

=>>
```

Figure 5.19 Result of the TFE Command

Following is a description of each column (#, Date, Time, etc.) of the event report. Through-fault events are numbered (# column) from 1 (the most recent event, at the top) to a maximum of 500 through-fault events.

Under the date and time columns, the event shows the date of occurrence and the start time of each event (the date format depends upon the DATE_F setting).

Although the element processes all values each cycle, event duration (Duration column) is reported in seconds with processing interval resolution. If the event duration is equal to or greater than 60 seconds, the element appends a “+” to the time value of 60 seconds.

IA, IB, and IC show the maximum primary current for each phase, with a maximum of 100,000 A primary.

A, B, and C show the amount (percent increase) of the present fault for each phase. Alarm shows those phase(s) that were in the alarm state at the end of the through-fault event.

Table 5.11 shows events report messages and the reason why these messages may appear in the events report.

Table 5.11 Through-Fault Events Report Messages

Message	Cause
Invalid Data	The accumulated data are corrupt.
Through Fault Event Monitor Disabled	The ETHRFLT setting is NA, or evaluates to logical 0.
Too many events - Data Lost	The memory is full.
Through Fault Event Buffer Empty	There are no event records in the nonvolatile memory
Memory resources are low; check for activity on other ports	There is insufficient memory to display the event records

Use the **TFE A** command to list all the stored through-fault events (not only the last 20 events) since the monitor was last reset. To list a particular number of through-fault events, enter the **TFE *n*** command (*n* = 1 to 500).

To clear event accumulated data, and all event records, use either the **TFE C** (clear) or **TFE R** (reset) command. Both commands have the same result, so you can use either of them. Note that when you change the ETHRFLT setting, the relay also clears the data and records, i.e. it has the same effect as the **TFE C** or **TFE R** command.

Use the **TFE P** command to preload or change the values of the through fault event accumulated data, as shown in *Figure 5.20*. Enter these values in percent for each phase, to a maximum value of 100.0 percent.

```
=>>TFE P
Winding 1 Total Accumulated Percentage of Through Fault Capability:
A_Phase = 0.00? 60.20
B_Phase = 0.00? 56.0
C_Phase = 0.00? 52
Are you sure (Y,N)? Y
Command Completed
=>>
```

Figure 5.20 Preload the Values of the Accumulated Data

Section 6

Settings

Overview

IMPORTANT: Upon relay initial power up or Port 1 setting changes or Logic setting changes, the user may have to wait as long as two minutes before an additional setting change can occur. Note that the relay is functional with protection enabled, as soon as the ENABLED LED comes ON (about 5–10 seconds from power up).

The SEL-787 Transformer Protection Relay stores the settings you enter in nonvolatile memory. Settings are divided into the following eight setting classes:

1. Group
2. Logic
3. Global
4. Port *p* (where *p* = F, 1 [Ethernet], 2, 3, or 4)
5. Front Panel
6. Report
7. Modbus
8. DNP3

Some setting classes have multiple instances. In the above list, there are five port setting instances, one for each port. Settings may be viewed or set in several ways, as shown in *Table 6.1*.

Table 6.1 Methods of Accessing Settings

	Serial Port Commands[a]	Front Panel HMI Set/Show Menu[b]	ACSELERATOR QuickSet SEL-5030 (PC Software)[c]
Display Settings	All settings (**SHO** command)	Global, Group, and Port settings	All settings
Change Settings	All settings (**SET** command)	Global, Group, and Port settings	All settings

[a] Refer to Section 7: Communications for detailed information on set-up and use of the serial communications port.
[b] Refer to Section 8: Front-Panel Operations for detailed information on the front-panel layout, menus and screens, and operator control pushbuttons.
[c] Refer to Section 3: PC Software for detailed information.

Setting entry error messages, together with corrective actions, are also discussed in this section to assist in correct settings entry.

The *SEL-787 Settings Sheets* at the end of this section list all SEL-787 settings, the setting definitions, and input ranges. Refer to *Section 4: Protection and Logic Functions* for detailed information on individual elements and settings.

View/Change Settings With Front Panel

You can use the pushbuttons on the front panel to view/change settings. *Section 8: Front-Panel Operations* presents the operating details of the front panel.

Enter the front-panel menu by pushing the **ESC** pushbutton. It will display the following message:

```
MAIN
Meter
```

Scroll down the menu by using the **Down Arrow** pushbutton until the display shows the following message:

```
Control
Set/Show
```

The cursor (underline) should be on the `Set/Show` command. Enter the `Set/Show` command by pushing the **ENT** pushbutton. The display shows the following message:

```
SET/SHOW
Global
```

Enter the underlined `RELAY` message with the **ENT** pushbutton, and the relay will present you with the `RELAY` settings as listed in the *SEL-787 Settings Sheets*. Use the **Up Arrow**, **Down Arrow**, **Left Arrow**, and **Right Arrow** pushbuttons to scroll through the relay settings. View and change the settings according to your needs by selecting and editing them. After viewing or changing the `RELAY` settings, press the **ESC** pushbutton until the following message appears:

NOTE: Each SEL-787 is shipped with default factory settings. Calculate the settings for your application to ensure secure and dependable protection. Document the settings on the SEL-787 Settings Sheets at the end of this section before entering new settings in the relay.

```
Save Changes?
Yes   No
```

Select and enter the appropriate command by pushing the **ENT** pushbutton. Select `Yes` to save the settings changes and `No` to discard the changes.

Figure 6.1 shows a front-panel menu navigation example for the relay to enter the `PHASE PT RATIO, PTR` setting.

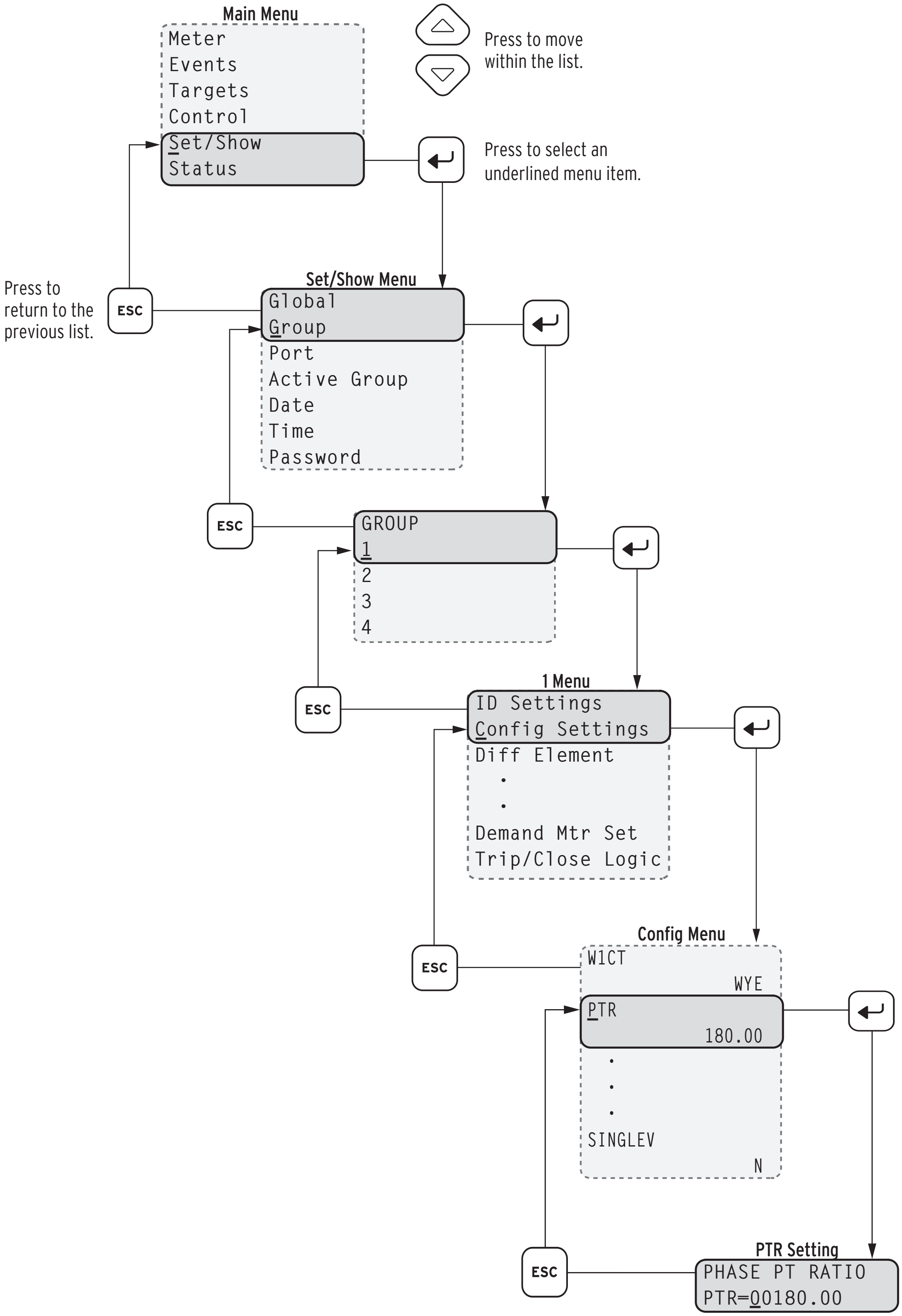


Figure 6.1 Front-Panel Setting Entry Example

View/Change Settings Over Communications Port

Refer to *Section 7: Communications* for information on how to set up and access the relay serial or Ethernet port with a personal computer and how to use ASCII commands to communicate with the relay.

View Settings

Use the **SHOW** command to view relay settings. The **SHOW** command is available from Access Level 1 and Access Level 2. *Table 6.2* lists the **SHOW** command options.

Table 6.2 SHOW Command Options

Command	Description
SHOW *n*	Show relay group settings. (*n* specifies the settings group 1, 2, or 3; *n* defaults to the active settings group if not listed.)
SHO D	Show DNP3 map settings.
SHO F	Show front-panel display and LED settings.
SHO G	Show global configuration settings.
SHO L *n*	Show logic settings. (*n* specifies the settings group 1, 2, or 3; *n* defaults to the active settings group if not listed.)
SHO M	Show Modbus map settings.
SHO P *n*	Show serial port settings for Port *n* (*n* = F, 1, 2, 3, or 4).
SHO R	Show Sequential Event Report (SER) and Event Report settings.

You may append a setting name to each of the commands to specify the first setting to display (e.g., **SHO 50P11P** displays the relay settings starting with setting **50P11P**). The default is the first setting. The **SHOW** command displays only the enabled settings.

Enter Settings

The **SET** command (available from Access Level 2) allows you to view or change settings. *Table 6.3* lists the **SET** command options.

Table 6.3 SET Command Options

Command	Settings Type	Description
SET *n*	Relay	Protection elements, timers, etc. (*n* specifies the settings group 1, 2, or 3.)
SET D	DNP	DNP3 map settings
SET F	Front Panel	Front-panel display and LED settings
SET G	Relay	Global configuration settings
SET L *n*	Logic	General logic settings (*n* specifies the settings group 1, 2, or 3.)
SET M	Modbus	Modbus user map
SET P *n*	Port	Serial port settings (*n* specifies the serial port 1, 2, 3, 4, or F.)
SET R	Reports	SER and Event Report settings

NOTE: The **SET** command is not available as long as 90 seconds after the relay is powered up and as long as 40 seconds after a setting change. If you issue a **SET** command during this period, the relay responds with the following message:

```
Command Unavailable;
Relay Configuration in
Progress, Try Again.
```

You may append a setting name to each of the commands to specify the first setting to display (e.g., **SET 50P1P** displays the relay settings starting with setting 50P1P). The default is the first setting.

When you issue the **SET** command, the relay presents a list of settings one at a time. Enter a new setting or press **<Enter>** to accept the existing setting. Editing keystrokes are listed in *Table 6.4*.

Table 6.4 SET Command Editing Keystrokes

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

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

When all the settings are entered, the relay displays the new settings and prompts you for approval to enable them. Press **Y <Enter>** to enable the new settings. The relay is disabled for as long as five seconds while it saves the new settings. The ALARM Relay Word bit is set momentarily, and the ENABLED LED extinguishes while the relay is disabled.

To change a specific setting, enter the command shown in *Table 6.5*.

Table 6.5 SET Command Format

SET n m s TERSE	
where:	
m	is left blank or is F, 1, 2, 3, or 4 when *n* = P.
n	is left blank or is D, G, L, F, R, M, or P to identify the class of settings.
s	is the name of the specific setting you wish to jump to and begin setting. If *s* is not entered, the relay starts at the first setting (e.g., enter 50P11P to start at phase overcurrent trip level setting).
TERSE	instructs the relay to skip the settings display after the last setting. Use this parameter to speed up the **SET** command. If you wish to review the settings before saving, do not use the TERSE option.

Setting Entry Error Messages

As you enter relay settings, the relay checks the setting entered against the range for the setting as published on the relay setting sheet. If any setting entered falls outside the corresponding range for that setting, the relay immediately responds `Out of Range` and prompts you to reenter the setting.

In addition to the immediate range check, several of the settings have interdependency checks with other settings. The relay checks setting interdependencies after you answer `Y` to the `Saves Settings?` prompt, but before the settings are stored. If any of these checks fail, the relay issues a self-explanatory error message, and returns you to the settings list for a correction. *Table 6.6* shows the settings interdependency error messages that require some additional explanation and guidance.

Table 6.6 Setting Interdependency Error Messages

Error Message	Setting/Function	Correct the Condition
Tap(s) out of range, enter values manually[a]	Group settings, differential element autocalculation of TAP1 and TAP2	Check: 0.1 • INOM*n* < TAP*n* < 6.2 • INOM*n*. (INOM*n* = 5 or 1 for 5 A and 1 A winding CT based on PARTNO). Should either TAP*n* value violate this requirement, adjust the affected TAP*n* to satisfy the check (*n* = 1 or 2).
Maximum-to-minimum TAP ratio must be ≤ 7.5[a]	Group settings, differential element autocalculation of TAP1 and TAP2	Check: [MAX (TAP1/INOM1, TAP2/INOM2)/MIN(TAP1/INOM1, TAP2/INOM2)] ≤ 7.5. Adjust TAP1 or TAP2 setting until the check is satisfied.
WnCT, REF1POL Setting Combination Invalid *n* = 1 or 2	Group settings, REF element	REF Element is only available when setting W*n*CT := WYE (*n* = 1 or 2).

[a] Relay forces MVA := OFF prior to this message.

SEL-787 Settings Sheets

These settings sheets include the definition and input range for each setting in the relay. You can access the settings from the relay front panel and the serial ports.

- Some settings require an optional module (see *Section 4: Protection and Logic Functions* for details).
- Some of the settings ranges may be more restrictive than shown, because of settings interdependency checks performed when new settings are saved (see *Setting Entry Error Messages on page 6.6*).
- The settings are not case sensitive.

Group Settings (SET Command)

Identifier

UNIT ID LINE 1 (16 Characters)	**RID**	:= ________
UNIT ID LINE 2 (16 Characters)	**TID**	:= ________

Configuration

WDG1 CT CONN (DELTA, WYE)	**W1CT**	:= ________
WDG2 CT CONN (DELTA, WYE)	**W2CT**	:= ________
WDG1 PHASE CTR (1–10000 {5 A IW1NOM}; 1–50000 {1 A IW1NOM})	**CTR1**	:= ________
WDG2 PHASE CTR (1–10000 {5 A IW2NOM}; 1–50000 {1 A IW2NOM})	**CTR2**	:= ________
MAX XFMR CAP (OFF, 0.2–5000.0 MVA)	**MVA**	:= ________
DEFINE CT COMP (Y, N)	**ICOM**	:= ________
WDG1 CT COMP (0–12) *(Hidden if ICOM := N)*	**W1CTC**	:= ________
WDG2 CT COMP (0–12) *(Hidden if ICOM := N)*	**W2CTC**	:= ________
WDG1 L-L VOLTS (0.20–1000.00 kV) *(Hidden if MVA := OFF)*	**VWDG1**	:= ________
WDG2 L-L VOLTS (0.20–1000.00 kV) *(Hidden if MVA := OFF)*	**VWDG2**	:= ________
NEUT 1 CT RATIO (1–10000 {5 A InNOM}; 1–50000 {1 A InNOM}) *(Hidden if neutral CT not included)*	**CTRN1**	:= ________
PHASE PT RATIO (1.00–10000.00) *(Hidden if voltages not included)*	**PTR**	:= ________
NOMINAL VOLTAGE (0.20–1000.00 kV) *(Hidden if voltages not included)*	**VNOM**	:= ________
PT CONNECTION (DELTA, WYE) *(Hidden if voltages not included)*	**DELTA_Y**	:= ________
VOLT-CURR WDG (1, 2) *(Hidden if voltages not included)*	**VIWDG**	:= ________
COMP ANGLE (0–360 Deg) *(Hidden if voltages not included, or if W1CT := Wye and VIWDG :=1, or if W2CT := Wye and VIWDG := 2)*	**COMPANG**	:= ________
SINGLE V INPUT (Y, N) *(Hidden if voltages not included)*	**SINGLEV**	:= ________

Differential

XFMR DIFF ENABLE (Y, N) *(All Differential settings below are hidden if E87 := N)*	**E87**	:=	

Note: TAP1 and TAP2 are autoset by relay if MVA setting is not OFF.

WDG1 CURR TAP (0.1–6.2 A [1 A nom.], 0.5–31.0 A [5 A nom.])	**TAP1**	:=	
WDG2 CURR TAP (0.1–6.2 A [1 A nom.], 0.5–31.0 A [5 A nom.])	**TAP2**	:=	
OPERATE CURR LVL (0.10–1.00 TAP)	**O87P**	:=	
DIFF CURR AL LVL (OFF, 0.05–1.00 TAP)	**87AP**	:=	
DIFF CURR AL DLY (1.0–120.0 sec.) *(Hidden if 87AP := OFF)*	**87AD**	:=	
RESTRAINT SLOPE1 (5–90 %)	**SLP1**	:=	
RESTRAINT SLOPE2 (5–90 %%)	**SLP2**	:=	
RES SLOPE1 LIMIT (1.0–20.0 TAP)	**IRS1**	:=	
UNRES CURR LVL (1.0–20.0 TAP)	**U87P**	:=	
2ND HARM BLOCK (OFF, 5–100 %)	**PCT2**	:=	
4TH HARM BLOCK (OFF, 5–100 %)	**PCT4**	:=	
5TH HARM BLOCK (OFF, 5–100 %)	**PCT5**	:=	
5TH HARM AL LVL (OFF, 0.02–3.20 TAP)	**TH5P**	:=	
5TH HARM AL DLY (0.0–120.0 s) *(Hidden if TH5P := OFF)*	**TH5D**	:=	
HARMONIC RESTRNT (Y, N)	**HRSTR**	:=	
HARMONIC BLOCK (Y, N)	**HBLK**	:=	

Restricted Earth Fault *(Hidden if neutral CT is not included.)*

POL QTY FROM WDG (OFF, 1, 2, 12)	**REF1POL**	:=	
REF1 TRQ CTRL (SELOGIC)	**REF1TC**	:=	
REF1 CURR LEVEL (0.05–3.00 pu)	**50REF1P**	:=	
52A BYPASS ENABL (Y, N)	**REF52BYP**	:=	

Winding 1 Maximum Phase Overcurrent

PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.]	**50P11P**	:=	
PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P11P := OFF)*	**50P11D**	:=	
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P11P := OFF)*	**50P11TC**	:=	
PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50P12P**	:=	
PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P12P := OFF)*	**50P12D**	:=	
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P12P := OFF)*	**50P12TC**	:=	
PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50P13P**	:=	

PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P13P := OFF)*	**50P13D**	:=	______
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P13P := OFF)*	**50P13TC**	:=	______
PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50P14P**	:=	______
PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P14P := OFF)*	**50P14D**	:=	______
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P14P := OFF)*	**50P14TC**	:=	______

Winding 1 Residual Overcurrent

(All settings below are hidden when W1CT := DELTA.)

RES IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50G11P**	:=	______
RES IOC DELAY (0.00–5.00 sec) *(Hidden if 50G11P := OFF)*	**50G11D**	:=	______
RES IOC TRQCTRL (SELOGIC) *(Hidden if 50G11P := OFF)*	**50G11TC**	:=	______
RES IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50G12P**	:=	______
RES IOC DELAY (0.00–5.00 sec) *(Hidden if 50G12P := OFF)*	**50G12D**	:=	______
RES IOC TRQCTRL (SELOGIC) *(Hidden if 50G12P := OFF)*	**50G12TC**	:=	______

Winding 1 Negative-Sequence Overcurrent

NSEQ IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50Q11P**	:=	______
NSEQ IOC DELAY (0.00–5.00 sec) *(Hidden if 50Q11P := OFF)*	**50Q11D**	:=	______
NSEQ IOC TRQCTRL (SELOGIC) *(Hidden if 50Q11P := OFF)*	**50Q11TC**	:=	______
NSEQ IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50Q12P**	:=	______
NSEQ IOC DELAY (0.00–5.00 sec) *(Hidden if 50Q12P := OFF)*	**50Q12D**	:=	______
NSEQ IOC TRQCTRL (SELOGIC) *(Hidden if 50Q12P := OFF)*	**50Q12TC**	:=	______

Winding 1 Maximum Phase Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P1P**	:=	______
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P1P := OFF)*	**51P1C**	:=	______
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P1P := OFF)*	**51P1TD**	:=	______
EM RESET DELAY (Y, N) *(Hidden if 51P1P := OFF)*	**51P1RS**	:=	______
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P1P := OFF)*	**51P1CT**	:=	______
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P1P := OFF)*	**51P1MR**	:=	______
PH TOC TRQCTRL (SELOGIC) *(Hidden if 51P1P := OFF)*	**51P1TC**	:=	______

Date ___________
Group___________

Winding 1 Phase A Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P1AP**	:= ______
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P1AP := OFF)*	**51P1AC**	:= ______
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P1AP := OFF)*	**51P1ATD**	:= ______
EM RESET DELAY (Y, N) *(Hidden if 51P1AP := OFF)*	**51P1ARS**	:= ______
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P1AP := OFF)*	**51P1ACT**	:= ______
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P1AP := OFF)*	**51P1AMR**	:= ______
PH TOC TRQCTRL (SELOGIC) *(Hidden if 51P1AP := OFF)*	**51P1ATC**	:= ______

Winding 1 Phase B Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P1BP**	:= ______
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P1BP := OFF)*	**51P1BC**	:= ______
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P1BP := OFF)*	**51P1BTD**	:= ______
EM RESET DELAY (Y, N) *(Hidden if 51P1BP := OFF)*	**51P1BRS**	:= ______
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P1BP := OFF)*	**51P1BCT**	:= ______
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P1BP := OFF)*	**51P1BMR**	:= ______
PH TOC TRQCTRL (SELOGIC) *(Hidden if 51P1BP := OFF)*	**51P1BTC**	:= ______

Winding 1 Phase C Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P1CP**	:= ______
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P1CP := OFF)*	**51P1CC**	:= ______
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P1CP := OFF)*	**51P1CTD**	:= ______
EM RESET DELAY (Y, N) *(Hidden if 51P1CP := OFF)*	**51P1CRS**	:= ______
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P1CP := OFF)*	**51P1CCT**	:= ______
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P1CP := OFF)*	**51P1CMR**	:= ______
PH TOC TRQCTRL (SELOGIC) *(Hidden if 51P1CP := OFF)*	**51P1CTC**	:= ______

Winding 1 Residual Time Overcurrent

All settings below are hidden when W1CT := DELTA.

RES TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51G1P**	:= ______

RES TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51G1P := OFF)*	**51G1C**	:=	________
RES TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51G1P := OFF)*	**51G1TD**	:=	________
EM RESET DELAY (Y, N) *(Hidden if 51G1P := OFF)*	**51G1RS**	:=	________
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51G1P := OFF)*	**51G1CT**	:=	________
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51G1P := OFF)*	**51G1MR**	:=	________
RES TOC TRQCTRL (SELOGIC) *(Hidden if 51G1P := OFF)*	**51G1TC**	:=	________

Winding 1 Negative-Sequence Time Overcurrent

NSEQ TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51Q1P**	:=	________
NSEQ TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51Q1P := OFF)*	**51Q1C**	:=	________
NSEQ TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51Q1P := OFF)*	**51Q1TD**	:=	________
EM RESET DELAY (Y, N) *(Hidden if 51Q1P := OFF)*	**51Q1RS**	:=	________
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51Q1P := OFF)*	**51Q1CT**	:=	________
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51Q1P := OFF)*	**51Q1MR**	:=	________
NSEQ TOC TRQCTRL (SELOGIC) *(Hidden if 51Q1P := OFF)*	**51Q1TC**	:=	________

Winding 2 Maximum Phase Overcurrent

PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50P21P**	:=	________
PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P21P := OFF)*	**50P21D**	:=	________
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P21P := OFF)*	**50P21TC**	:=	________
PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50P22P**	:=	________
PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P22P := OFF)*	**50P22D**	:=	________
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P22P := OFF)*	**50P22TC**	:=	________
PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50P23P**	:=	________
PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P23P := OFF)*	**50P23D**	:=	________
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P23P := OFF)*	**50P23TC**	:=	________
PHASE IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50P24P**	:=	________
PHASE IOC DELAY (0.00–5.00 sec) *(Hidden if 50P24P := OFF)*	**50P24D**	:=	________
PH IOC TRQCTRL (SELOGIC) *(Hidden if 50P24P := OFF)*	**50P24TC**	:=	________

Date ___________
Group___________

Winding 2 Residual Overcurrent

All settings below are hidden when W2CT := DELTA.

RES IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50G21P**	:=
RES IOC DELAY (0.00–5.00 sec) *(Hidden if 50G21P := OFF)*	**50G21D**	:=
RES IOC TRQCTRL (SELOGIC) *(Hidden if 50G21P := OFF)*	**50G21TC**	:=
RES IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50G22P**	:=
RES IOC DELAY (0.00–5.00 sec) *(Hidden if 50G22P := OFF)*	**50G22D**	:=
RES IOC TRQCTRL (SELOGIC) *(Hidden if 50G22P := OFF)*	**50G22TC**	:=

Winding 2 Negative-Sequence Overcurrent

NSEQ IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50Q21P**	:=
NSEQ IOC DELAY (0.00–5.00 sec) *(Hidden if 50Q21P := OFF)*	**50Q21D**	:=
NSEQ IOC TRQCTRL (SELOGIC) *(Hidden if 50Q21P := OFF)*	**50Q21TC**	:=
NSEQ IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50Q22P**	:=
NSEQ IOC DELAY (0.00–5.00 sec) *(Hidden if 50Q22P := OFF)*	**50Q22D**	:=
NSEQ IOC TRQCTRL (SELOGIC) *(Hidden if 50Q22P := OFF)*	**50Q22TC**	:=

Winding 2 Maximum Phase Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P2P**	:=
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P2P := OFF)*	**51P2C**	:=
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P2P := OFF)*	**51P2TD**	:=
EM RESET DELAY (Y, N) *(Hidden if 51 N1P := OFF)*	**51P2RS**	:=
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P2P := OFF)*	**51P2CT**	:=
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P2P := OFF)*	**51P2MR**	:=
PH TOC TRQCTRL (SELOGIC) *(Hidden if 51P2P := OFF)*	**51P2TC**	:=

Winding 2 Phase A Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P2AP**	:=
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P2AP := OFF)*	**51P2AC**	:=
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P2AP := OFF)*	**51P2ATD**	:=
EM RESET DELAY (Y, N) *(Hidden if 51P2AP := OFF)*	**51P2ARS**	:=

CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P2AP := OFF)*	**51P2ACT**	:= ____________
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P2AP := OFF)*	**51P2AMR**	:= ____________
PH A TOC TRQCTRL (SELOGIC) *(Hidden if 51P2AP := OFF)*	**51P2ATC**	:= ____________

Winding 2 Phase B Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P2BP**	:= ____________
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P2BP := OFF)*	**51P2BC**	:= ____________
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P2BP := OFF)*	**51P2BTD**	:= ____________
EM RESET DELAY (Y, N) *(Hidden if 51P2BP := OFF)*	**51P2BRS**	:= ____________
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P2BP := OFF)*	**51P2BCT**	:= ____________
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P2BP := OFF)*	**51P2BMR**	:= ____________
PH B TOC TRQCTRL (SELOGIC) *(Hidden if 51P2BP := OFF)*	**51P2BTC**	:= ____________

Winding 2 Phase C Time Overcurrent

PHASE TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51P2CP**	:= ____________
PHASE TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51P2CP := OFF)*	**51P2CC**	:= ____________
PHASE TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51P2CP := OFF)*	**51P2CTD**	:= ____________
EM RESET DELAY (Y, N) *(Hidden if 51P2CP := OFF)*	**51P2CRS**	:= ____________
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51P2CP := OFF)*	**51P2CCT**	:= ____________
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51P2CP := OFF)*	**51P2CMR**	:= ____________
PH C TOC TRQCTRL (SELOGIC) *(Hidden if 51P2CP := OFF)*	**51P2CTC**	:= ____________

Winding 2 Residual Time Overcurrent

All settings below are hidden when W2CT := DELTA.

RES TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51G2P**	:= ____________
RES TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51G2P := OFF)*	**51G2C**	:= ____________
RES TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51G2P := OFF)*	**51G2TD**	:= ____________
EM RESET DELAY (Y, N) *(Hidden if 51G2P := OFF)*	**51G2RS**	:= ____________
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51G2P := OFF)*	**51G2CT**	:= ____________
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51G2P := OFF)*	**51G2MR**	:= ____________
RES TOC TRQCTRL (SELOGIC) *(Hidden if 51G2P := OFF)*	**51G2TC**	:= ____________

Winding 2 Negative-Sequence Time Overcurrent

NSEQ TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51Q2P**	:=	
NSEQ TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51Q2P := OFF)*	**51Q2C**	:=	
NSEQ TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51Q2P := OFF)*	**51Q2TD**	:=	
EM RESET DELAY (Y, N) *(Hidden if 51Q2P := OFF)*	**51Q2RS**	:=	
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51Q2P := OFF)*	**51Q2CT**	:=	
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51Q2P := OFF)*	**51Q2MR**	:=	
NSEQ TOC TRQCTRL (SELOGIC) *(Hidden if 51Q2P := OFF)*	**51Q2TC**	:=	

Neutral Overcurrent

The following settings are hidden if neutral CT is not included.

NEUT IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50N11P**	:=	
NEUT IOC DELAY (0.00–5.00 sec) *(Hidden if 50N11P := OFF)*	**50N11D**	:=	
NEUT IOC TRQCTRL (SELOGIC) *(Hidden if 50N11P := OFF)*	**50N11TC**	:=	
NEUT IOC LEVEL (OFF, 0.50–96.00 A [5 A nom.], 0.10–19.20 A [1 A nom.])	**50N12P**	:=	
NEUT IOC DELAY (0.00–5.00 sec) *(Hidden if 50N12P := OFF)*	**50N12D**	:=	
NEUT IOC TRQCTRL (SELOGIC) *(Hidden if 50N12P := OFF)*	**50N12TC**	:=	

Neutral Time Overcurrent

The following settings are hidden if neutral CT is not included.

NEUT TOC LEVEL (OFF, 0.50–16.00 A [5 A nom.], 0.10–3.20 A [1 A nom.])	**51N1P**	:=	
RES TOC CURVE (U1, U2, U3, U4, U5, C1, C2, C3, C4, C5) *(Hidden if 51N1P := OFF)*	**51N1C**	:=	
RES TOC TDIAL (0.50–15.00 for U1–U5 OR 0.05–1.00 for C1–C5) *(Hidden if 51N1P := OFF)*	**51N1TD**	:=	
EM RESET DELAY (Y, N) *(Hidden if 51N1P := OFF)*	**51N1RS**	:=	
CONST TIME ADDER (0.00–1.00 sec) *(Hidden if 51N1P := OFF)*	**51N1CT**	:=	
MIN RESPONSE TIM (0.00–1.00 sec) *(Hidden if 51N1P := OFF)*	**51N1MR**	:=	
RES TOC TRQCTRL (SELOGIC) *(Hidden if 51N1P := OFF)*	**51N1TC**	:=	

RTD

RTD ENABLE (INT, EXT, NONE) (All RTD settings below hidden if E49RTD := NONE) *(INT hidden if Internal RTD card not detected)*	**E49RTD**	:=	

RTD1 LOCATION (OFF, AMB, OTH)	**RTD1LOC**	:= ________
RTD1 IDENTIFIER (10 characters) *(Hidden if RTD1LOC := OFF or AMB)*	**RTD1NAM**	:= ________
RTD1 TYPE (PT100, NI100, NI120, CU10) *(All RTD settings below hidden if E49RTD := NONE)*	**RTD1TY**	:= ________
RTD1 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD1LOC := OFF)*	**TRTMP1**	:= ________
RTD1 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD1LOC := OFF)*	**ALTMP1**	:= ________
RTD2 LOCATION (OFF, AMB, OTH)	**RTD2LOC**	:= ________
RTD2 IDENTIFIER (10 characters) *(Hidden if RTD2LOC := OFF or AMB)*	**RTD2NAM**	:= ________
RTD2 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD2LOC := OFF)*	**RTD2TY**	:= ________
RTD2 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD2LOC := OFF)*	**TRTMP2**	:= ________
RTD2 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD2LOC := OFF)*	**ALTMP2**	:= ________
RTD3 LOCATION (OFF, AMB, OTH)	**RTD3LOC**	:= ________
RTD3 IDENTIFIER (10 characters) *(Hidden if RTD3LOC := OFF or AMB)*	**RTD3NAM**	:= ________
RTD3 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD3LOC := OFF)*	**RTD3TY**	:= ________
RTD3 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD3LOC := OFF)*	**TRTMP3**	:= ________
RTD3 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD3LOC := OFF)*	**ALTMP3**	:= ________
RTD4 LOCATION (OFF, AMB, OTH)	**RTD4LOC**	:= ________
RTD4 IDENTIFIER (10 characters) *(Hidden if RTD4LOC := OFF or AMB)*	**RTD4NAM**	:= ________
RTD4 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD4LOC := OFF)*	**RTD4TY**	:= ________
RTD4 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD4LOC := OFF)*	**TRTMP4**	:= ________
RTD4 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD4LOC := OFF)*	**ALTMP4**	:= ________
RTD5 LOCATION (OFF, AMB, OTH)	**RTD5LOC**	:= ________
RTD5 IDENTIFIER (10 characters) *(Hidden if RTD5LOC := OFF or AMB)*	**RTD5NAM**	:= ________
RTD5 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD5LOC := OFF)*	**RTD5TY**	:= ________
RTD5 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD5LOC := OFF)*	**TRTMP5**	:= ________
RTD5 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD5LOC := OFF)*	**ALTMP5**	:= ________

RTD6 LOCATION (OFF, AMB, OTH)	**RTD6LOC**	:= ____________
RTD6 IDENTIFIER (10 characters) *(Hidden if RTD6LOC := OFF or AMB)*	**RTD6NAM**	:= ____________
RTD6 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD6LOC := OFF)*	**RTD6TY**	:= ____________
RTD6 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD6LOC := OFF)*	**TRTMP6**	:= ____________
RTD6 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD6LOC := OFF)*	**ALTMP6**	:= ____________
RTD7 LOCATION (OFF, AMB, OTH)	**RTD7LOC**	:= ____________
RTD7 IDENTIFIER (10 characters) *(Hidden if RTD7LOC := OFF or AMB)*	**RTD7NAM**	:= ____________
RTD7 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD7LOC := OFF)*	**RTD7TY**	:= ____________
RTD7 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD7LOC := OFF)*	**TRTMP7**	:= ____________
RTD7 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD7LOC := OFF)*	**ALTMP7**	:= ____________
RTD8 LOCATION (OFF, AMB, OTH)	**RTD8LOC**	:= ____________
RTD8 IDENTIFIER (10 characters) *(Hidden if RTD8LOC := OFF or AMB)*	**RTD8NAM**	:= ____________
RTD8 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD8LOC := OFF)*	**RTD8TY**	:= ____________
RTD8 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD8LOC := OFF)*	**TRTMP8**	:= ____________
RTD8 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD8LOC := OFF)*	**ALTMP8**	:= ____________
RTD9 LOCATION (OFF, AMB, OTH)	**RTD9LOC**	:= ____________
RTD9 IDENTIFIER (10 characters) *(Hidden if RTD9LOC := OFF or AMB)*	**RTD9NAM**	:= ____________
RTD9 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD9LOC := OFF)*	**RTD9TY**	:= ____________
RTD9 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD9LOC := OFF)*	**TRTMP9**	:= ____________
RTD9 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD9LOC := OFF)*	**ALTMP9**	:= ____________
RTD10 LOCATION (OFF, AMB, OTH)	**RTD10LOC**	:= ____________
RTD10 IDENTIFIER (10 characters) *(Hidden if RTD10LOC := OFF or AMB)*	**RTD10NAM**	:= ____________
RTD10 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD10LOC := OFF)*	**RTD10TY**	:= ____________
RTD10 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD10LOC := OFF)*	**TRTMP10**	:= ____________
RTD10 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD10LOC := OFF)*	**ALTMP10**	:= ____________

RTD11 LOCATION (OFF, AMB, OTH) *(Hidden if E49RTD := INT)*	**RTD11LOC**	:= ______________
RTD11 IDENTIFIER (10 characters) *(Hidden if RTD11LOC := OFF or AMB, or E49RTD := INT)*	**RTD11NAM**	:= ______________
RTD11 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD11LOC := OFF or E49RTD := INT)*	**RTD11TY**	:= ______________
RTD11 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD11LOC := OFF or E49RTD := INT)*	**TRTMP11**	:= ______________
RTD11 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD11LOC := OFF or E49RTD := INT)*	**ALTMP11**	:= ______________
RTD12 LOCATION (OFF, AMB, OTH) *(Hidden if E49RTD := INT)*	**RTD12LOC**	:= ______________
RTD12 IDENTIFIER (10 characters) *(Hidden if RTD12LOC := OFF or AMB, or E49RTD := INT)*	**RTD12NAM**	:= ______________
RTD12 TYPE (PT100, NI100, NI120, CU10) *(Hidden if RTD12LOC := OFF or E49RTD := INT)*	**RTD12TY**	:= ______________
RTD12 TRIP LEVEL (OFF, 1–250 degC) *(Hidden if RTD12LOC := OFF or E49RTD := INT)*	**TRTMP12**	:= ______________
RTD12 WARN LEVEL (OFF, 1–250 degC) *(Hidden if RTD12LOC := OFF or E49RTD := INT)*	**ALTMP12**	:= ______________

Phase Undervoltage *(Hidden if voltages not included.)*

PHASE UV LEVEL (OFF, 12.5–300.0 V)	**27P1P**	:= ______________
PHASE UV DELAY (0.0–120.0 sec) *(Hidden if 27P1P := OFF)*	**27P1D**	:= ______________
PHASE UV LEVEL (OFF, 12.5–300.0 V)	**27P2P**	:= ______________
PHASE UV DELAY (0.0–120.0 sec) *(Hidden if 27P2P := OFF)*	**27P2D**	:= ______________

Phase Overvoltage *(Hidden if voltages not included.)*

PHASE OV LEVEL (OFF, 12.5–300.0 V)	**59P1P**	:= ______________
PHASE OV DELAY (0.0–120.0 sec) *(Hidden if 59P1P := OFF)*	**59P1D**	:= ______________
PHASE OV LEVEL (OFF, 12.5–300.0 V)	**59P2P**	:= ______________
PHASE OV DELAY (0.0–120.0 sec) *(Hidden if 59P2P := OFF)*	**59P2D**	:= ______________

Negative-Sequence Overvoltage

(Hidden if voltages not included)

NSEQ OV LEVEL (OFF, 12.5–300.0 V)	**59Q1P**	:= ______________
NSEQ OV DELAY (0.0–120.0 sec) *(Hidden if 59Q1P := OFF)*	**59Q1D**	:= ______________
NSEQ OV LEVEL (OFF, 12.5–300.0 V)	**59Q2P**	:= ______________
NSEQ OV DELAY (0.0–120.0 sec) *(Hidden if 59Q2P := OFF)*	**59Q2D**	:= ______________

Volts/Hertz *(Hidden if voltages not included)*

ENABLE V/HZ PROT (Y, N) *(All V/HZ settings below hidden if E24 := N)*	**E24**	:= ______________

Date ____________
Group____________

XFMR WDG CONN (DELTA, WYE)	**24WDG**	:=
LVL1 V/HZ PICKUP (100–200 %)	**24D1P**	:=
LVL1 TIME DLY (0.04–400.00 s)	**24D1D**	:=
LVL2 CURVE SHAPE (OFF, DD, ID, I, U)	**24CCS**	:=
LVL2 INV-TM PU (100–200 %) *(Hidden if 24CCS := OFF or DD)*	**24IP**	:=
LVL2 INV-TM CURV (0.5, 1.0, 2.0) *(Hidden if 24CCS := OFF, DD or U)*	**24IC**	:=
LVL2 INV-TM FCTR (0.1–10.0 s) *(Hidden if 24CCS := OFF, DD or U)*	**24ITD**	:=
LVL2 PICKUP 1 (100–200 %) *(Hidden if 24CCS := OFF, ID, I or U)*	**24D2P1**	:=
LVL2 TIME DLY1 (0.04–400.00 s) *(Hidden if 24CCS := OFF, ID, I or U)*	**24D2D1**	:=
LVL2 PICKUP 2 (101–200 %) *(Hidden if 24CCS := OFF, I or U)*	**24D2P2**	:=
LVL2 TIME DLY2 (0.04–400.00 s) *(Hidden if 24CCS := OFF, I or U)*	**24D2D2**	:=
LVL2 RESET TIME (0.00–400.00 s) *(Hidden if 24CCS := OFF)*	**24CR**	:=
24ELEM TRQ-CNTRL (SELOGIC)	**24TC**	:=

Power *(Hidden if voltages not included)*

ENABLE POWER ELEM (N, 3P1, 3P2) *(All Power element settings below hidden if EPWR := N)*	**EPWR**	:=
3PH PWR ELEM PU (OFF, 0.2–1300.00 VA (1 A phase CTs), 1.0–6500.0 VA (5 A phase CTs)	**3PWR1P**	:=
PWR ELEM TYPE (+WATTS, -WATTS, +VARS, -VARS) *(Hidden if 3PRW1P := OFF)*	**PWR1T**	:=
PWR ELEM DELAY (0.0–240.0 s) *(Hidden if 3PRW1P := OFF)*	**PWR1D**	:=
3PH PWR ELEM PU (OFF, 0.2–1300.00 (1 A phase CTs), 1.0–6500.0 VA (5 A phase CTs) *(Hidden if EPWR := 3P1)*	**3PWR2P**	:=
PWR ELEM TYPE (+WATTS, -WATTS, +VARS, -VARS) *(Hidden if 3PRW2P := OFF or if EPWR := 3P1)*	**PWR2T**	:=
PWR ELEM DELAY (0.0–240.0 s) *(Hidden if 3PRW2P := OFF or if EPWR := 3P1)*	**PWR2D**	:=

Frequency *(Hidden if voltages not included)*

FREQ1 TRIP LEVEL (OFF, 20.0–70.0 Hz)	**81D1TP**	:=
FREQ1 TRIP DELAY (0.0–240.0 sec) *(Hidden if 81D1TP := OFF)*	**81D1TD**	:=
FREQ2 TRIP LEVEL (OFF, 20.0–70.0 Hz)	**81D2TP**	:=
FREQ2 TRIP DELAY (0.0–240.0 sec) *(Hidden if 81D2TP := OFF)*	**81D2TD**	:=
FREQ3 TRIP LEVEL (OFF, 20.0–70.0 Hz)	**81D3TP**	:=
FREQ3 TRIP DELAY (0.0–240.0 sec) *(Hidden if 81D3TP := OFF)*	**81D3TD**	:=

FREQ4 TRIP LEVEL (OFF, 20.0–70.0 Hz)	**81D4TP**	:=
FREQ4 TRIP DELAY (0.0–240.0 sec) *(Hidden if 81D4TP := OFF)*	**81D4TD**	:=

Demand Metering

ENABLE DEM MTR (OFF, W1, W2)	**EDEM**	:=
DEMAND MTR TYPE (THM, ROL) *(Hidden if EDEM := OFF)*	**DEMTY**	:=
DEM TIME CONSTNT (5, 10, 15, 30, 60 min) *(Hidden if EDEM := OFF)*	**DMTC**	:=
PH CURR DEM LVL (OFF, 0.50–16.00 A [5 A nom], 0.10–3.20 A [1 A nom]) *(Hidden if EDEM := OFF)*	**PHDEMP**	:=
RES CURR DEM LVL (OFF, 0.50–16.00 A [5 A nom], 0.10–3.20 A [1 A nom]) *(Hidden if EDEM := OFF)*	**GNDEMP**	:=
3I2 CURR DEM LVL (OFF, 0.50–16.00 A [5 A nom], 0.10–3.20 A [1 A nom]) *(Hidden if EDEM := OFF)*	**3I2DEMP**	:=

Trip/Close Logic

MIN TRIP TIME (0.0–400.0 sec)	**TDURD**	:=
CLOSE 1 FAIL DLY (0.0–400.0 sec)	**CFD1**	:=
CLOSE 2 FAIL DLY (0.0–400.0 sec)	**CFD2**	:=
TRIP 1 EQUATION (SELOGIC)	**TR1**	:=
TRIP 2 EQUATION (SELOGIC)	**TR2**	:=
TRIP XFMR EQN (SELOGIC)	**TRXFMR**	:=
REMOTE TRIP EQN (SELOGIC)	**REMTRIP**	:=
UNLATCH TRIP 1 (SELOGIC)	**ULTRIP1**	:=
UNLATCH TRIP 2 (SELOGIC)	**ULTRIP2**	:=
UNLATCH TRP XFMR (SELOGIC)	**ULTRXFMR**	:=
BREAKER 1 STATUS (SELOGIC)	**52A1**	:=
CLOSE 1 EQUATION (SELOGIC)	**CL1**	:=
UNLATCH CLOSE 1 EQUATION (SELOGIC)	**ULCL1**	:=
BREAKER 2 STATUS (SELOGIC)	**52A2**	:=
CLOSE 2 EQUATION (SELOGIC)	**CL2**	:=
UNLATCH CLOSE 2 EQUATION (SELOGIC)	**ULCL2**	:=

Logic Settings (SET L Command)

SELogic Enables

SELogic LATCHES (N, 1–32)	**ELAT**	:= ________
SV/TIMERS (N, 1–32)	**ESV**	:= ________
SELogic COUNTERS (N, 1–32)	**ESC**	:= ________
MATH VARIABLES (N, 1–32)	**EMV**	:= ________

Latch Bits Equations

SET01 := ________

RST01 := ________

SET02 := ________

RST02 := ________

SET03 := ________

RST03 := ________

SET04 := ________

RST04 := ________

SET05 := ________

RST05 := ________

SET06 := ________

RST06 := ________

SET07 := ________

RST07 := ________

SET08 := ________

RST08 := ________

SET09 := ________

RST09 := ________

SET10 := ________

RST10 := ________

SET11 := ________

RST11 := ________

SET12 := ________

RST12 := ________

SET13 := ________

RST13 := ________

SET14 := ________

RST14 := ________

SET15 := ________

RST15 := ________________

SET16 := ________________

RST16 := ________________

SET17 := ________________

RST17 := ________________

SET18 := ________________

RST18 := ________________

SET19 := ________________

RST19 := ________________

SET20 := ________________

RST20 := ________________

SET21 := ________________

RST21 := ________________

SET22 := ________________

RST22 := ________________

SET23 := ________________

RST23 := ________________

SET24 := ________________

RST24 := ________________

SET25 := ________________

RST25 := ________________

SET26 := ________________

RST26 := ________________

SET27 := ________________

RST27 := ________________

SET28 := ________________

RST28 := ________________

SET29 := ________________

RST29 := ________________

SET30 := ________________

RST30 := ________________

SET31 := ________________

RST31 := ________________

SET32 := ________________

RST32 := ________________

SV/Timers

SV TIMER PICKUP (0.00–3000.00 sec)	**SV01PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV01DO**	:=	
SV INPUT (SELOGIC)	**SV01**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV02PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV02DO**	:=	
SV INPUT (SELOGIC)	**SV02**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV03PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV03DO**	:=	
SV INPUT (SELOGIC)	**SV03**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV04PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV04DO**	:=	
SV INPUT (SELOGIC)	**SV04**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV05PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV05DO**	:=	
SV INPUT (SELOGIC)	**SV05**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV06PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV06DO**	:=	
SV INPUT (SELOGIC)	**SV06**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV07PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV07DO**	:=	
SV INPUT (SELOGIC)	**SV07**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV08PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV08DO**	:=	
SV INPUT (SELOGIC)	**SV08**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV09PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV09DO**	:=	
SV INPUT (SELOGIC)	**SV09**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV10PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV10DO**	:=	
SV INPUT (SELOGIC)	**SV10**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV11PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV11DO**	:=	
SV INPUT (SELOGIC)	**SV11**	:=	
SV TIMER PICKUP (0.00–3000.00 sec)	**SV12PU**	:=	
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV12DO**	:=	
SV INPUT (SELOGIC)	**SV12**	:=	

SV TIMER PICKUP (0.00–3000.00 sec)	**SV13PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV13DO**	:=	______
SV INPUT (SELOGIC)	**SV13**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV14PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV14DO**	:=	______
SV INPUT (SELOGIC)	**SV14**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV15PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV15DO**	:=	______
SV INPUT (SELOGIC)	**SV15**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV16PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV16DO**	:=	______
SV INPUT (SELOGIC)	**SV16**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV17PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV17DO**	:=	______
SV INPUT (SELOGIC)	**SV17**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV18PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV18DO**	:=	______
SV INPUT (SELOGIC)	**SV18**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV19PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV19DO**	:=	______
SV INPUT (SELOGIC)	**SV19**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV20PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV20DO**	:=	______
SV INPUT (SELOGIC)	**SV20**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV21PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV21DO**	:=	______
SV INPUT (SELOGIC)	**SV21**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV22PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV22DO**	:=	______
SV INPUT (SELOGIC)	**SV22**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV23PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV23DO**	:=	______
SV INPUT (SELOGIC)	**SV23**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV24PU**	:=	______
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV24DO**	:=	______
SV INPUT (SELOGIC)	**SV24**	:=	______
SV TIMER PICKUP (0.00–3000.00 sec)	**SV25PU**	:=	______

Date ____________
Group___________

SV TIMER DROPOUT (0.00–3000.00 sec)	**SV25DO**	:=	____________
SV INPUT (SELOGIC)	**SV25**	:=	____________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV26PU**	:=	____________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV26DO**	:=	____________
SV INPUT (SELOGIC)	**SV26**	:=	____________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV27PU**	:=	____________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV27DO**	:=	____________
SV INPUT (SELOGIC)	**SV27**	:=	____________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV28PU**	:=	____________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV28DO**	:=	____________
SV INPUT (SELOGIC)	**SV28**	:=	____________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV29PU**	:=	____________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV29DO**	:=	____________
SV INPUT (SELOGIC)	**SV29**	:=	____________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV30PU**	:=	____________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV30DO**	:=	____________
SV INPUT (SELOGIC)	**SV30**	:=	____________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV31PU**	:=	____________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV31DO**	:=	____________
SV INPU (SELOGIC)	**SV31**	:=	____________
SV TIMER PICKUP (0.00–3000.00 sec)	**SV32PU**	:=	____________
SV TIMER DROPOUT (0.00–3000.00 sec)	**SV32DO**	:=	____________
SV INPUT (SELOGIC)	**SV32**	:=	____________

Counters Equations

SC PRESET VALUE (1–65000)	**SC01PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC01R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC01LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC01CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC01CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC02PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC02R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC02LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC02CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC02CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC03PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC03R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC03LD**	:=	____________

SC CNT UP INPUT (SELOGIC)	**SC03CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC03CD**	:=	______
SC PRESET VALUE (1–65000)	**SC04PV**	:=	______
SC RESET INPUT (SELOGIC)	**SC04R**	:=	______
SC LOAD PV INPUT (SELOGIC)	**SC04LD**	:=	______
SC CNT UP INPUT (SELOGIC)	**SC04CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC04CD**	:=	______
SC PRESET VALUE (1–65000)	**SC05PV**	:=	______
SC RESET INPUT (SELOGIC)	**SC05R**	:=	______
SC LOAD PV INPUT (SELOGIC)	**SC05LD**	:=	______
SC CNT UP INPUT (SELOGIC)	**SC05CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC05CD**	:=	______
SC PRESET VALUE (1–65000)	**SC06PV**	:=	______
SC RESET INPUT (SELOGIC)	**SC06R**	:=	______
SC LOAD PV INPUT (SELOGIC)	**SC06LD**	:=	______
SC CNT UP INPUT (SELOGIC)	**SC06CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC06CD**	:=	______
SC PRESET VALUE (1–65000)	**SC07PV**	:=	______
SC RESET INPUT (SELOGIC)	**SC07R**	:=	______
SC LOAD PV INPUT (SELOGIC)	**SC07LD**	:=	______
SC CNT UP INPUT (SELOGIC)	**SC07CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC07CD**	:=	______
SC PRESET VALUE (1–65000)	**SC08PV**	:=	______
SC RESET INPUT (SELOGIC)	**SC08R**	:=	______
SC LOAD PV INPUT (SELOGIC)	**SC08LD**	:=	______
SC CNT UP INPUT (SELOGIC)	**SC08CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC08CD**	:=	______
SC PRESET VALUE (1–65000)	**SC09PV**	:=	______
SC RESET INPUT (SELOGIC)	**SC09R**	:=	______
SC LOAD PV INPUT (SELOGIC)	**SC09LD**	:=	______
SC CNT UP INPUT (SELOGIC)	**SC09CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC09CD**	:=	______
SC PRESET VALUE (1–65000)	**SC10PV**	:=	______
SC RESET INPUT (SELOGIC)	**SC10R**	:=	______
SC LOAD PV INPUT (SELOGIC)	**SC10LD**	:=	______
SC CNT UP INPUT (SELOGIC)	**SC10CU**	:=	______
SC CNT DN INPUT (SELOGIC)	**SC10CD**	:=	______

SC PRESET VALUE (1–65000)	**SC11PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC11R**	:= ______
SC LOAD PV INPUT (SELOGIC)	**SC11LD**	:= ______
SC CNT UP INPUT (SELOGIC)	**SC11CU**	:= ______
SC CNT DN INPUT (SELOGIC)	**SC11CD**	:= ______
SC PRESET VALUE (1–65000)	**SC12PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC12R**	:= ______
SC LOAD PV INPUT (SELOGIC)	**SC12LD**	:= ______
SC CNT UP INPUT (SELOGIC)	**SC12CU**	:= ______
SC CNT DN INPUT (SELOGIC)	**SC12CD**	:= ______
SC PRESET VALUE (1–65000)	**SC13PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC13R**	:= ______
SC LOAD PV INPUT (SELOGIC)	**SC13LD**	:= ______
SC CNT UP INPUT (SELOGIC)	**SC13CU**	:= ______
SC CNT DN INPUT (SELOGIC)	**SC13CD**	:= ______
SC PRESET VALUE (1–65000)	**SC14PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC14R**	:= ______
SC LOAD PV INPUT (SELOGIC)	**SC14LD**	:= ______
SC CNT UP INPUT (SELOGIC)	**SC14CU**	:= ______
SC CNT DN INPUT (SELOGIC)	**SC14CD**	:= ______
SC PRESET VALUE (1–65000)	**SC15PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC15R**	:= ______
SC LOAD PV INPUT (SELOGIC)	**SC15LD**	:= ______
SC CNT UP INPUT (SELOGIC)	**SC15CU**	:= ______
SC CNT DN INPUT (SELOGIC)	**SC15CD**	:= ______
SC PRESET VALUE (1–65000)	**SC16PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC16R**	:= ______
SC LOAD PV INPUT (SELOGIC)	**SC16LD**	:= ______
SC CNT UP INPUT (SELOGIC)	**SC16CU**	:= ______
SC CNT DN INPUT (SELOGIC)	**SC16CD**	:= ______
SC PRESET VALUE (1–65000)	**SC17PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC17R**	:= ______
SC LOAD PV INPUT (SELOGIC)	**SC17LD**	:= ______
SC CNT UP INPUT (SELOGIC)	**SC17CU**	:= ______
SC CNT DN INPUT (SELOGIC)	**SC17CD**	:= ______
SC PRESET VALUE (1–65000)	**SC18PV**	:= ______
SC RESET INPUT (SELOGIC)	**SC18R**	:= ______

SC LOAD PV INPUT (SELOGIC)	**SC18LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC18CU**	:= ____________
SC CNT DN INPUT (SELOGIC)	**SC18CD**	:= ____________
SC PRESET VALUE (1–65000)	**SC19PV**	:= ____________
SC RESET INPUT (SELOGIC)	**SC19R**	:= ____________
SC LOAD PV INPUT (SELOGIC)	**SC19LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC19CU**	:= ____________
SC CNT DN INPUT (SELOGIC)	**SC19CD**	:= ____________
SC PRESET VALUE (1–65000)	**SC20PV**	:= ____________
SC RESET INPUT (SELOGIC)	**SC20R**	:= ____________
SC LOAD PV INPUT (SELOGIC)	**SC20LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC20CU**	:= ____________
SC CNT DN INPUT (SELOGIC)	**SC20CD**	:= ____________
SC PRESET VALUE (1–65000)	**SC21PV**	:= ____________
SC RESET INPUT (SELOGIC)	**SC21R**	:= ____________
SC LOAD PV INPUT (SELOGIC)	**SC21LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC21CU**	:= ____________
SC CNT DN INPUT (SELOGIC)	**SC21CD**	:= ____________
SC PRESET VALUE (1–65000)	**SC22PV**	:= ____________
SC RESET INPUT (SELOGIC)	**SC22R**	:= ____________
SC LOAD PV INPUT (SELOGIC)	**SC22LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC22CU**	:= ____________
SC CNT DN INPUT (SELOGIC)	**SC22CD**	:= ____________
SC PRESET VALUE (1–65000)	**SC23PV**	:= ____________
SC RESET INPUT (SELOGIC)	**SC23R**	:= ____________
SC LOAD PV INPUT (SELOGIC)	**SC23LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC23CU**	:= ____________
SC CNT DN INPUT (SELOGIC)	**SC23CD**	:= ____________
SC PRESET VALUE (1–65000)	**SC24PV**	:= ____________
SC RESET INPUT (SELOGIC)	**SC24R**	:= ____________
SC LOAD PV INPUT (SELOGIC)	**SC24LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC24CU**	:= ____________
SC CNT DN INPUT (SELOGIC)	**SC24CD**	:= ____________
SC PRESET VALUE (1–65000)	**SC25PV**	:= ____________
SC RESET INPUT (SELOGIC)	**SC25R**	:= ____________
SC LOAD PV INPUT (SELOGIC)	**SC25LD**	:= ____________
SC CNT UP INPUT (SELOGIC)	**SC25CU**	:= ____________

SC CNT DN INPUT (SELOGIC)	**SC25CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC26PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC26R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC26LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC26CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC26CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC27PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC27R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC27LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC27CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC27CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC28PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC28R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC28LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC28CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC28CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC29PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC29R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC29LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC29CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC29CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC30PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC30R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC30LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC30CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC30CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC31PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC31R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC31LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC31CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC31CD**	:=	____________
SC PRESET VALUE (1–65000)	**SC32PV**	:=	____________
SC RESET INPUT (SELOGIC)	**SC32R**	:=	____________
SC LOAD PV INPUT (SELOGIC)	**SC32LD**	:=	____________
SC CNT UP INPUT (SELOGIC)	**SC32CU**	:=	____________
SC CNT DN INPUT (SELOGIC)	**SC32CD**	:=	____________

Math Variables

MV01	:=	______
MV02	:=	______
MV03	:=	______
MV04	:=	______
MV05	:=	______
MV06	:=	______
MV07	:=	______
MV08	:=	______
MV09	:=	______
MV10	:=	______
MV11	:=	______
MV12	:=	______
MV13	:=	______
MV14	:=	______
MV15	:=	______
MV16	:=	______
MV17	:=	______
MV18	:=	______
MV19	:=	______
MV20	:=	______
MV21	:=	______
MV22	:=	______
MV23	:=	______
MV24	:=	______
MV25	:=	______
MV26	:=	______
MV27	:=	______
MV28	:=	______
MV29	:=	______
MV30	:=	______
MV31	:=	______
MV32	:=	______

Date ____________
Group____________

Base Output

OUT101 FAIL-SAFE (Y, N) **OUT101FS** := ____________

OUT101 := ____________

OUT102 FAIL-SAFE (Y, N) **OUT102FS** := ____________

OUT102 := ____________

OUT103 FAIL-SAFE (Y, N) **OUT103FS** := ____________

OUT103 := ____________

Slot C Output

OUT301 FAIL-SAFE (Y, N) **OUT301FS** := ____________

OUT301 := ____________

OUT302 FAIL-SAFE (Y, N) **OUT302FS** := ____________

OUT302 := ____________

OUT303 FAIL-SAFE (Y, N) **OUT303FS** := ____________

OUT303 := ____________

OUT304 FAIL-SAFE (Y, N) **OUT304FS** := ____________

OUT304 := ____________

Slot D Output

OUT401 FAIL-SAFE (Y, N) **OUT401FS** := ____________

OUT401 := ____________

OUT402 FAIL-SAFE (Y, N) **OUT402FS** := ____________

OUT402 := ____________

OUT403 FAIL-SAFE (Y, N) **OUT403FS** := ____________

OUT403 := ____________

OUT404 FAIL-SAFE (Y, N) **OUT404FS** := ____________

OUT404 := ____________

Slot E Output

OUT501 FAIL-SAFE (Y, N) **OUT501FS** := ____________

OUT501 := ____________

OUT502 FAIL-SAFE (Y, N) **OUT502FS** := ____________

OUT502 := ____________

OUT503 FAIL-SAFE (Y, N) **OUT503FS** := ____________

OUT503 := ____________

OUT504 FAIL-SAFE (Y, N) **OUT504FS** := ____________

OUT504 := ____________

MIRRORED BITS Transmit SELOGIC Equations

(Hidden if PROTO is not MBxx on any of the communications ports.)

TMB1A := ______________________

TMB2A := ______________________

TMB3A := ______________________

TMB4A := ______________________

TMB5A := ______________________

TMB6A := ______________________

TMB7A := ______________________

TMB8A := ______________________

TMB1B := ______________________

TMB2B := ______________________

TMB3B := ______________________

TMB4B := ______________________

TMB5B := ______________________

TMB6B := ______________________

TMB7B := ______________________

TMB8B := ______________________

Date ____________
Group___________

Global Settings (SET G Command)

General

PHASE ROTATION (ABC, ACB)	**PHROT**	:=	________
RATED FREQ. (50, 60 Hz)	**FNOM**	:=	________
DATE FORMAT (MDY, YMD, DMY)	**DATE_F**	:=	________
FAULT CONDITION (SELOGIC)	**FAULT**	:=	________
EVE MSG PTS ENABL (N, 1–32)	**EMP**	:=	________

Event Messenger Points (Only the points enabled by EMP are visible)

MESSENGER POINT MP01 TRIGGER (Off, 1 Relay Word bit)	**MPTR01**	:=	________
MESSENGER POINT MP01 AQ (None, 1 analog quantity)	**MPAQ01**	:=	________
MESSENGER POINT MP01 TEXT (148 characters)	**MPTX01**	:=	________
MESSENGER POINT MP02 TRIGGER (Off, 1 Relay Word bit)	**MPTR02**	:=	________
MESSENGER POINT MP02 AQ (None, 1 analog quantity)	**MPAQ02**	:=	________
MESSENGER POINT MP02 TEXT (148 characters)	**MPTX02**	:=	________
MESSENGER POINT MP03 TRIGGER (Off, 1 Relay Word bit)	**MPTR03**	:=	________
MESSENGER POINT MP03 AQ (None, 1 analog quantity)	**MPAQ03**	:=	________
MESSENGER POINT MP03 TEXT (148 characters)	**MPTX03**	:=	________
MESSENGER POINT MP04 TRIGGER (Off, 1 Relay Word bit)	**MPTR04**	:=	________
MESSENGER POINT MP04 AQ (None, 1 analog quantity)	**MPAQ04**	:=	________
MESSENGER POINT MP04 TEXT (148 characters)	**MPTX04**	:=	________
MESSENGER POINT MP05 TRIGGER (Off, 1 Relay Word bit)	**MPTR05**	:=	________
MESSENGER POINT MP05 AQ (None, 1 analog quantity)	**MPAQ05**	:=	________
MESSENGER POINT MP05 TEXT (148 characters)	**MPTX05**	:=	________
MESSENGER POINT MP06 TRIGGER (Off, 1 Relay Word bit)	**MPTR06**	:=	________
MESSENGER POINT MP06 AQ (None, 1 analog quantity)	**MPAQ06**	:=	________
MESSENGER POINT MP06 TEXT (148 characters)	**MPTX06**	:=	________
MESSENGER POINT MP07 TRIGGER (Off, 1 Relay Word bit)	**MPTR07**	:=	________
MESSENGER POINT MP07 AQ (None, 1 analog quantity)	**MPAQ07**	:=	________
MESSENGER POINT MP07 TEXT (148 characters)	**MPTX07**	:=	________
MESSENGER POINT MP08 TRIGGER (Off, 1 Relay Word bit)	**MPTR08**	:=	________
MESSENGER POINT MP08 AQ (None, 1 analog quantity)	**MPAQ08**	:=	________
MESSENGER POINT MP08 TEXT (148 characters)	**MPTX08**	:=	________
MESSENGER POINT MP09 TRIGGER (Off, 1 Relay Word bit)	**MPTR09**	:=	________
MESSENGER POINT MP09 AQ (None, 1 analog quantity)	**MPAQ09**	:=	________
MESSENGER POINT MP09 TEXT (148 characters)	**MPTX09**	:=	________
MESSENGER POINT MP10 TRIGGER (Off, 1 Relay Word bit)	**MPTR10**	:=	________

MESSENGER POINT MP10 AQ (None, 1 analog quantity)	**MPAQ10**	:=	______
MESSENGER POINT MP10 TEXT (148 characters)	**MPTX10**	:=	______
MESSENGER POINT MP11 TRIGGER (Off, 1 Relay Word bit)	**MPTR11**	:=	______
MESSENGER POINT MP11 AQ (None, 1 analog quantity)	**MPAQ11**	:=	______
MESSENGER POINT MP11 TEXT (148 characters)	**MPTX11**	:=	______
MESSENGER POINT MP12 TRIGGER (Off, 1 Relay Word bit)	**MPTR12**	:=	______
MESSENGER POINT MP12 AQ (None, 1 analog quantity)	**MPAQ12**	:=	______
MESSENGER POINT MP12 TEXT (148 characters)	**MPTX12**	:=	______
MESSENGER POINT MP13 TRIGGER (Off, 1 Relay Word bit)	**MPTR13**	:=	______
MESSENGER POINT MP13 AQ (None, 1 analog quantity)	**MPAQ13**	:=	______
MESSENGER POINT MP13 TEXT (148 characters)	**MPTX13**	:=	______
MESSENGER POINT MP14 TRIGGER (Off, 1 Relay Word bit)	**MPTR14**	:=	______
MESSENGER POINT MP14 AQ (None, 1 analog quantity)	**MPAQ14**	:=	______
MESSENGER POINT MP14 TEXT (148 characters)	**MPTX14**	:=	______
MESSENGER POINT MP15 TRIGGER (Off, 1 Relay Word bit)	**MPTR15**	:=	______
MESSENGER POINT MP15 AQ (None, 1 analog quantity)	**MPAQ15**	:=	______
MESSENGER POINT MP15 TEXT (148 characters)	**MPTX15**	:=	______
MESSENGER POINT MP16 TRIGGER (Off, 1 Relay Word bit)	**MPTR16**	:=	______
MESSENGER POINT MP16 AQ (None, 1 analog quantity)	**MPAQ16**	:=	______
MESSENGER POINT MP16 TEXT (148 characters)	**MPTX16**	:=	______
MESSENGER POINT MP17 TRIGGER (Off, 1 Relay Word bit)	**MPTR17**	:=	______
MESSENGER POINT MP17 AQ (None, 1 analog quantity)	**MPAQ17**	:=	______
MESSENGER POINT MP17 TEXT (148 characters)	**MPTX17**	:=	______
MESSENGER POINT MP18 TRIGGER (Off, 1 Relay Word bit)	**MPTR18**	:=	______
MESSENGER POINT MP18 AQ (None, 1 analog quantity)	**MPAQ18**	:=	______
MESSENGER POINT MP18 TEXT (148 characters)	**MPTX18**	:=	______
MESSENGER POINT MP19 TRIGGER (Off, 1 Relay Word bit)	**MPTR19**	:=	______
MESSENGER POINT MP19 AQ (None, 1 analog quantity)	**MPAQ19**	:=	______
MESSENGER POINT MP19 TEXT (148 characters)	**MPTX19**	:=	______
MESSENGER POINT MP20 TRIGGER (Off, 1 Relay Word bit)	**MPTR20**	:=	______
MESSENGER POINT MP20 AQ (None, 1 analog quantity)	**MPAQ20**	:=	______
MESSENGER POINT MP20 TEXT (148 characters)	**MPTX20**	:=	______
MESSENGER POINT MP21 TRIGGER (Off, 1 Relay Word bit)	**MPTR21**	:=	______
MESSENGER POINT MP21 AQ (None, 1 analog quantity)	**MPAQ21**	:=	______
MESSENGER POINT MP21 TEXT (148 characters)	**MPTX21**	:=	______
MESSENGER POINT MP22 TRIGGER (Off, 1 Relay Word bit)	**MPTR22**	:=	______
MESSENGER POINT MP22 AQ (None, 1 analog quantity)	**MPAQ22**	:=	______

MESSENGER POINT MP22 TEXT (148 characters)	**MPTX22**	:= ________
MESSENGER POINT MP23 TRIGGER (Off, 1 Relay Word bit)	**MPTR23**	:= ________
MESSENGER POINT MP23 AQ (None, 1 analog quantity)	**MPAQ23**	:= ________
MESSENGER POINT MP23 TEXT (148 characters)	**MPTX23**	:= ________
MESSENGER POINT MP24 TRIGGER (Off, 1 Relay Word bit)	**MPTR24**	:= ________
MESSENGER POINT MP24 AQ (None, 1 analog quantity)	**MPAQ24**	:= ________
MESSENGER POINT MP24 TEXT (148 characters)	**MPTX24**	:= ________
MESSENGER POINT MP25 TRIGGER (Off, 1 Relay Word bit)	**MPTR25**	:= ________
MESSENGER POINT MP25 AQ (None, 1 analog quantity)	**MPAQ25**	:= ________
MESSENGER POINT MP25 TEXT (148 characters)	**MPTX25**	:= ________
MESSENGER POINT MP26 TRIGGER (Off, 1 Relay Word bit)	**MPTR26**	:= ________
MESSENGER POINT MP26 AQ (None, 1 analog quantity)	**MPAQ26**	:= ________
MESSENGER POINT MP26 TEXT (148 characters)	**MPTX26**	:= ________
MESSENGER POINT MP27 TRIGGER (Off, 1 Relay Word bit)	**MPTR27**	:= ________
MESSENGER POINT MP27 AQ (None, 1 analog quantity)	**MPAQ27**	:= ________
MESSENGER POINT MP27 TEXT (148 characters)	**MPTX27**	:= ________
MESSENGER POINT MP28 TRIGGER (Off, 1 Relay Word bit)	**MPTR28**	:= ________
MESSENGER POINT MP28 AQ (None, 1 analog quantity)	**MPAQ28**	:= ________
MESSENGER POINT MP28 TEXT (148 characters)	**MPTX28**	:= ________
MESSENGER POINT MP29 TRIGGER (Off, 1 Relay Word bit)	**MPTR29**	:= ________
MESSENGER POINT MP29 AQ (None, 1 analog quantity)	**MPAQ29**	:= ________
MESSENGER POINT MP29 TEXT (148 characters)	**MPTX29**	:= ________
MESSENGER POINT MP30 TRIGGER (Off, 1 Relay Word bit)	**MPTR30**	:= ________
MESSENGER POINT MP30 AQ (None, 1 analog quantity)	**MPAQ30**	:= ________
MESSENGER POINT MP30 TEXT (148 characters)	**MPTX30**	:= ________
MESSENGER POINT MP31 TRIGGER (Off, 1 Relay Word bit)	**MPTR31**	:= ________
MESSENGER POINT MP31 AQ (None, 1 analog quantity)	**MPAQ31**	:= ________
MESSENGER POINT MP31 TEXT (148 characters)	**MPTX31**	:= ________
MESSENGER POINT MP32 TRIGGER (Off, 1 Relay Word bit)	**MPTR32**	:= ________
MESSENGER POINT MP32 AQ (None, 1 analog quantity)	**MPAQ32**	:= ________
MESSENGER POINT MP32 TEXT (148 characters)	**MPTX32**	:= ________

Group Selection

GRP CHG DELAY (0–400 sec)	**TGR**	:= ________
SELECT GROUP1 (SELOGIC)	**SS1**	:= ________
SELECT GROUP2 (SELOGIC)	**SS2**	:= ________
SELECT GROUP3 (SELOGIC)	**SS3**	:= ________
SELECT GROUP4 (SELOGIC)	**SS4**	:= ________

Phasor Measurement (PMU)

EN SYNCHRO PHSOR (Y, N) *(All subsequent PMU settings hidden if EPMU :=N)*	**EPMU**	:= ______
MESSAGES PER SEC (1, 2, 5, 10)	**MRATE**	:= ______
STATION NAME (16 characters)	**PMSTN**	:= ______
PMU HARDWARE ID (1–65534)	**PMID**	:= ______
VOLTAGE DATA SET (V1, ALL, NA) *(Hidden if no voltages)*	**PHDATAV**	:= ______
VOLT COMP ANGLE (-179.99 to 180.00 deg) *(Hidden if PHDATAV := NA)*	**VCOMP**	:= ______
CURRENT DATA SET (I1, ALL, NA)	**PHDATAI**	:= ______
CURRENT SOURCE (IW1, IW2, BOTH) *(Hidden if PHDATAI := NA)*	**PHCURR**	:= ______
IW1 COMP ANGLE (-179.99 to 180.00 deg) *(Hidden if PHCURR := IW2 or if PHDATAI := NA)*	**IW1COMP**	:= ______
IW2 COMP ANGLE (-179.99 to 180.00 deg) *(Hidden if PHCURR := IW1 or if PHDATAI := NA)*	**IW2COMP**	:= ______
NUM ANALOGS (0–4)	**NUMANA**	:= ______
NUM 16BIT DIGTAL (0, 1)	**NUMDSW**	:= ______
TRIG REASON BIT1 (SELOGIC)	**TREA1**	:= ______
TRIG REASON BIT2 (SELOGIC)	**TREA2**	:= ______
TRIG REASON BIT3 (SELOGIC)	**TREA3**	:= ______
TRIG REASON BIT4 (SELOGIC)	**TREA4**	:= ______
TRIGGER ((SELOGIC)	**PMTRIG**	:= ______

Time and Date Management

CTRL BITS DEFN (NONE, C37.118)	**IRIGC**	:= ______
OFFSET FROM UTC (–24.00 to 24.00) rounded up to quarter	**UTC_OFF**	:= ______
MONTH TO BEGIN DST (OFF, 1–12)	**DST_BEGM**	:= ______
WEEK OF THE MONTH TO BEGIN DST (1–3, L) L = Last week of the month (*Hidden if DST_BEGM := OFF*)	**DST_BEGW**	:= ______
DAY OF THE WEEK TO BEGIN DST (SUN, MON, TUE, WED, THU, FRI, SAT) (*Hidden if DST_BEGM := OFF*)	**DST_BEGD**	:= ______
LOCAL HOUR TO BEGIN DST (0–23)(*Hidden if DST_BEGM := OFF*)	**DST_BEGH**	:= ______
MONTH TO END DST (1–12) (*Hidden if DST_BEGM := OFF*)	**DST_ENDM**	:= ______
WEEK OF THE MONTH TO END DST (1–3, L) L = Last week of the month (*Hidden if DST_BEGM := OFF*)	**DST_ENDW**	:= ______
DAY OF THE WEEK TO END DST (SUN, MON, TUE, WED, THU, FRI, SAT) (*Hidden if DST_BEGM := OFF*)	**DST_ENDD**	:= ______
LOCAL HOUR TO END DST (0–23) (*Hidden if DST_BEGM := OFF*)	**DST_ENDH**	:= ______

Breaker Failure

52A INTERLOCK (Y, N)	**52ABF**	:= ______

BRKR1 FAIL DELAY (0.00–2.00 sec)	**BFD1**	:=
BRKR1 FAIL INITIATE ((SELOGIC)	**BFI1**	:=
BRKR2 FAIL DELAY (0.00–2.00 sec)	**BFD2**	:=
BRKR2 FAIL INITIATE ((SELOGIC)	**BFI2**	:=

Through Fault

THR FLT WDG (OFF, 1, 2)	**THFLTD**	:=
ENABLE THR FLT ((SELOGIC) *(Hidden if THFLTD := OFF)*	**ETHRFLT**	:=
THR FLT ALARM PU (50.0–900.0 %) *(Hidden if THFLTD := OFF)*	**THFLTPU**	:=
XFMR IMPEDANCE (2.0–40.0 %) *(Hidden if THFLTD := OFF)*	**XFMRZ**	:=

Analog Inputs

For the following settings, x is the card position (3, 4, or 5 in Slot **C**, **D**, and **E**, respectively).

AIx01

AI*x*01 TAG NAME (8 characters 0–9, A–Z, _)	**AI*x*01NAM**	:=
AI*x*01 TYPE (I, V)	**AI*x*01TYP**	:=
If AI*x*01TYP = I		
AI*x*01 LOW IN VAL (–20.480 to +20.480; mA)	**AI*x*01L**	:=
AI*x*01 HI IN VAL (–20.480 to +20.480; mA)	**AI*x*01H**	:=
If AI*x*01TYP = V		
AI*x*01 LOW IN VAL (–10.240 to +10.240 V)	**AI*x*01L**	:=
AI*x*01 HI IN VAL (–10.240 to +10.240 V)	**AI*x*01H**	:=

NOTE: Set Warn and Alarm to a value between Engr Low and Engr High settings.

AI*x*01 ENG UNITS (16 characters)	**AI*x*01EU**	:=
AI*x*01 EU LOW (–99999.000 to +99999.000)	**AI*x*01EL**	:=
AI*x*01 EU HI (–99999.000 to +99999.000)	**AI*x*01EH**	:=
AI*x*01 LO WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*01LW1**	:=
AI*x*01 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*01LW2**	:=
AI*x*01 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*01LAL**	:=
AI*x*01 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*01HW1**	:=
AI*x*01 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*01HW2**	:=
AI*x*01 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*01HAL**	:=

AIx02

AI*x*02 TAG NAME (8 characters 0–9, A–Z, _)	**AI*x*02NAM**	:=
AI*x*02 TYPE (I, V)	**AIx02TYP**	:=

If AI*x*02TYP = I		
AI*x*02 LOW IN VAL (–20.480 to +20.480; mA)	**AI*x*02L**	:=
AI*x*02 HI IN VAL (–20.480 to +20.480; mA)	**AI*x*02H**	:=
If AI*x*02TYP = V		
AI*x*02 LOW IN VAL (–10.240 to +10.240 V)	**AI*x*02L**	:=
AI*x*02 HI IN VAL (–10.240 to +10.240 V)	**AI*x*02H**	:=
AI*x*02 ENG UNITS (16 characters)	**AI*x*02EU**	:=
AI*x*02 EU LOW (–99999.000 to +99999.000)	**AI*x*02EL**	:=
AI*x*02 EU HI (–99999.000 to +99999.000)	**AI*x*02EH**	:=
AI*x*02 LO WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*02LW1**	:=
AI*x*02 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*02LW2**	:=
AI*x*02 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*02LAL**	:=
AI*x*02 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*02HW1**	:=
AI*x*02 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*02HW2**	:=
AI*x*02 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*02HAL**	:=

AIx03

AI*x*03 TAG NAME (8 characters 0–9, A–Z, _)	**AI*x*03NAM**	:=
AI*x*03 TYPE (I, V)	**AIx03TYP**	:=
If AI*x*03TYP = I		
AI*x*03 LOW IN VAL (–20.480 to +20.480; mA)	**AI*x*03L**	:=
AI*x*03 HI IN VAL (–20.480 to +20.480; mA)	**AI*x*03H**	:=
If AI*x*03TYP = V		
AI*x*03 LOW IN VAL (–10.240 to +10.240 V)	**AI*x*03L**	:=
AI*x*03 HI IN VAL (–10.240 to +10.240 V)	**AI*x*03H**	:=
AI*x*03 ENG UNITS (16 characters)	**AI*x*03EU**	:=
AI*x*03 EU LOW (–99999.000 to +99999.000)	**AI*x*03EL**	:=
AI*x*03 EU HI (–99999.000 to +99999.000)	**AI*x*03EH**	:=
AI*x*03 LO WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*03LW1**	:=
AI*x*03 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*03LW2**	:=
AI*x*03 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*03LAL**	:=
AI*x*03 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*03HW1**	:=
AI*x*03 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*03HW2**	:=
AI*x*03 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*03HAL**	:=

AIx04

AI*x*04 TAG NAME (8 characters 0–9, A–Z, _)	**AI*x*04NAM**	:=
AI*x*04 TYPE (I, V)	**AIx04TYP**	:=
If AI*x*04TYP = I		
AI*x*04 LOW IN VAL (–20.480 to +20.480; mA)	**AI*x*04L**	:=

AI*x*04 HI IN VAL (–20.480 to +20.480; mA)	**AI*x*04H**	:=
If AI*x*04TYP = V		
AI*x*04 LOW IN VAL (–10.240 to +10.240 V)	**AI*x*04L**	:=
AI*x*04 HI IN VAL (–10.240 to +10.240 V)	**AI*x*04H**	:=
AI*x*04 ENG UNITS (16 characters)	**AI*x*04EU**	:=
AI*x*04 EU LOW (–99999.000 to +99999.000)	**AI*x*04EL**	:=
AI*x*04 EU HI (–99999.000 to +99999.000)	**AI*x*04EH**	:=
AI*x*04 LO WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*04LW1**	:=
AI*x*04 LO WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*04LW2**	:=
AI*x*04 LO ALARM (OFF, –99999.000 to +99999.000)	**AI*x*04LAL**	:=
AI*x*04 HI WARN L1 (OFF, –99999.000 to +99999.000)	**AI*x*04HW1**	:=
AI*x*04 HI WARN L2 (OFF, –99999.000 to +99999.000)	**AI*x*04HW2**	:=
AI*x*04 HI ALARM (OFF, –99999.000 to +99999.000)	**AI*x*04HAL**	:=

Analog Outputs

For the following settings, x is the card position (3, 4, or 5 in Slot **C**, **D**, and **E**, respectively).

AOx01

AO*x*01 ANALOG QTY (Off, 1 analog quantity)	**AO*x*01AQ**	:=
AO*x*01 TYPE (I, V)	**AO*x*01TYP**	:=
AO*x*01 AQTY LOW (–2147483647 to +2147483647)	**AO*x*01AQL**	:=
AO*x*01 AQTY HI (–2147483647 to +2147483647)	**AO*x*01AQH**	:=
If AO*x*01TYP = I		
AO*x*01 LO OUT VAL (–20.480 to +20.480 mA)	**AO*x*01L**	:=
AO*x*01 HI OUT VAL (–20.480 to +20.480 mA)	**AO*x*01H**	:=
If AO*x*01TYP = V		
AO*x*01 LO OUT VAL (–10.240 to +10.240 V)	**AO*x*01L**	:=
AO*x*01 HI OUT VAL (–10.240 to +10.240 V)	**AO*x*01H**	:=

AOx02

AO*x*02 ANALOG QTY (Off, 1 analog quantity)	**AO*x*02AQ**	:=
AO*x*02 TYPE (I, V)	**AO*x*02TYP**	:=
AO*x*02 AQTY LOW (–2147483647 to +2147483647)	**AO*x*02AQL**	:=
AO*x*02 AQTY HI (–2147483647 to +2147483647)	**AO*x*02AQH**	:=
If AO*x*02TYP = I		
AO*x*02 LO OUT VAL (–20.480 to +20.480 mA)	**AO*x*02L**	:=
AO*x*02 HI OUT VAL (–20.480 to +20.480 mA)	**AO*x*02H**	:=
If AO*x*02TYP = V		
AO*x*02 LO OUT VAL (–10.240 to +10.240 V)	**AO*x*02L**	:=
AO*x*02 HI OUT VAL (–10.240 to +10.240 V)	**AO*x*02H**	:=

AOx03

AO*x*03 ANALOG QTY (Off, 1 analog quantity)	**AO*x*03AQ**	:= ______
AO*x*03 TYPE (I, V)	**AO*x*03TYP**	:= ______
AO*x*03 AQTY LOW (–2147483647 to +2147483647)	**AO*x*03AQL**	:= ______
AO*x*03 AQTY HI (–2147483647 to +2147483647)	**AO*x*03AQH**	:= ______
If AO*x*03TYP = I		
AO*x*03 LO OUT VAL (–20.480 to +20.480 mA)	**AO*x*03L**	:= ______
AO*x*03 HI OUT VAL (–20.480 to +20.480 mA)	**AO*x*03H**	:= ______
If AO*x*03TYP = V		
AO*x*03 LO OUT VAL (–10.240 to +10.240 V)	**AO*x*03L**	:= ______
AO*x*03 HI OUT VAL (–10.240 to +10.240 V)	**AO*x*03H**	:= ______

AOx04

AO*x*04 ANALOG QTY (Off, 1 analog quantity)	**AO*x*04AQ**	:= ______
AO*x*04 TYPE (I, V)	**AO*x*04TYP**	:= ______
AO*x*04 AQTY LOW (–2147483647 to +2147483647)	**AO*x*04AQL**	:= ______
AO*x*04 AQTY HI (–2147483647 to +2147483647)	**AO*x*04AQH**	:= ______
If AO*x*04TYP = I		
AO*x*04 LO OUT VAL (–20.480 to +20.480 mA)	**AO*x*04L**	:= ______
AO*x*04 HI OUT VAL (–20.480 to +20.480 mA)	**AO*x*04H**	:= ______
If AO*x*04TYP = V		
AO*x*04 LO OUT VAL (–10.240 to +10.240 V)	**AO*x*04L**	:= ______
AO*x*04 HI OUT VAL (–10.240 to +10.240 V)	**AO*x*04H**	:= ______

Input Debounce Settings (Base Unit)

IN101 Debounce (AC, 0–65000 ms)	**IN101D**	:= ______
IN102 Debounce (AC, 0–65000 ms)	**IN102D**	:= ______

Input Debounce Settings (Slot C)

IN301 Debounce (AC, 0–65000 ms)	**IN301D**	:= ______
IN302 Debounce (AC, 0–65000 ms)	**IN302D**	:= ______
IN303 Debounce (AC, 0–65000 ms)	**IN303D**	:= ______
IN304 Debounce (AC, 0–65000 ms)	**IN304D**	:= ______
IN305 Debounce (AC, 0–65000 ms)	**IN305D**	:= ______
IN306 Debounce (AC, 0–65000 ms)	**IN306D**	:= ______
IN307 Debounce (AC, 0–65000 ms)	**IN307D**	:= ______
IN308 Debounce (AC, 0–65000 ms)	**IN308D**	:= ______

Date ____________
Group___________

Input Debounce Settings (Slot D)

IN401 Debounce (AC, 0–65000 ms)	**IN401D**	:=
IN402 Debounce (AC, 0–65000 ms)	**IN402D**	:=
IN403 Debounce (AC, 0–65000 ms)	**IN403D**	:=
IN404 Debounce (AC, 0–65000 ms)	**IN404D**	:=
IN405 Debounce (AC, 0–65000 ms)	**IN405D**	:=
IN406 Debounce (AC, 0–65000 ms)	**IN406D**	:=
IN407 Debounce (AC, 0–65000 ms)	**IN407D**	:=
IN408 Debounce (AC, 0–65000 ms)	**IN408D**	:=

Input Debounce Settings (Slot E)

IN501 Debounce (AC, 0–65000 ms)	**IN501D**	:=
IN502 Debounce (AC, 0–65000 ms)	**IN502D**	:=
IN503 Debounce (AC, 0–65000 ms)	**IN503D**	:=
IN504 Debounce (AC, 0–65000 ms)	**IN504D**	:=
IN505 Debounce (AC, 0–65000 ms)	**IN505D**	:=
IN506 Debounce (AC, 0–65000 ms)	**IN506D**	:=
IN507 Debounce (AC, 0–65000 ms)	**IN507D**	:=
IN508 Debounce (AC, 0–65000 ms)	**IN508D**	:=

Data Reset

RESET TARGETS (SELOGIC)	**RSTTRGT**	:=
RESET ENERGY (SELOGIC)	**RSTENRGY**	:=
RESET MAX/MIN (SELOGIC)	**RSTMXMN**	:=
RESET DEMAND ((SELOGIC)	**RSTDEM**	:=
RESET PK DEMAND ((SELOGIC)	**RSTPKDEM**	:=

Access Control

DISABLE SETTINGS (SELOGIC)	**DSABLSET**	:=
BLOCK MODBUS SET (NONE, R_S, ALL)	**BLKMBSET**	:=

Time Synchronization Source

IRIG TIME SOURCE (IRIG1, IRIG2)	**TIME_SRC**	:=

SET PORT p (p = F, 1, 2, 3, or 4) Command

PORT F

All serial port settings are hidden if EPORT := N.

ENABLE PORT (Y, N)	**EPORT**	:=
PROTOCOL (SEL, MOD, EVMSG, PMU)	**PROTO**	:=

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps)	**SPEED**	:=
DATA BITS (7, 8 bits) *(Hidden if PROTO := MOD, EVMSG, or PMU)*	**BITS**	:=
PARITY (O, E, N) *(Hidden if PROTO := EVMSG or PMU)*	**PARITY**	:=
STOP BITS (1, 2 bits) *(Hidden if PROTO := MOD or EVMSG)*	**STOP**	:=
PORT TIME-OUT (0–30 min) *(Hidden if PROTO := MOD, EVMSG, or PMU)*	**T_OUT**	:=
SEND AUTOMESSAGE (Y, N) *(Hidden if PROTO := MOD, EVMSG, or PMU)*	**AUTO**	:=
HDWR HANDSHAKING (Y, N) *(Hidden if PROTO := MOD or EVMSG)*	**RTSCTS**	:=

Modbus Protocol

MODBUS SLAVE ID (1–247) *(Hidden if PROTO := SEL, EVMSG, or PMU)*	**SLAVEID**	:=

PORT 1 (Ethernet Port in Slot B)

All Ethernet settings are hidden if an Ethernet option is not available.

(IP addresses are entered using zzz = 1–126, 128–223; yyy = 0–255; xxx = 0–255; www = 0–255)

ENABLE PORT (Y, N)	**EPORT**	:=
IP ADDRESS (zzz.yyy.xxx.www)	**IPADDR**	:=
SUBNET MASK (zzz.yyy.xxx.www)	**SUBNETM**	:=
DEFAULT ROUTER (zzz.yyy.xxx.www) *(NOTE: Setting DEFRTR := 0.0.0.0 disables the default router)*	**DEFRTR**	:=
Enable TCP Keep-Alive (Y, N)	**ETCPKA**	:=
TCP Keep-Alive Idle Range (1–20 sec) *(Hidden if ETCPKA := N)*	**KAIDLE**	:=
TCP Keep-Alive Interval Range (1–20 sec) *(Hidden if ETCPKA := N)*	**KAINTV**	:=
TCP Keep-Alive Count Range (1–20 sec) *(Hidden if ETCPKA := N)*	**KACNT**	:=
FAST OP MESSAGES (Y, N)	**FASTOP**	:=
OPERATING MODE (Fixed, Failover, Switched) *(Hidden if not dual redundant Ethernet Port option)*	**NETMODE**	:=
FAILOVER TIMEOUT (0.10–65.00 sec) *(Hidden if not dual redundant Ethernet Port option or if NETMODE is not FAILOVER)*	**FTIME**	:=
PRIMARY NET PORT (A, B, D) *(Hidden if not dual redundant Ethernet Port option)*	**NETPORT**	:=
NETWRK PORTA SPD (Auto, 10, 100 Mbps)	**NETASPD**	:=

NETWRK PORTB SPD (Auto, 10, 100 Mbps) *(Hidden if not dual redundant Ethernet Port option)*	**NETBSPD**	:=
ENABLE TELNET (Y, N)	**ETELNET**	:=
TELNET PORT (23, 1025–65534) *(NOTE: See Table SET.1 and the note at the end of Port 1 settings)*	**TPORT**	:=
TELNET TIME-OUT (1–30 min)	**TIDLE**	:=
ENABLE FTP (Y, N)	**EFTPSERV**	:=
FTP USER NAME (20 characters)	**FTPUSER**	:=
Enable IEC 61850 Protocol (Y, N) *(Hidden if 61850 not supported)*	**E61850**	:=
Enable IEC 61850 GSE (Y, N) *(Hidden if E61850 := N)*	**EGSE**	:=
Enable Modbus Sessions (0–2)	**EMOD**	:=
Modbus TCP Port1 (1–65534) *(Hidden if EMOD := 0)* *(NOTE: See Table SET.1 and the note at the end of Port 1 settings)*	**MODNUM1**	:=
Modbus TCP Port2 (1–65534) *(Hidden if EMOD := 0 or 1)* *(NOTE: See Table SET.1 and the note at the end of Port 1 settings)*	**MODNUM2**	:=
Modbus Timeout 1 (15–900 sec) *(Hidden if EMOD := 0)*	**MTIMEO1**	:=
Modbus Timeout 2 (15–900 sec) *(Hidden if EMOD := 0 or 1)*	**MTIMEO2**	:=

DNP3 Protocol

All DNP3 settings below are hidden if DNP3 is not an option.

Enable DNP3 Sessions (0–3) (DNP3 settings below *hidden if EDNP := 0)*	**EDNP**	:=
DNP TCP and UDP Port (1–65534) *(NOTE: See Table SET.1 and the note at the end of Port 1 settings)*	**DNPNUM**	:=
DNP Address (0–65519)	**DNPADR**	:=

Session 1

NOTE: The DNP IP address of each session (DNPIP1, DNPIP2, etc.) must be unique

IP Address [zzz.yyy.xxx.www] (15 characters)	**DNPIP1**	:=
Transport Protocol (UDP, TCP)	**DNPTR1**	:=
UDP Response Port (REQ, 1–65534)	**DNPUDP1**	:=
DNP Address to Report to (0–65519)	**REPADR1**	:=
DNP Map (1–3)	**DNPMAP1**	:=
Analog Input Default Variation (1–6)	**DVARAI1**	:=
Class for Binary Event Data (0–3)	**ECLASSB1**	:=
Class for Counter Event Data (0–3)	**ECLASSC1**	:=
Class for Analog Event Data (0–3)	**ECLASSA1**	:=
Currents Scaling Decimal Places (0–3)	**DECPLA1**	:=
Voltages Scaling Decimal Places (0–3)	**DECPLV1**	:=
Misc Data Scaling Decimal Places (0–3)	**DECPLM1**	:=
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBA1**	:=

Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBV1**	:= ________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0)*	**ANADBM1**	:= ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1**	:= ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO1**	:= ________
Seconds to send Data Link Heartbeat (0–7200) *(Hidden if DNPTR1 := UDP)*	**DNPINA1**	:= ________
Event Message Confirm Time-Out (1–50 sec))	**ETIMEO1**	:= ________
Enable Unsolicited Reporting (Y, N) *(Hidden if ECLASSA1 := 0, ECLASSB1 := 0, ECLASSC1 := 0, and ECLASSV1 := 0)*	**UNSOL1**	:= ________
Enable Unsolicited Reporting at Power-Up (Y, N) *(Hidden if UNSOL1 := N)*	**PUNSOL1**	:= ________
Number of Events to Transmit On (1–200) *(Hidden if UNSOL1 := N)*	**NUMEVE1**	:= ________
Oldest Event to Tx On (0.0–99999.0 sec) *(Hidden if UNSOL1 := N)*	**AGEEVE1**	:= ________
Unsolicited Message Max Retry Attempts (2–10) *(Hidden if UNSOL1 := N)*	**URETRY1**	:= ________
Unsolicited Message Offline Time-Out (1–5000 sec) *(Hidden if UNSOL1 := N)*	**UTIMEO1**	:= ________

Session 2

All Session 2 settings are hidden if EDNP < 2.

IP Address [zzz.yyy.xxx.www] (15 characters)	**DNPIP2**	:= ________
Transport Protocol (UDP, TCP)	**DNPTR2**	:= ________
UDP Response Port (REQ, 1–65534)	**DNPUDP2**	:= ________
DNP Address to Report to (0–65519)	**REPADR2**	:= ________
DNP Map (1–3)	**DNPMAP2**	:= ________
Analog Input Default Variation (1–6)	**DVARAI2**	:= ________
Class for Binary Event Data (0–3)	**ECLASSB2**	:= ________
Class for Counter Event Data (0–3)	**ECLASSC2**	:= ________
Class for Analog Event Data (0–3)	**ECLASSA2**	:= ________
Currents Scaling Decimal Places (0–3)	**DECPLA2**	:= ________
Voltages Scaling Decimal Places (0–3)	**DECPLV2**	:= ________
Misc Data Scaling Decimal Places (0–3)	**DECPLM2**	:= ________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA2 := 0)*	**ANADBA2**	:= ________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA2 := 0)*	**ANADBV2**	:= ________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA2 := 0 and ECLASSC2 := 0)*	**ANADBM2**	:= ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ2**	:= ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO2**	:= ________

Seconds to send Data Link Heartbeat (0–7200) *(Hidden if DNPTR2 := UDP)*	**DNPINA2**	:=
Event Message Confirm Time-Out (1–50 sec))	**ETIMEO2**	:=
Enable Unsolicited Reporting (Y, N) *(Hidden if ECLASSA2 := 0, ECLASSB2 := 0, ECLASSC2 := 0, and ECLASSV2 := 0)*	**UNSOL2**	:=
Enable Unsolicited Reporting at Power-Up (Y, N) *(Hidden if UNSOL2 := N)*	**PUNSOL2**	:=
Number of Events to Transmit On (1–200) *(Hidden if UNSOL2 := N)*	**NUMEVE2**	:=
Oldest Event to Tx On (0.0–99999.0 sec) *(Hidden if UNSOL2 := N)*	**AGEEVE2**	:=
Unsolicited Message Max Retry Attempts (2–10) *(Hidden if UNSOL2 := N)*	**URETRY2**	:=
Unsolicited Message Offline Time-Out (1–5000 sec) *(Hidden if UNSOL2 := N)*	**UTIMEO2**	:=

Session 3

All Session 3 settings are hidden if EDNP < 3.

IP Address [zzz.yyy.xxx.www] (15 characters)	**DNPIP3**	:=
Transport Protocol (UDP, TCP)	**DNPTR3**	:=
UDP Response Port (REQ, 1–65534)	**DNPUDP3**	:=
DNP Address to Report to (0–65519)	**REPADR3**	:=
DNP Map (1–3)	**DNPMAP3**	:=
Analog Input Default Variation (1–6)	**DVARAI3**	:=
Class for Binary Event Data (0–3)	**ECLASSB3**	:=
Class for Counter Event Data (0–3)	**ECLASSC3**	:=
Class for Analog Event Data (0–3)	**ECLASSA3**	:=
Currents Scaling Decimal Places (0–3)	**DECPLA3**	:=
Voltages Scaling Decimal Places (0–3)	**DECPLV3**	:=
Misc Data Scaling Decimal Places (0–3)	**DECPLM3**	:=
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA3 := 0)*	**ANADBA3**	:=
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA3 := 0)*	**ANADBV3**	:=
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA3 := 0 and ECLASSC3 := 0)*	**ANADBM3**	:=
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ3**	:=
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO3**	:=
Seconds to send Data Link Heartbeat (0–7200) *(Hidden if DNPTR3 := UDP)*	**DNPINA3**	:=
Event Message Confirm Time-Out (1–50 sec))	**ETIMEO3**	:=
Enable Unsolicited Reporting (Y, N) *(Hidden if ECLASSA3 := 0, ECLASSB3 := 0, ECLASSC3 := 0, and ECLASSV3 := 0)*	**UNSOL3**	:=

Enable Unsolicited Reporting at Power-Up (Y, N) *(Hidden if UNSOL3 := N)*	**PUNSOL3**	:= ________________
Number of Events to Transmit On (1–200) *(Hidden if UNSOL3 := N)*	**NUMEVE3**	:= ________________
Oldest Event to Tx On (0.0–99999.0 sec) *(Hidden if UNSOL3 := N)*	**AGEEVE3**	:= ________________
Unsolicited Message Max Retry Attempts (2–10) *(Hidden if UNSOL3 := N)*	**URETRY3**	:= ________________
Unsolicited Message Offline Time-Out (1–5000 sec) *(Hidden if UNSOL3 := N)*	**UTIMEO3**	:= ________________

SNTP Client Protocol Settings

Enable SNTP Client (OFF, UNICAST, MANYCAST, BROADCAST)	**ESNTP**	:= ________________
Make the following settings when ESNTP ≠ OFF.		
Primary Server IP Address (zzz.yyy.xxx.www)	**SNTPPSIP**	:= ________________
NOTE: To accept updates from any server when ESNTP = BROADCAST, set SNTPPSIP to 0.0.0.0.		
NOTE: Only IP addresses in the range 224.0.0.1 through 239.255.255.255 are valid when ESNTP = MANYCAST.		
Make the following setting when ESNTP = UNICAST.		
Backup Server IP Address (zzz.yyy.xxx.www)	**SNTPBSIP**	:= ________________
SNTP IP (Local) Port Number (1-65534)		
NOTE: See *Table SET.1* and the note at the end of Port 1 settings.	**SNTPPORT**	:= ________________
SNTP Update Rate (15–3600 seconds)	**SNTPRATE**	: = ________________
Make the following setting when ESNTP = UNICAST or MANYCAST.		
SNTP Timeout (5–20 seconds)	**SNTPTO**	: = ________________
NOTE: SNTPTO must be less than setting SNTPRATE.		

Port Number Settings Must be Unique

When making the SEL-787 Port 1 settings, port number settings cannot be used for more than one protocol. The relay checks all of the settings shown in *Table SET.1* before saving changes. If a port number is used more than once, or if it matches any of the fixed port numbers (20, 21, 102, 502, 23), the relay will display an error message and return to the first setting that is in error or contains a duplicate value.

Table SET.1 Port Number Settings That Must be Unique

Setting	Name	Setting Required When
TPORT	Telnet Port	Always
MODNUM1[a]	Modbus TCP Port 1	EMOD > 0
MODNUM2[a]	Modbus TCP Port 2	EMOD > 1
DNPNUM	DNPTCP and UDP Port	EDNP > 0
SNTPPORT	SNTPIP (Local) Port Number	ESNTP ≠ OFF

[a] MODNUM1 and MODNUM2 can have the same port number. The relay displays an error message if this number matches with the port numbers of the other protocols.

PORT 2 (Fiber-Optic Serial Port in Slot B)

(Hidden if E49RTD := EXT.)

All port settings are hidden if EPORT := N.

ENABLE PORT (Y, N)	**EPORT**	:= ____________
PROTOCOL (SEL, DNP, MOD, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB)	**PROTO**	:= ____________

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps)	**SPEED**	:= ____________
DATA BITS (7, 8 bits) *(Hidden if PROTO := MOD, DNP, PMU, EVMSG, or MB_)*	**BITS**	:= ____________
PARITY (O, E, N) *(Hidden if PROTO := EVMSG, PMU or MB_)*	**PARITY**	:= ____________
STOP BITS (1, 2 bits) *(Hidden if PROTO := MOD, EVMSG, or MB_)*	**STOP**	:= ____________
PORT TIME-OUT (0–30 min) *(Hidden if PROTO := MOD, EVMSG, PMU or MB_)*	**T_OUT**	:= ____________
SEND AUTOMESSAGE (Y, N) *(Hidden if PROTO := MOD, DNP, PMU, EVMSG, or MB_)*	**AUTO**	:= ____________
FAST OP MESSAGES (Y, N) *(Hidden if PROTO := MOD, EVMSG, DNP, PMU or MB_)*	**FASTOP**	:= ____________
HDWR HANDSHAKING (Y, N) *(Hidden if PROTO := MOD, EVMSG, DNP, SEL or MB_)*	**RTSCTS**	:= ____________

DNP3 Protocol

(Hidden if PROTO := SEL, EVMSG, MB, PMU or MOD.)

DNP Address (0–65519)	**DNPADR**	:= ____________
DNP Address to Report to (0–65519)	**REPADR1**	:= ____________
DNP Map (1–3)	**DNPMAP1**	:= ____________
Analog Input Default Variation (1–6)	**DVARAI1**	:= ____________
Class for Binary Event Data (0–3)	**ECLASSB1**	:= ____________
Class for Counter Event Data (0–3)	**ECLASSC1**	:= ____________
Class for Analog Event Data (0–3)	**ECLASSA1**	:= ____________
Currents Scaling Decimal Places (0–3)	**DECPLA1**	:= ____________
Voltages Scaling Decimal Places (0–3)	**DECPLV1**	:= ____________
Misc Data Scaling Decimal Places (0–3)	**DECPLM1**	:= ____________
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBA1**	:= ____________
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBV1**	:= ____________
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0)*	**ANADBM1**	:= ____________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1**	:= ____________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO1**	:= ____________
Data Link Retries (0–15)	**DRETRY1**	:= ____________

Seconds to Data Link Time-Out (0–5) *(Hidden if DRETRY1 := 0)*	**DTIMEO1**	:=	____________
Event Message Confirm Time-Out (1–50 sec))	**ETIMEO1**	:=	____________
Enable Unsolicited Reporting (Y, N) *(Hidden if ECLASSA1 := 0, ECLASSB1 := 0 and ECLASSC1 := 0)*	**UNSOL1**	:=	____________
Enable Unsolicited Reporting at Power-Up (Y, N) *(Hidden if UNSOL1 := N)*	**PUNSOL1**	:=	____________
Number of Events to Transmit On (1–200) *(Hidden if UNSOL1 := N)*	**NUMEVE1**	:=	____________
Oldest Event to Tx On (0.0–99999.0 sec) *(Hidden if UNSOL1 := N)*	**AGEEVE1**	:=	____________
Unsolicited Message Max Retry Attempts (2–10) *(Hidden if UNSOL1 := N)*	**URETRY1**	:=	____________
Unsolicited Message Offline Time-Out (1–5000 sec) *(Hidden if UNSOL1 := N)*	**UTIMEO1**	:=	____________

Modbus Protocol

MODBUS SLAVE ID (1–247) *(Hidden if PROTO := SEL, DNP, PMU, EVMSG, or MB_)*	**SLAVEID**	:=	____________

MIRRORED BITS Protocol

(Hidden if PROTO := SEL, EVMSG, DNP, PMU, or MOD.)

MB Transmit Identifier (1–4)	**TXID**	:=	____________
MB Receive Identifier (1–4)	**RXID**	:=	____________
MB RX Bad Pickup Time (0–10000 seconds)	**RBADPU**	:=	____________
MB Channel Bad Pickup (1–10000 ppm)	**CBADPU**	:=	____________
MB Receive Default State (8 characters)	**RXDFLT**	:=	____________
RMB1 Pickup Debounce Messages (1–8)	**RMB1PU**	:=	____________
RMB1 Dropout Debounce Messages (1–8)	**RMB1DO**	:=	____________
RMB2 Pickup Debounce Messages (1–8)	**RMB2PU**	:=	____________
RMB2 Dropout Debounce Messages (1–8)	**RMB2DO**	:=	____________
RMB3 Pickup Debounce Messages (1–8)	**RMB3PU**	:=	____________
RMB3 Dropout Debounce Messages (1–8)	**RMB3DO**	:=	____________
RMB4 Pickup Debounce Messages (1–8)	**RMB4PU**	:=	____________
RMB4 Dropout Debounce Messages (1–8)	**RMB4DO**	:=	____________
RMB5 Pickup Debounce Messages (1–8)	**RMB5PU**	:=	____________
RMB5 Dropout Debounce Messages (1–8)	**RMB5DO**	:=	____________
RMB6 Pickup Debounce Messages (1–8)	**RMB6PU**	:=	____________
RMB6 Dropout Debounce Messages (1–8)	**RMB6DO**	:=	____________
RMB7 Pickup Debounce Messages (1–8)	**RMB7PU**	:=	____________
RMB7 Dropout Debounce Messages (1–8)	**RMB7DO**	:=	____________
RMB8 Pickup Debounce Messages (1–8)	**RMB8PU**	:=	____________
RMB8 Dropout Debounce Messages (1–8)	**RMB8DO**	:=	____________

PORT 3 (EIA-232 or EIA-485 Port in Slot B [ordering option])

All serial port settings are hidden if EPORT := N.

ENABLE PORT (Y, N)	**EPORT**	:=
PROTOCOL (SEL, DNP, MOD, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB)	**PROTO**	:=

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps)	**SPEED**	:=
DATA BITS (7, 8 bits) *(Hidden if PROTO := MOD, DNP, PMU, EVMSG, or MB_)*	**BITS**	:=
PARITY (O, E, N) *(Hidden if PROTO := EVMSG, PMU, or MB_)*	**PARITY**	:=
STOP BITS (1, 2 bits) *(Hidden if PROTO := MOD, EVMSG, or MB_)*	**STOP**	:=
PORT TIME-OUT (0–30 min) *(Hidden if PROTO := MOD, PMU, EVMSG, or MB_)*	**T_OUT**	:=
SEND AUTOMESSAGE (Y, N) *(Hidden if PROTO := MOD, DNP, PMU, EVMSG, or MB_)*	**AUTO**	:=
HDWR HANDSHAKING (Y, N) *(Hidden if EIA-485 Port or PROTO := MOD, DNP, EVMSG, or MB_)*	**RTSCTS**	:=
FAST OP MESSAGES (Y, N) *(Hidden if PROTO := MOD, DNP, PMU, EVMSG, or MB_)*	**FASTOP**	:=

DNP3 Protocol

(Hidden if PROTO := SEL, EVMSG, MB, PMU or MOD.)

DNP Address (0–65519)	**DNPADR**	:=
DNP Address to Report to (0–65519)	**REPADR1**	:=
DNP Map (1–3)	**DNPMAP1**	:=
Analog Input Default Variation (1–6)	**DVARAI1**	:=
Class for Binary Event Data (0–3)	**ECLASSB1**	:=
Class for Counter Event Data (0–3)	**ECLASSC1**	:=
Class for Analog Event Data (0–3)	**ECLASSA1**	:=
Currents Scaling Decimal Places (0–3)	**DECPLA1**	:=
Voltages Scaling Decimal Places (0–3)	**DECPLV1**	:=
Misc Data Scaling Decimal Places (0–3)	**DECPLM1**	:=
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBA1**	:=
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBV1**	:=
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0)*	**ANADBM1**	:=
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1**	:=
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO1**	:=
Data Link Retries (0–15)	**DRETRY1**	:=
Seconds to Data Link Time-Out (0–5) *(Hidden if DRETRY1 := 0)*	**DTIMEO1**	:=

Event Message Confirm Time-Out (1–50 sec))	**ETIMEO1**	:= ____________
Enable Unsolicited Reporting (Y, N) *(Hidden if ECLASSA1 := 0, ECLASSB1 := 0 and ECLASSC1 := 0)*	**UNSOL1**	:= ____________
Enable Unsolicited Reporting at Power-Up (Y, N) *(Hidden if UNSOL1 := N)*	**PUNSOL1**	:= ____________
Number of Events to Transmit On (1–200) *(Hidden if UNSOL1 := N)*	**NUMEVE1**	:= ____________
Oldest Event to Tx On (0.0–99999.0 sec) *(Hidden if UNSOL1 := N)*	**AGEEVE1**	:= ____________
Unsolicited Message Max Retry Attempts (2–10) *(Hidden if UNSOL1 := N)*	**URETRY1**	:= ____________
Unsolicited Message Offline Time-Out (1–5000 sec) *(Hidden if UNSOL1 := N)*	**UTIMEO1**	:= ____________
Minimum Seconds from DCD to TX (0.00–1.00)	**MINDLY**	:= ____________
Maximum Seconds from DCD to TX (0.00–1.00)	**MAXDLY**	:= ____________
Settle Time from RTS On to TX (OFF, 0.00–30.00 sec)	**PREDLY**	:= ____________
Settle Time from TX to RTS OFF (0.00–30.00 sec)	**PSTDLY**	:= ____________

Modem Protocol (for DNP3 session and EIA-232 port only)

Modem Connected to Port (Y, N)	**MODEM**	:= ____________
Modem Startup String (30 characters)	**MSTR**	:= ____________
Phone Number for Dial-Out (30 characters)	**PH_NUM1**	:= ____________
Phone Number for Dial-Out (30 characters)	**PH_NUM2**	:= ____________
Retry Attempts for Phone 1 Dial-Out (1–20)	**RETRY1**	:= ____________
Retry Attempts for Phone 2 Dial-Out (1–20)	**RETRY2**	:= ____________
Time to Attempt Dial (5–300 sec)	**MDTIME**	:= ____________
Time Between Dial-Out Attempts (5–3600 sec)	**MDRET**	:= ____________

Modbus Protocol

MODBUS SLAVE ID (1–247) *(Hidden if PROTO := SEL, DNP, PMU, EVMSG, or MB_)*	**SLAVEID**	:= ____________

MIRRORED BITS Protocol

(Hidden if PROTO := SEL, DNP, PMU, EVMSG, or MOD.)

MB Transmit Identifier (1–4)	**TXID**	:= ____________
MB Receive Identifier (1–4)	**RXID**	:= ____________
MB RX Bad Pickup Time (0–10000 seconds)	**RBADPU**	:= ____________
MB Channel Bad Pickup (1–10000 ppm)	**CBADPU**	:= ____________
MB Receive Default State (8 characters)	**RXDFLT**	:= ____________
RMB1 Pickup Debounce Messages (1–8)	**RMB1PU**	:= ____________
RMB1 Dropout Debounce Messages (1–8)	**RMB1DO**	:= ____________
RMB2 Pickup Debounce Messages (1–8)	**RMB2PU**	:= ____________
RMB2 Dropout Debounce Messages (1–8)	**RMB2DO**	:= ____________

RMB3 Pickup Debounce Messages (1–8)	**RMB3PU**	:=
RMB3 Dropout Debounce Messages (1–8)	**RMB3DO**	:=
RMB4 Pickup Debounce Messages (1–8)	**RMB4PU**	:=
RMB4 Dropout Debounce Messages (1–8)	**RMB4DO**	:=
RMB5 Pickup Debounce Messages (1–8)	**RMB5PU**	:=
RMB5 Dropout Debounce Messages (1–8)	**RMB5DO**	:=
RMB6 Pickup Debounce Messages (1–8)	**RMB6PU**	:=
RMB6 Dropout Debounce Messages (1–8)	**RMB6DO**	:=
RMB7 Pickup Debounce Messages (1–8)	**RMB7PU**	:=
RMB7 Dropout Debounce Messages (1–8)	**RMB7DO**	:=
RMB8 Pickup Debounce Messages (1–8)	**RMB8PU**	:=
RMB8 Dropout Debounce Messages (1–8)	**RMB8DO**	:=

PORT 4 (EIA-232/485 Port or DeviceNet Port in Slot C)

All serial port settings are hidden if EPORT := N.

ENABLE PORT (Y, N)	**EPORT**	:=
PROTOCOL (SEL, DNP, MOD, DNET, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB)	**PROTO**	:=

Interface Select

(Hidden if PROTO := DNET.)

COMM INTERFACE (232, 485)	**COMMINF**	:=

Communications

SPEED (300, 1200, 2400, 4800, 9600, 19200, 38400 bps) *(Hidden if PROTO := DNET)*	**SPEED**	:=
DATA BITS (7, 8 bits) *(Hidden if PROTO := DNP, MOD, PMU, EVMSG, MB_, or DNET)*	**BITS**	:=
PARITY (O, E, N) *(Hidden if PROTO := DNET, EVMSG, PMU, or MB_)*	**PARITY**	:=
STOP BITS (1, 2 bits) *(Hidden if PROTO := MOD, EVMSG, MB_, or DNET)*	**STOP**	:=
PORT TIME-OUT (0–30 min) *(Hidden if PROTO :=MOD, EVMSG, MB_, PMU or DNET)*	**T_OUT**	:=
SEND AUTOMESSAGE (Y, N) *(Hidden if PROTO :=DNP, MOD, EVMSG, MB_, PMU or DNET)*	**AUTO**	:=
HDWR HANDSHAKING (Y, N) *(Hidden if COMMINF :=485 or PROTO := MOD, DNP, EVMSG, MB_, or DNET)*	**RTSCTS**	:=
FAST OP MESSAGES (Y, N) *(Hidden if PROTO := DNP, MOD, EVMSG, MB_, PMU or DNET)*	**FASTOP**	:=

DNP3 Protocol

(Hidden if PROTO := SEL, EVMSG, MB, PMU , DNET or MOD.)

DNP Address (0–65519)	**DNPADR**	:=
DNP Address to Report to (0–65519)	**REPADR1**	:=

DNP Map (1–3)	**DNPMAP1**	:= ______
Analog Input Default Variation (1–6)	**DVARAI1**	:= ______
Class for Binary Event Data (0–3)	**ECLASSB1**	:= ______
Class for Counter Event Data (0–3)	**ECLASSC1**	:= ______
Class for Analog Event Data (0–3)	**ECLASSA1**	:= ______
Currents Scaling Decimal Places (0–3)	**DECPLA1**	:= ______
Voltages Scaling Decimal Places (0–3)	**DECPLV1**	:= ______
Misc Data Scaling Decimal Places (0–3)	**DECPLM1**	:= ______
Amps Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBA1**	:= ______
Volts Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0)*	**ANADBV1**	:= ______
Misc Data Reporting Deadband Counts (0–32767) *(Hidden if ECLASSA1 := 0 and ECLASSC1 := 0)*	**ANADBM1**	:= ______
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1**	:= ______
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO1**	:= ______
Data Link Retries (0–15)	**DRETRY1**	:= ______
Seconds to Data Link Time-Out (0–5) *(Hidden if DRETRY1 := 0)*	**DTIMEO1**	:= ______
Event Message Confirm Time-Out (1–50 sec))	**ETIMEO1**	:= ______
Enable Unsolicited Reporting (Y, N) *(Hidden if ECLASSA1 := 0, ECLASSB1 := 0, ECLASSC1 := 0, and ECLASSV1 := 0)*	**UNSOL1**	:= ______
Enable Unsolicited Reporting at Power-Up (Y, N) *(Hidden if UNSOL1 := N)*	**PUNSOL1**	:= ______
Number of Events to Transmit On (1–200) *(Hidden if UNSOL1 := N)*	**NUMEVE1**	:= ______
Oldest Event to Tx On (0.0–99999.0 sec) *(Hidden if UNSOL1 := N)*	**AGEEVE1**	:= ______
Unsolicited Message Max Retry Attempts (2–10) *(Hidden if UNSOL1 := N)*	**URETRY1**	:= ______
Unsolicited Message Offline Time-Out (1–5000 sec) *(Hidden if UNSOL1 := N)*	**UTIMEO1**	:= ______
Minimum Seconds from DCD to TX (0.00–1.00)	**MINDLY**	:= ______
Maximum Seconds from DCD to TX (0.00–1.00)	**MAXDLY**	:= ______
Settle Time from RTS On to TX (OFF, 0.00–30.00 sec)	**PREDLY**	:= ______
Settle Time from TX to RTS OFF (0.00–30.00 sec)	**PSTDLY**	:= ______

Modem Protocol **(for DNP3 session and EIA232 port only)**

Modem Connected to Port (Y, N)	**MODEM**	:= ______
Modem Startup String (30 characters)	**MSTR**	:= ______
Phone Number for Dial-Out (30 characters)	**PH_NUM1**	:= ______
Phone Number for Dial-Out (30 characters)	**PH_NUM2**	:= ______
Retry Attempts for Phone 1 Dial-Out (1–20)	**RETRY1**	:= ______

Retry Attempts for Phone 2 Dial-Out (1–20)	**RETRY2**	:= ______
Time to Attempt Dial (5–300 sec)	**MDTIME**	:= ______
Time Between Dial-Out Attempts (5–3600 sec)	**MDRET**	:= ______

Modbus Protocol

MODBUS SLAVE ID (1–247) *(Hidden if PROTO := SEL, DNP, PMU, EVMSG, MB_, or DNET)*	**SLAVEID**	:= ______

MIRRORED BITS Protocol

(Hidden if PROTO := SEL, EVMSG, DNP, PMU, DNET or MOD.)

MB Transmit Identifier (1–4)	**TXID**	:= ______
MB Receive Identifier (1–4)	**RXID**	:= ______
MB RX Bad Pickup Time (0–10000 seconds)	**RBADPU**	:= ______
MB Channel Bad Pickup (1–10000 ppm)	**CBADPU**	:= ______
MB Receive Default State (8 characters)	**RXDFLT**	:= ______
RMB1 Pickup Debounce Messages (1–8)	**RMB1PU**	:= ______
RMB1 Dropout Debounce Messages (1–8)	**RMB1DO**	:= ______
RMB2 Pickup Debounce Messages (1–8)	**RMB2PU**	:= ______
RMB2 Dropout Debounce Messages (1–8)	**RMB2DO**	:= ______
RMB3 Pickup Debounce Messages (1–8)	**RMB3PU**	:= ______
RMB3 Dropout Debounce Messages (1–8)	**RMB3DO**	:= ______
RMB4 Pickup Debounce Messages (1–8)	**RMB4PU**	:= ______
RMB4 Dropout Debounce Messages (1–8)	**RMB4DO**	:= ______
RMB5 Pickup Debounce Messages (1–8)	**RMB5PU**	:= ______
RMB5 Dropout Debounce Messages (1–8)	**RMB5DO**	:= ______
RMB6 Pickup Debounce Messages (1–8)	**RMB6PU**	:= ______
RMB6 Dropout Debounce Messages (1–8)	**RMB6DO**	:= ______
RMB7 Pickup Debounce Messages (1–8)	**RMB7PU**	:= ______
RMB7 Dropout Debounce Messages (1–8)	**RMB7DO**	:= ______
RMB8 Pickup Debounce Messages (1–8)	**RMB8PU**	:= ______
RMB8 Dropout Debounce Messages (1–8)	**RMB8DO**	:= ______

Front-Panel Settings (SET F Command)

General

DISPLY PTS ENABL (N, 1–32)	**EDP**	:=
LOCAL BITS ENABL (N, 1–32)	**ELB**	:=
LCD TIMEOUT (OFF, 1–30 min)	**FP_TO**	:=
LCD CONTRAST (1–8)	**FP_CONT**	:=
FP AUTOMESSAGES (OVERRIDE, ROTATING)	**FP_AUTO**	:=
CLOSE RESET LEDS (Y, N)	**RSTLED**	:=

Target LED

TRIP LATCH T_LED (Y, N)	**T01LEDL**	:=
LED1 EQUATION (SELOGIC)	**T01_LED**	:=
TRIP LATCH T_LED (Y, N)	**T02LEDL**	:=
LED2 EQUATION (SELOGIC)	**T02_LED**	:=
TRIP LATCH T_LED (Y, N)	**T03LEDL**	:=
LED3 EQUATION (SELOGIC)	**T03_LED**	:=
TRIP LATCH T_LED (Y, N)	**T04LEDL**	:=
LED4 EQUATION (SELOGIC)	**T04_LED**	:=
TRIP LATCH T_LED (Y, N)	**T05LEDL**	:=
LED5 EQUATION (SELOGIC)	**T05_LED**	:=
TRIP LATCH T_LED (Y, N)	**T06LEDL**	:=
LED6 EQUATION (SELOGIC)	**T06_LED**	:=
PB1A_LED EQUATION (SELOGIC)	**PB1A_LED**	:=
PB1B_LED EQUATION (SELOGIC)	**PB1B_LED**	:=
PB2A_LED EQUATION (SELOGIC)	**PB2A_LED**	:=
PB2B_LED EQUATION (SELOGIC)	**PB2B_LED**	:=
PB3A_LED EQUATION (SELOGIC)	**PB3A_LED**	:=
PB3B_LED EQUATION (SELOGIC)	**PB3B_LED**	:=
PB4A_LED EQUATION (SELOGIC)	**PB4A_LED**	:=
PB4B_LED EQUATION (SELOGIC)	**PB4B_LED**	:=

Display Points

Display Point Settings (maximum 60 characters):

- (Boolean): Relay Word Bit Name, "Alias", "Set String", "Clear String"
- (Analog): Analog Quantity Name, "User Text and Formatting"

DISPLAY POINT DP01 (60 characters)	**DP01**	:=
DISPLAY POINT DP02 (60 characters)	**DP02**	:=

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DISPLAY POINT DP03 (60 characters)	**DP03**	:=	____________
DISPLAY POINT DP04 (60 characters)	**DP04**	:=	____________
DISPLAY POINT DP05 (60 characters)	**DP05**	:=	____________
DISPLAY POINT DP06 (60 characters)	**DP06**	:=	____________
DISPLAY POINT DP07 (60 characters)	**DP07**	:=	____________
DISPLAY POINT DP08 (60 characters)	**DP08**	:=	____________
DISPLAY POINT DP09 (60 characters)	**DP09**	:=	____________
DISPLAY POINT DP10 (60 characters)	**DP10**	:=	____________
DISPLAY POINT DP11 (60 characters)	**DP11**	:=	____________
DISPLAY POINT DP12 (60 characters)	**DP12**	:=	____________
DISPLAY POINT DP13 (60 characters)	**DP13**	:=	____________
DISPLAY POINT DP14 (60 characters)	**DP14**	:=	____________
DISPLAY POINT DP15 (60 characters)	**DP15**	:=	____________
DISPLAY POINT DP16 (60 characters)	**DP16**	:=	____________
DISPLAY POINT DP17 (60 characters)	**DP17**	:=	____________
DISPLAY POINT DP18 (60 characters)	**DP18**	:=	____________
DISPLAY POINT DP19 (60 characters)	**DP19**	:=	____________
DISPLAY POINT DP20 (60 characters)	**DP20**	:=	____________
DISPLAY POINT DP21 (60 characters)	**DP21**	:=	____________
DISPLAY POINT DP22 (60 characters)	**DP22**	:=	____________
DISPLAY POINT DP23 (60 characters)	**DP23**	:=	____________
DISPLAY POINT DP24 (60 characters)	**DP24**	:=	____________
DISPLAY POINT DP25 (60 characters)	**DP25**	:=	____________
DISPLAY POINT DP26 (60 characters)	**DP26**	:=	____________
DISPLAY POINT DP27 (60 characters)	**DP27**	:=	____________
DISPLAY POINT DP28 (60 characters)	**DP28**	:=	____________
DISPLAY POINT DP29 (60 characters)	**DP29**	:=	____________
DISPLAY POINT DP30 (60 characters)	**DP30**	:=	____________
DISPLAY POINT DP31 (60 characters)	**DP31**	:=	____________
DISPLAY POINT DP32 (60 characters)	**DP32**	:=	____________

Local Bits Labels

LB_NAME (14 characters)	**NLB01**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB01**	:=	____________
SET LB_ LABEL (7 characters)	**SLB01**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB01**	:=	____________
LB_NAME (14 characters)	**NLB02**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB02**	:=	____________

SET LB_ LABEL (7 characters)	**SLB02**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB02**	:=	____________
LB_NAME (14 characters)	**NLB03**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB03**	:=	____________
SET LB_ LABEL (7 characters)	**SLB03**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB03**	:=	____________
LB_NAME (14 characters)	**NLB04**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB04**	:=	____________
SET LB_ LABEL (7 characters)	**SLB04**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB04**	:=	____________
LB_NAME (14 characters)	**NLB05**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB05**	:=	____________
SET LB_ LABEL (7 characters)	**SLB05**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB05**	:=	____________
LB_NAME (14 characters)	**NLB06**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB06**	:=	____________
SET LB_ LABEL (7 characters)	**SLB06**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB06**	:=	____________
LB_NAME (14 characters)	**NLB07**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB07**	:=	____________
SET LB_ LABEL (7 characters)	**SLB07**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB07**	:=	____________
LB_NAME (14 characters)	**NLB08**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB08**	:=	____________
SET LB_ LABEL (7 characters)	**SLB08**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB08**	:=	____________
LB_NAME (14 characters)	**NLB09**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB09**	:=	____________
SET LB_ LABEL (7 characters)	**SLB09**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB09**	:=	____________
LB_NAME (14 characters)	**NLB10**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB10**	:=	____________
SET LB_ LABEL (7 characters)	**SLB10**	:=	____________
PULSE LB_ LABEL (7 characters)	**PLB10**	:=	____________
LB_NAME (14 characters)	**NLB11**	:=	____________
CLEAR LB_ LABEL (7 characters)	**CLB11**	:=	____________
SET LB_ LABEL (7 characters)	**SLB11**	:=	____________

PULSE LB_ LABEL (7 characters)	**PLB11**	:= ________
LB_NAME (14 characters)	**NLB12**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB12**	:= ________
SET LB_ LABEL (7 characters)	**SLB12**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB12**	:= ________
LB_NAME (14 characters)	**NLB13**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB13**	:= ________
SET LB_ LABEL (7 characters)	**SLB13**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB13**	:= ________
LB_NAME (14 characters)	**NLB14**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB14**	:= ________
SET LB_ LABEL (7 characters)	**SLB14**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB14**	:= ________
LB_NAME (14 characters)	**NLB15**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB15**	:= ________
SET LB_ LABEL (7 characters)	**SLB15**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB15**	:= ________
LB_NAME (14 characters)	**NLB16**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB16**	:= ________
SET LB_ LABEL (7 characters)	**SLB16**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB16**	:= ________
LB_NAME (14 characters)	**NLB17**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB17**	:= ________
SET LB_ LABEL (7 characters)	**SLB17**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB17**	:= ________
LB_NAME (14 characters)	**NLB18**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB18**	:= ________
SET LB_ LABEL (7 characters)	**SLB18**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB18**	:= ________
LB_NAME (14 characters)	**NLB19**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB19**	:= ________
SET LB_ LABEL (7 characters)	**SLB19**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB19**	:= ________
LB_NAME (14 characters)	**NLB20**	:= ________
CLEAR LB_ LABEL (7 characters)	**CLB20**	:= ________
SET LB_ LABEL (7 characters)	**SLB20**	:= ________
PULSE LB_ LABEL (7 characters)	**PLB20**	:= ________

LB_NAME (14 characters)	**NLB21**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB21**	:= ______
SET LB_ LABEL (7 characters)	**SLB21**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB21**	:= ______
LB_NAME (14 characters)	**NLB22**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB22**	:= ______
SET LB_ LABEL (7 characters)	**SLB22**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB22**	:= ______
LB_NAME (14 characters)	**NLB23**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB23**	:= ______
SET LB_ LABEL (7 characters)	**SLB23**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB23**	:= ______
LB_NAME (14 characters)	**NLB24**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB24**	:= ______
SET LB_ LABEL (7 characters)	**SLB24**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB24**	:= ______
LB_NAME (14 characters)	**NLB25**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB25**	:= ______
SET LB_ LABEL (7 characters)	**SLB25**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB25**	:= ______
LB_NAME (14 characters)	**NLB26**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB26**	:= ______
SET LB_ LABEL (7 characters)	**SLB26**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB26**	:= ______
LB_NAME (14 characters)	**NLB27**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB27**	:= ______
SET LB_ LABEL (7 characters)	**SLB27**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB27**	:= ______
LB_NAME (14 characters)	**NLB28**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB28**	:= ______
SET LB_ LABEL (7 characters)	**SLB28**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB28**	:= ______
LB_NAME (14 characters)	**NLB29**	:= ______
CLEAR LB_ LABEL (7 characters)	**CLB29**	:= ______
SET LB_ LABEL (7 characters)	**SLB29**	:= ______
PULSE LB_ LABEL (7 characters)	**PLB29**	:= ______
LB_NAME (14 characters)	**NLB30**	:= ______

CLEAR LB_ LABEL (7 characters)	**CLB30**	:=
SET LB_ LABEL (7 characters)	**SLB30**	:=
PULSE LB_ LABEL (7 characters)	**PLB30**	:=
LB_NAME (14 characters)	**NLB31**	:=
CLEAR LB_ LABEL (7 characters)	**CLB31**	:=
SET LB_ LABEL (7 characters)	**SLB31**	:=
PULSE LB_ LABEL (7 characters)	**PLB31**	:=
LB_NAME (14 characters)	**NLB32**	:=
CLEAR LB_ LABEL (7 characters)	**CLB32**	:=
SET LB_ LABEL (7 characters)	**SLB32**	:=
PULSE LB_ LABEL (7 characters)	**PLB32**	:=

Report Settings (SET R Command)

SER Chatter Criteria

Auto-Removal Enable (Y, N)	**ESERDEL**	:=
Number of Counts (2–20 counts)	**SRDLCNT**	:=
Removal Time (0.1–90.0 seconds)	**SRDLTIM**	:=

SER Trigger Lists

SERn = As many as 24 Relay-Word elements separated by spaces or commas. Use NA to disable setting.

SER1 :=

SER2 :=

SER3 :=

SER4 :=

Relay Word Bit Aliases

ALIASn= 'RW Bit'(space)'Alias'(space)'Asserted Text'(space)'Deasserted Text'. Alias, Asserted, and Deasserted text strings can be as long as 15 characters. Use NA to disable setting.

Enable ALIAS (N, 1–20)	**EALIAS**	:=
ALIAS 1	**ALIAS1**	:=
ALIAS 2	**ALIAS2**	:=
ALIAS 3	**ALIAS3**	:=
ALIAS 4	**ALIAS4**	:=
ALIAS 5	**ALIAS5**	:=
ALIAS 6	**ALIAS6**	:=
ALIAS 7	**ALIAS7**	:=
ALIAS 8	**ALIAS8**	:=
ALIAS 9	**ALIAS9**	:=

ALIAS 10	**ALIAS10**	:=	________
ALIAS 11	**ALIAS11**	:=	________
ALIAS 12	**ALIAS12**	:=	________
ALIAS 13	**ALIAS13**	:=	________
ALIAS 14	**ALIAS14**	:=	________
ALIAS 15	**ALIAS15**	:=	________
ALIAS 16	**ALIAS16**	:=	________
ALIAS 17	**ALIAS17**	:=	________
ALIAS 18	**ALIAS18**	:=	________
ALIAS 19	**ALIAS19**	:=	________
ALIAS 20	**ALIAS20**	:=	________

Event Report

EVENT TRIGGER (SELOGIC)	**ER**	:=	________
EVENT LENGTH (15, 64 cyc)	**LER**	:=	________
PREFAULT LENGTH (1–59 cyc {if LER := 15}, 1–10 cyc {if LER := 64})	**PRE**	:=	________

Load Profile

LDP LIST (NA, as many as 17 analog quantities)	**LDLIST**	:=	________
LDP ACQ RATE (5, 10, 15, 30, 60 min.)	**LDAR**	:=	________

Modbus Map Settings (SET M Command)

Modbus User Map

See Appendix E: Modbus Communications for additional details.

User Map Register Label Name (8 characters) **MOD_001** := ____________

User Map Register Label Name (8 characters) **MOD_002** := ____________

User Map Register Label Name (8 characters) **MOD_003** := ____________

User Map Register Label Name (8 characters) **MOD_004** := ____________

User Map Register Label Name (8 characters) **MOD_005** := ____________

User Map Register Label Name (8 characters) **MOD_006** := ____________

User Map Register Label Name (8 characters) **MOD_007** := ____________

User Map Register Label Name (8 characters) **MOD_008** := ____________

User Map Register Label Name (8 characters) **MOD_009** := ____________

User Map Register Label Name (8 characters) **MOD_010** := ____________

User Map Register Label Name (8 characters) **MOD_011** := ____________

User Map Register Label Name (8 characters) **MOD_012** := ____________

User Map Register Label Name (8 characters) **MOD_013** := ____________

User Map Register Label Name (8 characters) **MOD_014** := ____________

User Map Register Label Name (8 characters) **MOD_015** := ____________

User Map Register Label Name (8 characters) **MOD_016** := ____________

User Map Register Label Name (8 characters) **MOD_017** := ____________

User Map Register Label Name (8 characters) **MOD_018** := ____________

User Map Register Label Name (8 characters) **MOD_019** := ____________

User Map Register Label Name (8 characters) **MOD_020** := ____________

User Map Register Label Name (8 characters) **MOD_021** := ____________

User Map Register Label Name (8 characters) **MOD_022** := ____________

User Map Register Label Name (8 characters) **MOD_023** := ____________

User Map Register Label Name (8 characters) **MOD_024** := ____________

User Map Register Label Name (8 characters) **MOD_025** := ____________

User Map Register Label Name (8 characters) **MOD_026** := ____________

User Map Register Label Name (8 characters) **MOD_027** := ____________

User Map Register Label Name (8 characters) **MOD_028** := ____________

User Map Register Label Name (8 characters) **MOD_029** := ____________

User Map Register Label Name (8 characters) **MOD_030** := ____________

User Map Register Label Name (8 characters) **MOD_031** := ____________

User Map Register Label Name (8 characters) **MOD_032** := ____________

User Map Register Label Name (8 characters) **MOD_033** := ____________

User Map Register Label Name (8 characters) **MOD_034** := ____________

User Map Register Label Name (8 characters)	**MOD_035**	:=	________________
User Map Register Label Name (8 characters)	**MOD_036**	:=	________________
User Map Register Label Name (8 characters)	**MOD_037**	:=	________________
User Map Register Label Name (8 characters)	**MOD_038**	:=	________________
User Map Register Label Name (8 characters)	**MOD_039**	:=	________________
User Map Register Label Name (8 characters)	**MOD_040**	:=	________________
User Map Register Label Name (8 characters)	**MOD_041**	:=	________________
User Map Register Label Name (8 characters)	**MOD_042**	:=	________________
User Map Register Label Name (8 characters)	**MOD_043**	:=	________________
User Map Register Label Name (8 characters)	**MOD_044**	:=	________________
User Map Register Label Name (8 characters)	**MOD_045**	:=	________________
User Map Register Label Name (8 characters)	**MOD_046**	:=	________________
User Map Register Label Name (8 characters)	**MOD_047**	:=	________________
User Map Register Label Name (8 characters)	**MOD_048**	:=	________________
User Map Register Label Name (8 characters)	**MOD_049**	:=	________________
User Map Register Label Name (8 characters)	**MOD_050**	:=	________________
User Map Register Label Name (8 characters)	**MOD_051**	:=	________________
User Map Register Label Name (8 characters)	**MOD_052**	:=	________________
User Map Register Label Name (8 characters)	**MOD_053**	:=	________________
User Map Register Label Name (8 characters)	**MOD_054**	:=	________________
User Map Register Label Name (8 characters)	**MOD_055**	:=	________________
User Map Register Label Name (8 characters)	**MOD_056**	:=	________________
User Map Register Label Name (8 characters)	**MOD_057**	:=	________________
User Map Register Label Name (8 characters)	**MOD_058**	:=	________________
User Map Register Label Name (8 characters)	**MOD_059**	:=	________________
User Map Register Label Name (8 characters)	**MOD_060**	:=	________________
User Map Register Label Name (8 characters)	**MOD_061**	:=	________________
User Map Register Label Name (8 characters)	**MOD_062**	:=	________________
User Map Register Label Name (8 characters)	**MOD_063**	:=	________________
User Map Register Label Name (8 characters)	**MOD_064**	:=	________________
User Map Register Label Name (8 characters)	**MOD_065**	:=	________________
User Map Register Label Name (8 characters)	**MOD_066**	:=	________________
User Map Register Label Name (8 characters)	**MOD_067**	:=	________________
User Map Register Label Name (8 characters)	**MOD_068**	:=	________________
User Map Register Label Name (8 characters)	**MOD_069**	:=	________________
User Map Register Label Name (8 characters)	**MOD_070**	:=	________________
User Map Register Label Name (8 characters)	**MOD_071**	:=	________________

User Map Register Label Name (8 characters)	**MOD_072**	:=
User Map Register Label Name (8 characters)	**MOD_073**	:=
User Map Register Label Name (8 characters)	**MOD_074**	:=
User Map Register Label Name (8 characters)	**MOD_075**	:=
User Map Register Label Name (8 characters)	**MOD_076**	:=
User Map Register Label Name (8 characters)	**MOD_077**	:=
User Map Register Label Name (8 characters)	**MOD_078**	:=
User Map Register Label Name (8 characters)	**MOD_079**	:=
User Map Register Label Name (8 characters)	**MOD_080**	:=
User Map Register Label Name (8 characters)	**MOD_081**	:=
User Map Register Label Name (8 characters)	**MOD_082**	:=
User Map Register Label Name (8 characters)	**MOD_083**	:=
User Map Register Label Name (8 characters)	**MOD_084**	:=
User Map Register Label Name (8 characters)	**MOD_085**	:=
User Map Register Label Name (8 characters)	**MOD_086**	:=
User Map Register Label Name (8 characters)	**MOD_087**	:=
User Map Register Label Name (8 characters)	**MOD_088**	:=
User Map Register Label Name (8 characters)	**MOD_089**	:=
User Map Register Label Name (8 characters)	**MOD_090**	:=
User Map Register Label Name (8 characters)	**MOD_091**	:=
User Map Register Label Name (8 characters)	**MOD_092**	:=
User Map Register Label Name (8 characters)	**MOD_093**	:=
User Map Register Label Name (8 characters)	**MOD_094**	:=
User Map Register Label Name (8 characters)	**MOD_095**	:=
User Map Register Label Name (8 characters)	**MOD_096**	:=
User Map Register Label Name (8 characters)	**MOD_097**	:=
User Map Register Label Name (8 characters)	**MOD_098**	:=
User Map Register Label Name (8 characters)	**MOD_099**	:=
User Map Register Label Name (8 characters)	**MOD_100**	:=
User Map Register Label Name (8 characters)	**MOD_101**	:=
User Map Register Label Name (8 characters)	**MOD_102**	:=
User Map Register Label Name (8 characters)	**MOD_103**	:=
User Map Register Label Name (8 characters)	**MOD_104**	:=
User Map Register Label Name (8 characters)	**MOD_105**	:=
User Map Register Label Name (8 characters)	**MOD_106**	:=
User Map Register Label Name (8 characters)	**MOD_107**	:=
User Map Register Label Name (8 characters)	**MOD_108**	:=

User Map Register Label Name (8 characters)	**MOD_109**	:=	______________
User Map Register Label Name (8 characters)	**MOD_110**	:=	______________
User Map Register Label Name (8 characters)	**MOD_111**	:=	______________
User Map Register Label Name (8 characters)	**MOD_112**	:=	______________
User Map Register Label Name (8 characters)	**MOD_113**	:=	______________
User Map Register Label Name (8 characters)	**MOD_114**	:=	______________
User Map Register Label Name (8 characters)	**MOD_115**	:=	______________
User Map Register Label Name (8 characters)	**MOD_116**	:=	______________
User Map Register Label Name (8 characters)	**MOD_117**	:=	______________
User Map Register Label Name (8 characters)	**MOD_118**	:=	______________
User Map Register Label Name (8 characters)	**MOD_119**	:=	______________
User Map Register Label Name (8 characters)	**MOD_120**	:=	______________
User Map Register Label Name (8 characters)	**MOD_121**	:=	______________
User Map Register Label Name (8 characters)	**MOD_122**	:=	______________
User Map Register Label Name (8 characters)	**MOD_123**	:=	______________
User Map Register Label Name (8 characters)	**MOD_124**	:=	______________
User Map Register Label Name (8 characters)	**MOD_125**	:=	______________

Date ____________
Group____________

DNP3 Map Settings (SET DNP n Command)

Use **SET DNP n** command with n = 1, 2, or 3 to create as many as three DNP User Maps. Refer to Appendix D: DNP3 Communications for details.

This is DNP Map 1 (DNP Map 2 and DNP Map 3 tables are identical to DNP Map 1 table).

Binary Input Map

DNP Binary Input Label Name (10 characters)	**BI_00**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_01**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_02**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_03**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_04**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_05**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_06**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_07**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_08**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_09**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_10**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_11**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_12**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_13**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_14**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_15**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_16**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_17**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_18**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_19**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_20**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_21**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_22**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_23**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_24**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_25**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_26**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_27**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_28**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_29**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_30**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_31**	:= ____________

DNP Binary Input Label Name (10 characters)	**BI_32**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_33**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_34**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_35**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_36**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_37**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_38**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_39**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_40**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_41**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_42**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_43**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_44**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_45**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_46**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_47**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_48**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_49**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_50**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_51**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_52**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_53**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_54**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_55**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_56**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_57**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_58**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_59**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_60**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_61**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_62**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_63**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_64**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_65**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_66**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_67**	:= ____________
DNP Binary Input Label Name (10 characters)	**BI_68**	:= ____________

DNP Binary Input Label Name (10 characters)	**BI_69**	:=
DNP Binary Input Label Name (10 characters)	**BI_70**	:=
DNP Binary Input Label Name (10 characters)	**BI_71**	:=
DNP Binary Input Label Name (10 characters)	**BI_72**	:=
DNP Binary Input Label Name (10 characters)	**BI_73**	:=
DNP Binary Input Label Name (10 characters)	**BI_74**	:=
DNP Binary Input Label Name (10 characters)	**BI_75**	:=
DNP Binary Input Label Name (10 characters)	**BI_76**	:=
DNP Binary Input Label Name (10 characters)	**BI_77**	:=
DNP Binary Input Label Name (10 characters)	**BI_78**	:=
DNP Binary Input Label Name (10 characters)	**BI_79**	:=
DNP Binary Input Label Name (10 characters)	**BI_80**	:=
DNP Binary Input Label Name (10 characters)	**BI_81**	:=
DNP Binary Input Label Name (10 characters)	**BI_82**	:=
DNP Binary Input Label Name (10 characters)	**BI_83**	:=
DNP Binary Input Label Name (10 characters)	**BI_84**	:=
DNP Binary Input Label Name (10 characters)	**BI_85**	:=
DNP Binary Input Label Name (10 characters)	**BI_86**	:=
DNP Binary Input Label Name (10 characters)	**BI_87**	:=
DNP Binary Input Label Name (10 characters)	**BI_88**	:=
DNP Binary Input Label Name (10 characters)	**BI_89**	:=
DNP Binary Input Label Name (10 characters)	**BI_90**	:=
DNP Binary Input Label Name (10 characters)	**BI_91**	:=
DNP Binary Input Label Name (10 characters)	**BI_92**	:=
DNP Binary Input Label Name (10 characters)	**BI_93**	:=
DNP Binary Input Label Name (10 characters)	**BI_94**	:=
DNP Binary Input Label Name (10 characters)	**BI_95**	:=
DNP Binary Input Label Name (10 characters)	**BI_96**	:=
DNP Binary Input Label Name (10 characters)	**BI_97**	:=
DNP Binary Input Label Name (10 characters)	**BI_98**	:=
DNP Binary Input Label Name (10 characters)	**BI_99**	:=

Binary Output Map

DNP Binary Output Label Name (10 characters)	**BO_00**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_01**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_02**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_03**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_04**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_05**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_06**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_07**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_08**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_09**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_10**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_11**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_12**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_13**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_14**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_15**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_16**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_17**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_18**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_19**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_20**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_21**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_22**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_23**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_24**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_25**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_26**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_27**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_28**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_29**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_30**	:= ______
DNP Binary Output Label Name (10 characters)	**BO_31**	:= ______

Analog Input Map

DNP Analog Input Label Name (24 characters)

AI_00 := ______________________
AI_01 := ______________________
AI_02 := ______________________
AI_03 := ______________________
AI_04 := ______________________
AI_05 := ______________________
AI_06 := ______________________
AI_07 := ______________________
AI_08 := ______________________
AI_09 := ______________________
AI_10 := ______________________
AI_11 := ______________________
AI_12 := ______________________
AI_13 := ______________________
AI_14 := ______________________
AI_15 := ______________________
AI_16 := ______________________
AI_17 := ______________________
AI_18 := ______________________
AI_19 := ______________________
AI_20 := ______________________
AI_21 := ______________________
AI_22 := ______________________
AI_23 := ______________________
AI_24 := ______________________
AI_25 := ______________________
AI_26 := ______________________
AI_27 := ______________________
AI_28 := ______________________
AI_29 := ______________________
AI_30 := ______________________
AI_31 := ______________________
AI_32 := ______________________
AI_33 := ______________________
AI_34 := ______________________

AI_35 := ____________________

AI_36 := ____________________

AI_37 := ____________________

AI_38 := ____________________

AI_39 := ____________________

AI_40 := ____________________

AI_41 := ____________________

AI_42 := ____________________

AI_43 := ____________________

AI_44 := ____________________

AI_45 := ____________________

AI_46 := ____________________

AI_47 := ____________________

AI_48 := ____________________

AI_49 := ____________________

AI_50 := ____________________

AI_51 := ____________________

AI_52 := ____________________

AI_53 := ____________________

AI_54 := ____________________

AI_55 := ____________________

AI_56 := ____________________

AI_57 := ____________________

AI_58 := ____________________

AI_59 := ____________________

AI_60 := ____________________

AI_61 := ____________________

AI_62 := ____________________

AI_63 := ____________________

AI_64 := ____________________

AI_65 := ____________________

AI_66 := ____________________

AI_67 := ____________________

AI_68 := ____________________

AI_69 := ____________________

AI_70 := ____________________

AI_71 := ____________________

AI_72 := ______________________________
AI_73 := ______________________________
AI_74 := ______________________________
AI_75 := ______________________________
AI_76 := ______________________________
AI_77 := ______________________________
AI_78 := ______________________________
AI_79 := ______________________________
AI_80 := ______________________________
AI_81 := ______________________________
AI_82 := ______________________________
AI_83 := ______________________________
AI_84 := ______________________________
AI_85 := ______________________________
AI_86 := ______________________________
AI_87 := ______________________________
AI_88 := ______________________________
AI_89 := ______________________________
AI_90 := ______________________________
AI_91 := ______________________________
AI_92 := ______________________________
AI_93 := ______________________________
AI_94 := ______________________________
AI_95 := ______________________________
AI_96 := ______________________________
AI_97 := ______________________________
AI_98 := ______________________________
AI_99 := ______________________________

Analog Output Map

DNP Analog Output Label Name (6 characters)	**AO_00**	:= ____________
DNP Analog Output Label Name (6 characters)	**AO_01**	:= ____________
DNP Analog Output Label Name (6 characters)	**AO_02**	:= ____________
DNP Analog Output Label Name (6 characters)	**AO_03**	:= ____________
DNP Analog Output Label Name (6 characters)	**AO_04**	:= ____________
DNP Analog Output Label Name (6 characters)	**AO_05**	:= ____________
DNP Analog Output Label Name (6 characters)	**AO_06**	:= ____________

DNP Analog Output Label Name (6 characters)	**AO_07**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_08**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_09**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_10**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_11**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_12**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_13**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_14**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_15**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_16**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_17**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_18**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_19**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_20**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_21**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_22**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_23**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_24**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_25**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_26**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_27**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_28**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_29**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_30**	:= ______
DNP Analog Output Label Name (6 characters)	**AO_31**	:= ______

Counter Map

DNP Counter Label Name (11 characters)	**CO_00**	:= ______
DNP Counter Label Name (11 characters)	**CO_01**	:= ______
DNP Counter Label Name (11 characters)	**CO_02**	:= ______
DNP Counter Label Name (11 characters)	**CO_03**	:= ______
DNP Counter Label Name (11 characters)	**CO_04**	:= ______
DNP Counter Label Name (11 characters)	**CO_05**	:= ______
DNP Counter Label Name (11 characters)	**CO_06**	:= ______
DNP Counter Label Name (11 characters)	**CO_07**	:= ______
DNP Counter Label Name (11 characters)	**CO_08**	:= ______
DNP Counter Label Name (11 characters)	**CO_09**	:= ______
DNP Counter Label Name (11 characters)	**CO_10**	:= ______

DNP Counter Label Name (11 characters)	**CO_11**	:=
DNP Counter Label Name (11 characters)	**CO_12**	:=
DNP Counter Label Name (11 characters)	**CO_13**	:=
DNP Counter Label Name (11 characters)	**CO_14**	:=
DNP Counter Label Name (11 characters)	**CO_15**	:=
DNP Counter Label Name (11 characters)	**CO_16**	:=
DNP Counter Label Name (11 characters)	**CO_17**	:=
DNP Counter Label Name (11 characters)	**CO_18**	:=
DNP Counter Label Name (11 characters)	**CO_19**	:=
DNP Counter Label Name (11 characters)	**CO_20**	:=
DNP Counter Label Name (11 characters)	**CO_21**	:=
DNP Counter Label Name (11 characters)	**CO_22**	:=
DNP Counter Label Name (11 characters)	**CO_23**	:=
DNP Counter Label Name (11 characters)	**CO_24**	:=
DNP Counter Label Name (11 characters)	**CO_25**	:=
DNP Counter Label Name (11 characters)	**CO_26**	:=
DNP Counter Label Name (11 characters)	**CO_27**	:=
DNP Counter Label Name (11 characters)	**CO_28**	:=
DNP Counter Label Name (11 characters)	**CO_29**	:=
DNP Counter Label Name (11 characters)	**CO_30**	:=
DNP Counter Label Name (11 characters)	**CO_31**	:=

Section 7
Communications

Overview

A communications interface and protocol are required for communicating with the SEL-787 Transformer Protection Relay. A communications interface is the physical connection on a device. Once you have established a physical connection, you must use a communications protocol to interact with the relay.

The first part of this section describes communications interfaces and protocols available with the relay, including communication interface connections. The remainder of the section describes the ASCII commands you can use to communicate with the relay to obtain information, reports, data, or perform control functions.

Communications Interfaces

The SEL-787 physical interfaces are shown in *Table 7.1*. Several optional SEL devices are available to provide alternative physical interfaces, including EIA-485, EIA-232 fiber-optic serial port, copper or fiber Ethernet port, single or dual redundant.

Table 7.1 SEL-787 Communications Port Interfaces

	Communications Port Interfaces	Location	Feature
PORT F	EIA-232	Front	Standard
PORT 1	Option 1: 10/100BASE-T Ethernet (RJ45 connector) Option 2: Dual, redundant 10/100 BASE-T Ethernet (Port 1A, Port 1B) Option 3: 100BASE-FX Ethernet (LC connector) Option 4: Dual, redundant 100BASE-FX Ethernet (Port 1A, Port 1B)	Rear	Ordering Option
PORT 2[a]	Multimode Fiber-Optic Serial (ST connector and SEL-2812 compatible))	Rear	Standard
PORT 3	Option 1: EIA-232 Option 2: EIA-485	Rear	Standard
PORT 4	Option 1: EIA-232 or EIA-485 Serial Communications Card Option 2: DeviceNet Communications Card[b]	Rear	Ordering Option

[a] This port can receive the RTD measurement information from the optional external SEL-2600 RTD Module. Refer to the applicable SEL-2600 RTD Module Instruction Manual for information on the fiber-optic interface.
[b] Refer to Appendix G: DeviceNet Communications for information on the DeviceNet communications card.

Be sure to evaluate the installation and communications necessary to integrate with existing devices before ordering your SEL-787. For example, consider the fiber-optic interface in noisy installations or for large communications distances. Following is general information on possible applications of the different interfaces.

Serial (EIA-232 and EIA-485) Port

Use the EIA-232 port for communications distances of ≤15 m (50 feet) in low noise environments. Use the optional EIA-485 port for communications distances ≤1200 m (4000 feet) maximum distance (to achieve this performance, ensure proper line termination at the receiver).

To connect a PC serial port to the relay front-panel serial port and enter relay commands, you will need the following:

- ➤ A personal computer equipped with one available EIA-232 serial port
- ➤ A communications cable to connect the computer serial port to the relay serial ports
- ➤ Terminal emulation software to control the computer serial port
- ➤ An SEL-787 Relay

Some of the SEL devices available for integration or communication system robustness are included in the following list:

- ➤ SEL Communications Processors (SEL-2032, SEL-2030, SEL-2020)
- ➤ SEL-2800 Series Fiber-Optic Transceivers
- ➤ SEL-2890 Ethernet Transceiver
- ➤ SEL-3010 Event Messenger
- ➤ SEL-2505 SEL Remote I/O Module (with SEL-2812 compatible ST fiber-optic port) for connection to relay fiber-optic serial Port 2, or use SEL-2505 with EIA-232 (DB-9) serial port to connect to EIA-232 Port 3 on the relay

A variety of terminal emulation programs on personal computers can communicate with the relay. For the best display, use VT-100 terminal emulation or the closest variation.

The default settings for all EIA-232 serial ports are listed below:

- ➤ Data Rate = 9600
- ➤ Data Bits = 8
- ➤ Parity = N
- ➤ Stop Bits = 1

To change the port settings, use the **SET P** command (see *Section 6: Settings*) or the front-panel. *Section 8: Front-Panel Operations* provides details on making settings with the front panel.

Hardware Flow Control

All EIA-232 serial ports support RTS/CTS hardware handshaking (hardware flow control). To enable hardware handshaking, use the **SET P** command or front-panel PORT submenu to set RTSCTS = Y. Disable hardware handshaking by setting RTSCTS := N.

- ➤ If RTSCTS := N, the relay permanently asserts the RTS line.
- ➤ If RTSCTS := Y, the relay deasserts RTS when it is unable to receive characters.
- ➤ If RTSCTS := Y, the relay does not send characters until the CTS input is asserted.

Fiber-Optic Serial Port

Use the optional fiber-optic port (PORT 2) for safety and communications distances as far as 1 km. Communications distances as far as 4 km can be achieved by using an SEL-2812 transceiver on PORT 3. While PORT 2 and the SEL-2812 are compatible, PORT 2 is less sensitive than the SEL-2812, which limits the distance to 1 km.

Ethernet Port

Use the Ethernet port for interfacing with an Ethernet network environment. SEL-787 Ethernet port choices include single or dual copper or fiber-optic configurations. With dual Ethernet ports the unit has an unmanaged Ethernet switch. Redundant configurations support automatic failover switching from primary to backup network if a failure in the primary network is detected. In addition to failover mode, the unit can operate in a "fixed connection (to netport) mode" or in a "switched mode" (as an unmanaged switch).

Figure 7.1 shows an example of a Simple Ethernet Network Configuration, *Figure 7.2* shows an example of an Ethernet Network Configuration with Dual Redundant Connections, and *Figure 7.3* shows an example of an Ethernet Network Configuration with Ring Structure.

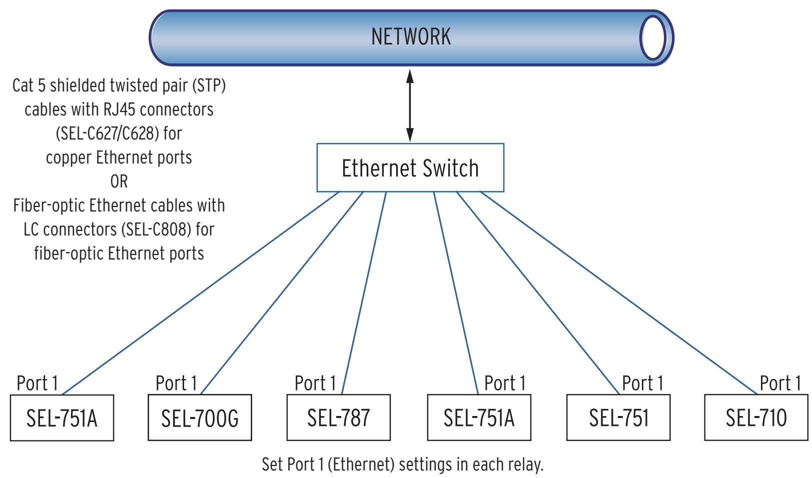


Figure 7.1 Simple Ethernet Network Configuration

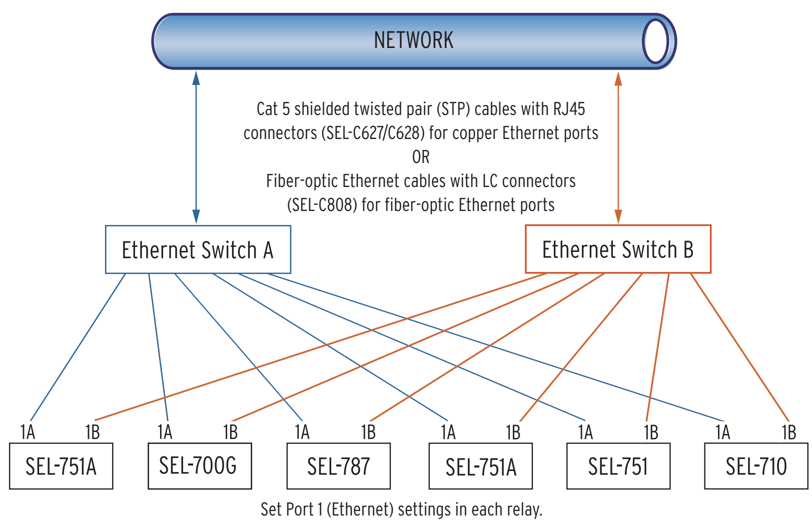


Figure 7.2 Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)

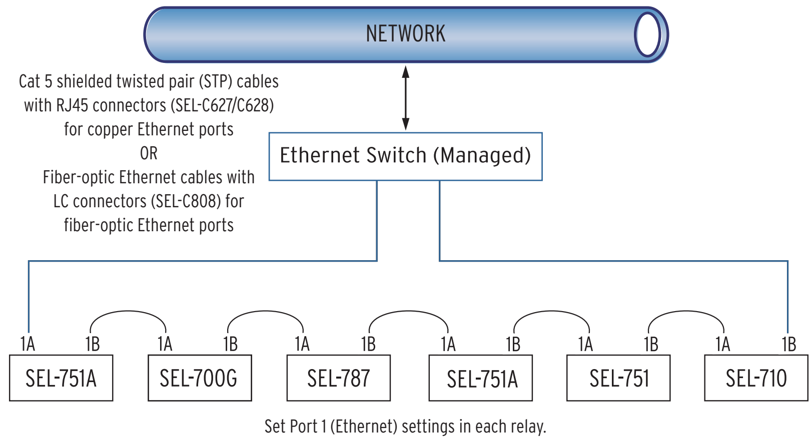


Figure 7.3 Ethernet Network Configuration With Ring Structure (Switched Mode)

Dual Network Port Operation

The SEL-787 dual Ethernet port option has two network ports. Network port failover mode enables the dual Ethernet port to operate as a single network adapter with a primary and standby physical interface. You can connect the two network ports to the same network or to different networks depending on your specific Ethernet network architecture.

Failover Mode

In the failover mode operation, the relay determines the active port. To use failover mode, proceed with the following steps.

NOTE: If you change settings for the host port in the relay and the standby network port is active, the relay resets and returns to operation on the primary port.

Step 1. Set NETMODE to FAILOVER.

Step 2. Set FTIME to the desired network port failover time.

Step 3. Set NETPORT to the preferred network interface.

On startup the relay communicates via NETPORT (primary port) selected. If the SEL-787 detects a link failure on the primary port, it activates the standby port after the failover time, FTIME, elapses. If the link status on the primary link returns to normal before the failover time expires, the failover timer resets and uninterrupted operation continues on the primary network port.

After failover, while communicating via standby port, the SEL-787 checks the primary link periodically and continues checking until it detects a normal link status. The relay continues to communicate via the standby port even after the primary port returns to normal. The port of choice for communications is reevaluated on change of settings or failure of the standby port or on reboot. The relay returns to operation on the primary link under those conditions if it detects a normal link status. When the active and backup links both fail, the relay alternates checking for the link status of the primary and standby ports.

Unmanaged Switch Mode

If you have a network configuration where you want to use the relay as an unmanaged switch, set NETMODE to SWITCHED. In this mode, both links are enabled. The relay will respond to the messages received on either port. All the messages received on one network port that are not addressed to the relay will be transmitted out of the other port without any modifications. In this mode NETPORT setting is ignored.

Fixed Connection Mode

If you have a single network and want to use only one network port, or if you have both ports connected but want to force usage of only one port for various reasons, set NETMODE to FIXED and set NETPORT to the port you want to use. Only the selected network port operates and the other port is disabled.

Autonegotiation, Speed, and Duplex Mode

Single or dual copper Ethernet ports are capable of autonegotiating to determine the link speed and duplex mode. This is accomplished by setting the NETASPD and NETBSPD (network speed) to AUTO. Single or dual copper ports can also be set to a specific speed to be able to apply them in networks with older switch devices. However, the speed setting is ignored for fiber Ethernet ports. The single and dual fiber Ethernet ports are fixed by the hardware to work at 100 Mbps and full duplex mode.

NETPORT Selection

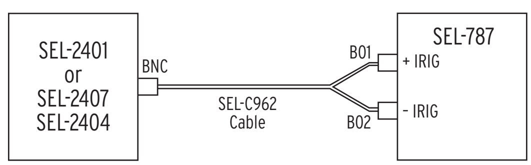
The NETPORT setting gives the user the option to select the primary port of communication in failover or fixed communication modes. Selecting “D” for this setting disables both the ports there by providing the user the security to turn off the ports even if the ports are physically connected to the network.

IRIG-B

The SEL-787 has three different physical interfaces, depending on the model options, to provide demodulated IRIG-B time-code input for time synchronization. If the relay has multiple options for IRIG-B input, only one input can be used at a time. Connection diagrams for IRIG-B and settings selection are in *Figure 7.4* through *Figure 7.6* in this section.

Option 1: Terminals B01 and B02

This input is available on all models with EIA-485 Port 3. Refer to *Figure 7.4* for a connection diagram.



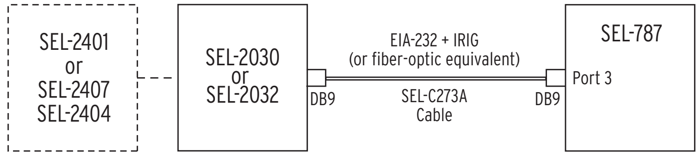
B01–B02 IRIG-B input is available on all models with EIA-485 Port 3.
Cannot bring IRIG-B via Port 2 if **B01–B02** input is used.
Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG1.

Figure 7.4 IRIG-B Input (Relay Terminals B01–B02)

Option 2: Port 3 (EIA-232 Option Only)

Connect to an SEL communications processor with an SEL-C273A Cable to bring IRIG-B input with the EIA-232 port. Refer to *Figure 7.5* for a connection diagram.

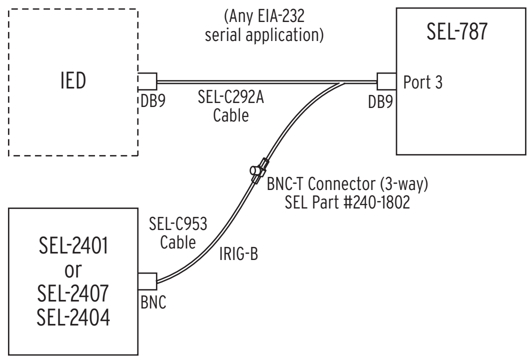
Refer to *Figure 7.6* on how to connect a SEL Time Source (SEL-2401, SEL-2404, SEL-2407) for IRIG-B Input to Port 3.



Cannot use Port 2 if Port 3 is used.

Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG1.

Figure 7.5 IRIG-B Input Via EIA-232 Port 3 (SEL Communications Processor as Source)



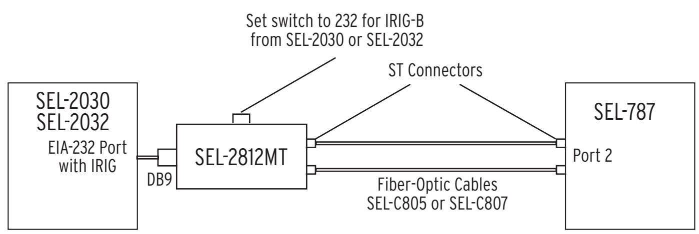
Cannot use Port 2 if Port 3 is used.

Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG1.

Figure 7.6 IRIG-B Input Via EIA-232 Port 3 (SEL-2401/2404/2407 Time Source)

Option 3: Port 2 (Fiber-Optic Serial Port)

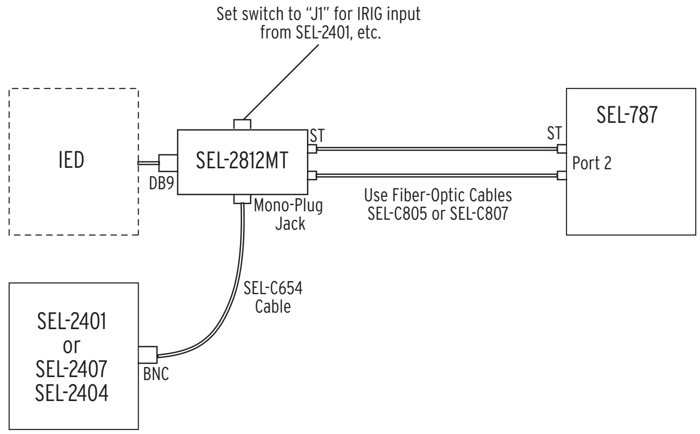
Fiber-Optic Serial Port 2 can be used to bring IRIG-B Input to the relay as shown in *Figure 7.7* and *Figure 7.8*.



Cannot use B01–B02 input or Port 3 input if Port 2 is used for IRIG-B input.

Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG2.

Figure 7.7 IRIG-B Input VIA Fiber-Optic EIA-232 Port 2 (SEL-2030/2032 Time Source)



Cannot use B01–B02 input or Port 3 input if Port 2 is used for IRIG-B input.

Set Global setting IRIG TIME SOURCE to TIME_SRC := IRIG2.

Figure 7.8 IRIG-B Input VIA Fiber-Optic EIA-232 Port 2 (SEL-2401/2404/2407 Time Source)

+5 Vdc Power Supply

Serial port power can provide as much as 0.25 A total from all of the +5 Vdc pins. Some SEL communications devices require the +5 Vdc power supply. This +5 Vdc is available on Pin 1 only.

Connect Your PC to the Relay

The front port of the SEL-787 is a standard female 9-pin connector. You can connect to a standard 9-pin computer port with an SEL-C234A Cable; wiring for this cable is shown in *Figure 7.10*. An SEL-C234A Cable and other cables are available from SEL. Use the SEL-5801 Cable Selector Software to select an appropriate cable for another application. This software is available for free download from the SEL website at selinc.com.

For best performance, an SEL-C234A Cable should not be more than 15 m (49 ft) long. For long-distance communications and for electrical isolation of communications ports, use the SEL family of fiber-optic transceivers. Contact SEL for more details on these devices.

Port Connector and Communications Cables

Figure 7.9 shows the front-panel EIA-232 serial port (PORT F) DB-9 connector pinout for the SEL-787.

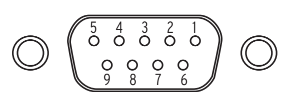


Figure 7.9 EIA-232 DB-9 Connector Pin Numbers

Table 7.2 shows the pin functions for the EIA-232 and EIA-485 serial ports.

Table 7.2 EIA-232/EIA-485 Serial Port Pin Functions (Sheet 1 of 2)

Pin[a]	PORT 3 EIA-232	PORT 3 EIA-485[a]	PORT 4C EIA-232	PORT 4A EIA-485[a]	PORT F EIA-232
1	+5 Vdc	+TX	+5 Vdc	+TX	N/C
2	RXD	–TX	RXD	–TX	RXD
3	TXD	+RX	TXD	+RX	TXD
4	IRIG+	–RX	N/C	–RX	N/C
5	GND	Shield	GND	Shield	GND
6	IRIG–		N/C		N/C
7	RTS		RTS		RTS

Table 7.2 EIA-232/EIA-485 Serial Port Pin Functions (Sheet 2 of 2)

Pin[a]	PORT 3 EIA-232	PORT 3 EIA-485[a]	PORT 4C EIA-232	PORT 4A EIA-485[a]	PORT F EIA-232
8	CTS		CTS		CTS
9	GND		GND		GND

[a] For EIA-485, the pin numbers represent relay terminals _01 through _05.

The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-787 to other devices. These and other cables are available from SEL. Contact the factory for more information.

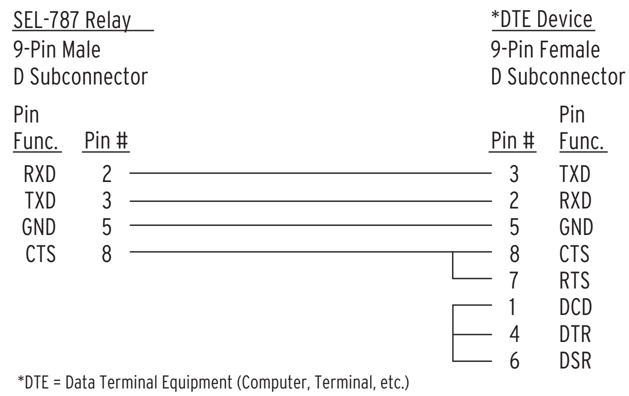


Figure 7.10 SEL Cable C234A—SEL-787 to DTE Device

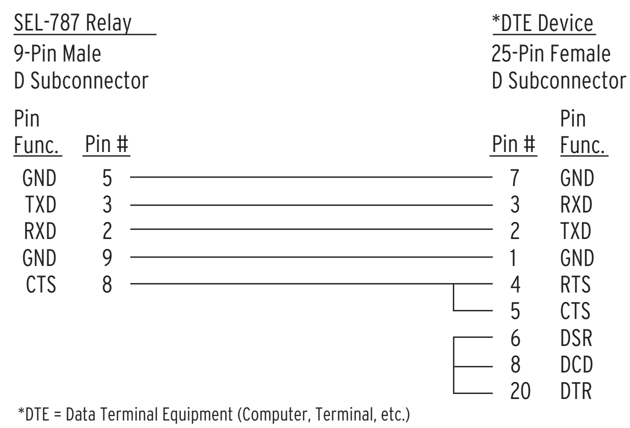


Figure 7.11 SEL Cable C227A—SEL-787 to DTE Device

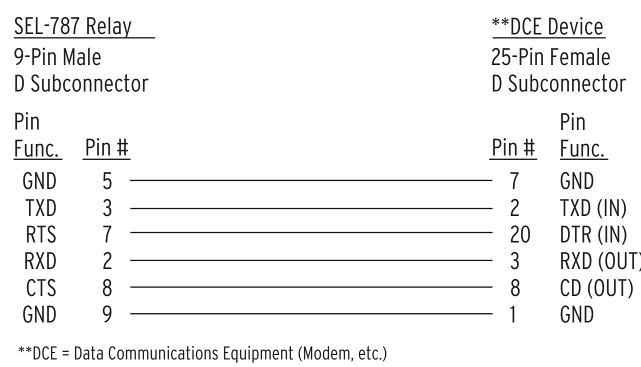


Figure 7.12 SEL Cable C222—SEL-787 to Modem

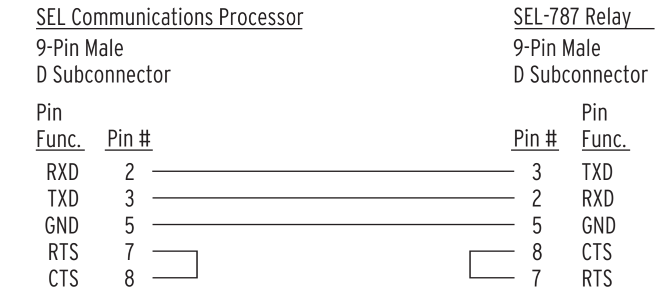


Figure 7.13 SEL Cable C272A—SEL-787 to SEL Communications Processor (Without IRIG-B Signal)

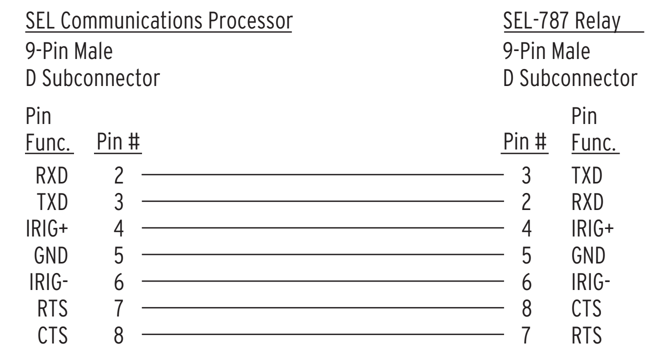


Figure 7.14 SEL Cable C273A—SEL-787 to SEL Communications Processor (With IRIG-B Signal)

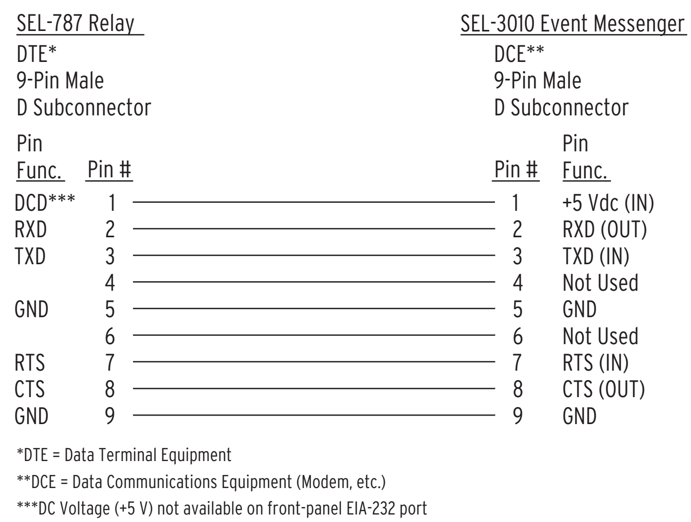


Figure 7.15 SEL Cable C387—SEL-787 to SEL-3010

Communications Protocols

Protocols

Although the SEL-787 supports a wide range of protocols, not all protocols are available on all ports. In addition, not all hardware options support all protocols.

Be sure to select the correct hardware to support a particular protocol. For example, if Modbus TCP is necessary for your application, be sure to order the Ethernet option for Port 1. *Table 7.3* shows the ports and the protocols available on each port.

NOTE: FTP, Modbus, and DeviceNet protocols ignore the hide rules of the settings.

Table 7.3 Protocols Supported on the Various Ports

	Supported Protocol
PORT F	SEL ASCII and Compressed ASCII Protocols, SELBOOT, File Transfer Protocol, Modbus RTU Slave, C37.118 Protocol (synchrophasor data), and Event Messenger
PORT 1	Modbus TCP/IP, FTP, TCP/IP, IEC 61850, SNTP. DNP3 LAN/WAN, and Telnet TCP/IP (SEL ASCII, Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER)[a]
PORT 2	All the protocols supported by **PORT 3**
PORT 3	SEL ASCII and Compressed ASCII Protocols, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, SEL Settings File Transfer, SEL MIRRORED BITS, DNP3, Modbus RTU Slave, C37.118 Protocol (synchrophasor data), and Event Messenger
PORT 4	All the protocols supported by **PORT 3** and DeviceNet

[a] PORT 1 concurrently supports two Modbus, two FTP, two Telnet, six IEC 61850, one SNTP, and three DNP3 LAN/WAN sessions.

SEL Communications Protocols

SEL ASCII. This protocol is described in *SEL ASCII Protocol and Commands on page 7.14*.

SEL Compressed ASCII. This protocol provides compressed versions of some of the ASCII commands. The compressed commands are described in *SEL ASCII Protocol and Commands*, and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Meter. This protocol supports binary messages to transfer metering and digital element messages. Compressed ASCII commands that support Fast Meter are described in *SEL ASCII Protocol and Commands*, and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Operate. This protocol supports binary messages to transfer operation messages. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast SER. This protocol is used to receive binary Sequential Events Record unsolicited responses. The protocol is described in *Appendix C: SEL Communications Processors*.

SEL Event Messenger. This is an SEL ASCII protocol with 8 data bits, no parity, and 1 stop bit for transmitting data to SEL-3010 Event Messenger. Only the communications speed is user settable to match the settings in the SEL-3010.

MIRRORED BITS Protocol

The SEL-787 supports two MIRRORED BITS communications channels, designated A and B. Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). You can, for example, set MBA on Port 3 of the base unit and MBB on Port 4A of the optional communications card. Attempting to set the PROTO setting to MBA, MB8A, or MBTA when channel A is already assigned to another port (or MBB, MB8B, or MBTB when channel B is already assigned on another port) results in the following error message: `This Mirrored Bits channel is assigned to another port.` After displaying the error message, the device returns to the PROTO setting for reentry.

C37.118 Protocol

The SEL-787 provides C37.118 protocol (synchrophasor data) support at one of the serial ports F, 2, 3, or 4. The protocol is described in *Appendix I: Synchrophasors*.

Modbus RTU Protocol

The SEL-787 provides Modbus RTU support. Modbus is a protocol described in *Appendix E: Modbus Communications*.

DNP3 (Distributed Network Protocol)

The SEL-787 provides DNP3 protocol support if the option is selected. The DNP3 protocol is described in *Appendix D: DNP3 Communications*.

DeviceNet

The SEL-787 provides DeviceNet support. DeviceNet is an optional protocol described in *Appendix G: DeviceNet Communications*.

Ethernet Protocols

As with other communications interfaces, you must choose a data exchange protocol that operates over the Ethernet network link in order to exchange data. The relay supports FTP, Telnet, Ping, Modbus/TCP, IEC 61850, and DNP3 LAN/WAN protocols.

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. Work with a networking professional to design your substation Ethernet network.

FTP Server

Use the single FTP (File Transfer Protocol) session to access the following files:

- CFG.XML—Configuration read-only file in XML format
- CFG.TXT—Configuration read-only file in TXT format
- ERR.TXT—Error read-only file in TXT format
- SET_61850.CID—IEC 61850 CID read-write file
- SET_xx.TXT—Setting files in TXT format

FTP is a standard TCP/IP protocol for exchanging files. A free FTP application is included with most web browser software. You can also obtain a free or inexpensive FTP application from the Internet. When you connect to the relay Ethernet port, you will find files stored in the root (top-level) directory.

Telnet Server

Use the Telnet session (TPORT default setting is port 23) to connect to the relay to use the protocols, which are described in more detail below:

- SEL ASCII
- Compressed ASCII
- Fast Meter
- Fast Operate

NOTE: Use the **QUIT** command prior to closing the Telnet-to-Host session to set the relay to Access Level 0. Otherwise the relay will remain at an elevated access level until TIDLE expires.

Telnet is a terminal connection across a TCP/IP network that operates in a manner very similar to a direct serial port connection to one of the relay ports. As with FTP, Telnet is a part of TCP/IP. A free Telnet application is included with most computer operating systems, or you can obtain low-cost or free Telnet applications on the Internet.

Ping Server

Use a Ping client with the relay Ping server to verify that your network configuration is correct. Ping is an application based on ICMP over an IP network. A free Ping application is included with most computer operating systems.

IEC 61850

Use as many as six sessions of MMS over a TCP network to exchange data with the relay. Use GOOSE to do real-time data exchange with as many as 16 incoming messages and 8 outgoing messages. For more details on the IEC 61850 protocol, see *Appendix F: IEC 61850 Communications*.

Simple Network Time Protocol (SNTP)

When Port 1 (Ethernet port) setting ESNTP is not OFF, the internal clock of the relay conditionally synchronizes to the time of day served by a Network Time Protocol (NTP) server. The relay uses a simplified version of NTP called the Simple Network Time Protocol (SNTP). SNTP is not as accurate as IRIG-B. The relay can use SNTP as a less accurate primary time source, or as a backup to the higher accuracy IRIG-B time source.

SNTP as Primary or Backup Time Source

If an IRIG-B time source is connected and either Relay Word bit TSOK or Relay Word bit IRIGOK asserts, then the relay synchronizes the internal time-of-day clock to the incoming IRIB-G time code signal, even if SNTP is configured in the relay and an NTP server is available. If the IRIG-B source is disconnected (if both TSOK and IRIGOK deassert) then the relay synchronizes the internal time-of-day clock to the NTP server, if available. In this way, an NTP server acts either as the primary time source or as a backup time source to the more accurate IRIG-B time source.

Creating an NTP Server

Three SEL application notes, available from the SEL website, describe how to create an NTP server.

- *AN2009-10: Using an SEL-2401, SEL-2404, or SEL-2407 to Serve NTP Via the SEL-3530 RTAC*
- *AN2009-38: Using SEL Satellite-Synchronized Clocks With the SEL-3332 or SEL-3351 to Output NTP*
- *AN2010-03: Using an SEL-2401, SEL-2404, or SEL-2407 to Create a Stratum 1 Linux NTP Server*

Configuring SNTP Client in the Relay

To enable SNTP in the relay, make Port 1 setting ESNTP = UNICAST, MANYCAST, or BROADCAST. *Table 7.4* shows each setting associated with SNTP.

Table 7.4 Settings Associated With SNTP

Setting	Range	Description
ESNTP	UNICAST, MANYCAST, BROADCAST	Selects the mode of operation of SNTP. See descriptions in *SNTP Operation Modes on page 7.13*.
SNTPPSIP	Valid IP Address	Selects primary NTP server when ENSTP = UNICAST, or broadcast address when ESNTP = MANYCAST or BROADCAST.
SNTPPSIB	Valid IP Address	Selects backup NTP server when ESNTP = UNICAST.
SNTPPORT	1–65534	Ethernet port used by SNTP. Leave at default value unless otherwise required.
SNTPRATE	15–3600 seconds	Determines the rate at which the relay asks for updated time from the NTP server when ESNTP = UNICAST or MANYCAST. Determines the time the relay will wait for an NTP broadcast when ENSTP = BROADCAST.
SNTPTO	5–20 seconds	Determines the time the relay will wait for the NTP master to respond when ENSTP = UNICAST or MANYCAST.

SNTP Operation Modes

The following sections explain the setting associated with each SNTP operation mode (UNICAST, MANYCAST, and BROADCAST).

ESNTP = UNICAST

In UNICAST mode of operation, the SNTP client in the relay requests time updates from the primary (IP address setting SNTPPSIP) or backup (IP address setting SNTPBSIP) NTP server at a rate defined by setting SNTPRATE. If the NTP server does not respond with the period defined by setting SNTPTO, then the relay tries the other SNTP server. When the relay successfully synchronizes to the primary NTP time server, Relay Word bit TSNTPP asserts. When the relay successfully synchronizes to the backup NTP time server, Relay Word bit TSNTPB asserts.

ESNTP = MANYCAST

In the MANYCAST mode of operation, the relay initially sends an NTP request to the broadcast address contained in setting SNTPPSIP. The relay continues to broadcast requests at a rate defined by setting SNTPRATE. When a server replies, the relay considers that server to be the primary NTP server, and switches to UNICAST mode, asserts Relay Word bit TSNTPP, and thereafter requests updates from the primary server. If the NTP server stops responding for time SNTPTO, the relay deasserts TSNTPP and begins to broadcast requests again until the original or another server responds.

ESNTP = BROADCAST

If setting SNTPPSIP = 0.0.0.0 while setting ESNTP = BROADCAST, the relay will listen for and synchronize to any broadcasting NTP server. If setting SNTPPSIP is set to a specific IP address while setting ESNTP = BROADCAST, then the relay will listen for and synchronize to only NTP server broadcasts from that address. When synchronized, the relay asserts Relay Word bit TSNTPP. Relay Word bit TNSTPP deasserts if the relay does not receive a valid broadcast within five seconds after the period defined by setting SNTPRATE.

SNTP Accuracy Considerations

SNTP time synchronization accuracy is limited by the accuracy of the SNTP Server and by the networking environment. The highest degree of SNTP time synchronization can be achieved by minimizing the number of switches and routers between the SNTP Server and the SEL-787. Network monitoring software can also be used to ensure that average and worst-case network bandwidth use is moderate.

When installed on a network configured with one Ethernet switch between the SEL-787 and the SNTP Server, and when using ESNTP = UNICAST or MANYCAST, the relay time synchronization error with the SNTP server is typically less than ±1 millisecond.

SEL ASCII Protocol and Commands

Message Format

SEL ASCII protocol is designed for manual and automatic communication. All commands the relay receives must be of the following form:

```
<command><CR>  or  <command><CRLF>
```

NOTE: The **<Enter>** key on most keyboards is configured to send the ASCII character 13 (**<Ctrl+M>**) for a carriage return. This manual instructs you to press the **<Enter>** key after commands to send the proper ASCII code to the SEL-787.

A command transmitted to the relay consists of the command followed by either a CR (carriage return) or a CRLF (carriage return and line feed). You can truncate commands to the first three characters. For example, **EVENT 1 <Enter>** becomes **EVE 1 <Enter>**. Use upper- and lowercase characters without distinction, except in passwords.

The relay transmits all messages in the following format:

```
<STX><MESSAGE LINE 1><CRLF>
<MESSAGE LINE 2><CRLF>
.
.
.
<LAST MESSAGE LINE><CRLF><ETX>
```

Each message begins with the start-of-transmission character (ASCII 02) and ends with the end-of-transmission character (ASCII 03). Each line of the message ends with a carriage return and line feed.

Software Flow Control

The relay implements XON/XOFF flow control. You can use the XON/XOFF protocol to control the relay during data transmission. When the relay receives XOFF during transmission, it pauses until it receives an XON character. If there is no message in progress when the relay receives XOFF, it blocks transmission of any message presented to the relay input buffer. Messages will be accepted after the relay receives XON.

The relay transmits XON (ASCII hex 11) and asserts the RTS output (if hardware handshaking is enabled) when the relay input buffer drops below 25 percent full.

The relay transmits XOFF (ASCII hex 13) when the buffer is more than 75 percent full. If hardware handshaking is enabled, the relay deasserts the RTS output when the buffer is approximately 95 percent full. Automatic transmission sources should monitor for the XOFF character to avoid overwriting the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and can resume when the relay sends XON.

The CAN character (ASCII hex 18) aborts a pending transmission. This is useful for terminating an unwanted transmission. You can send control characters from most keyboards with the following keystrokes:

- XOFF**: <Ctrl+S>** (hold down the **<Ctrl>** key and press **S**)
- XON: **<Ctrl+Q>** (hold down the **<Ctrl>** key and press **Q**)
- CAN: **<Ctrl+X>** (hold down the **<Ctrl>** key and press **X**)

Automatic Messages

When the serial port AUTO setting is Y, the relay sends automatic messages to indicate specific conditions. *Table 7.5* lists these messages.

Table 7.5 Serial Port Automatic Messages

Condition	Description
Power Up	The relay sends a message containing the present date and time, Relay and Terminal Identifiers, and the Access Level 0 prompt when the relay is turned on.
Event Trigger	The relay sends an event summary each time an event report is triggered. See *Section 9: Analyzing Events*.
Self-Test Warning or Failure	The SEL-787 sends a status report each time a self-test warning or failure condition is detected. See *STATUS Command (Relay Self-Test Status) on page 7.40*.

Access Levels

Commands can be issued to the SEL-787 via the serial port or Ethernet Telnet session to view metering values, change relay settings, etc. The available serial port commands are listed in the *SEL-787 Relay Command Summary* at the end of this manual. These commands can be accessed only from the corresponding access level, as shown in the *SEL-787 Relay Command Summary*. The access levels are:

- Access Level 0 (the lowest access level)
- Access Level 1
- Access Level 2 (the highest access level)
- Access Level C (restricted access level, should be used under direction of SEL only)

Access Level 0

Once serial port communication is established with the SEL-787, the relay sends the following prompt:

```
=
```

This is referred to as Access Level 0. Only a few commands are available at Access Level 0. One is the **ACC** command. See the *SEL-787 Relay Command Summary* at the end of this manual. Enter the **ACC** command at the Access Level 0 prompt:

```
=ACC <Enter>
```

The **ACC** command takes the SEL-787 to Access Level 1. See *Access Commands (ACCESS, 2ACCESS, and CAL) on page 7.18* for more detail.

Access Level 1

When the SEL-787 is in Access Level 1, the relay sends the following prompt:

```
=>
```

See the *SEL-787 Relay Command Summary* at the end of this manual for the commands available from Access Level 1. The relay can go to Access Level 2 from this level.

The **2AC** command places the relay in Access Level 2. See *Access Commands (ACCESS, 2ACCESS, and CAL)* for more detail. Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```

Access Level 2

When the relay is in Access Level 2, the SEL-787 sends the prompt:

```
=>>
```

See the *SEL-787 Relay Command Summary* at the end of this manual for the commands available from Access Level 2.

Any of the Access Level 1 commands are also available in Access Level 2.

Access Level C

The CAL access level is used exclusively by the SEL factory and SEL field service personnel to diagnose troublesome installations. A list of **CAL** level commands is available from SEL upon request. Do not enter the **CAL** access level, except as directed by SEL.

The **CAL** command allows the relay to go to Access Level C. Enter the **CAL** command at the Access Level 2 prompt:

```
=>>CAL <Enter>
```

Command Summary

The *SEL-787 Relay Command Summary* at the end of this manual lists the serial port commands alphabetically. Much of the information available from the serial port commands is also available via the front-panel pushbuttons.

Access Level Functions

The serial port commands at the different access levels offer varying levels of control:

- The Access Level 0 commands provide the first layer of security. In addition, Access Level 0 supports several commands required by SEL communications processors.
- The Access Level 1 commands are primarily for reviewing information only (settings, metering, etc.), not changing it.
- The Access Level 2 commands are primarily for changing relay settings.
- Access Level C (restricted access level, should be used under the direction of SEL only)

The SEL-787 responds with `Invalid Access Level` when a command is entered from an access level lower than the specified access level for the command. The relay responds with `Invalid Command` to commands that are not available or are entered incorrectly.

Header

Many of the command responses display the following header at the beginning:

```
[RID Setting]                              Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[TID Setting]                              Time Source: external
```

Table 7.6 lists the header items and their definitions.

Table 7.6 Command Response Header Definitions

Item	Definition
`[RID Setting]:`	This is the RID (Relay Identifier) setting. The relay ships with the default setting `RID = SEL-787`; see *ID Settings on page 4.2*.
`[TID Setting]:`	This is the TID (Terminal Identifier) setting. The relay ships with the default setting `TID = TRNSFRMR RELAY`; see *ID Settings on page 4.2*.
`Date:`	This is the date when the command response was given, except for relay response to the **EVE** command (Event), when it is the date the event occurred. You can modify the date display format (Month/Day/Year, Year/Month/Day, or Day/Month/Year) by changing the DATE_F relay setting.
`Time:`	This is the time when the command response was given, except for relay response to the **EVE** command, when it is the time the event occurred.
`Time Source:`	This is internal if no time-code input is attached and external if an input is attached.

Command Explanations

This section lists ASCII commands alphabetically. Commands, command options, and command variables to enter are shown in bold. Lowercase italic letters and words in a command represent command variables that are determined based on the application.

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the control function corresponding to the command or examples of the control response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return **<CR>** character or a carriage return character followed by a line feed character **<CR><LF>** to command the control to process the ASCII command. Usually, most terminals and terminal programs interpret the Enter key as a **<CR>**. For example, to send the **ACCESS** command, type **ACC <Enter>**.

Tables in this section show the access level(s) where the command or command option is active. Access levels in this device are Access Level 0, Access Level 1, and Access Level 2.

Access Commands (ACCESS, 2ACCESS, and CAL)

The **ACC, 2AC,** and **CAL** commands (see *Table 7.7*) provide entry to the multiple access levels. Different commands are available at the different access levels, as shown in the *SEL-787 Relay Command Summary* at the end of this manual. Commands **ACC** and **2AC** are explained together because they operate similarly. See *Access Levels on page 7.15* for a discussion of placing the relay in an access level.

Table 7.7 ACCESS Commands

Command	Description	Access Level
ACC	Moves from Access Level 0 to Access Level 1.	0
2AC	Moves from Access Level 1 to Access Level 2.	1
CAL	Moves from Access Level 2 to Access Level C.	2

Password Requirements

Passwords are required unless they are disabled. See *PASSWORD Command (Change Passwords) on page 7.33* for the list of default passwords and for more information on changing and disabling passwords.

Access Level Attempt (Password Required). Assume the following conditions:

- Access Level 1 password is not disabled.
- Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password is not disabled, the relay prompts you for the Access Level 1 password:

```
Password: ?
```

The relay is shipped with the default Access Level 1 password shown in *PASSWORD Command (Change Passwords) on page 7.33*. At the prompt, enter the default password and press the **<Enter>** key. The relay responds with the following:

```
[RID Setting]                             Date: mm/dd/yyyy  Time: hh:mm:ss
[TID Setting]                             Time Source: external

Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

If the entered password is incorrect, the relay prompts you for the password again (`Password: ?`). The relay prompts for the password as many as three times. If the requested password is incorrectly entered three times, the relay pulses the SALARM Relay Word bit for one second and remains at Access Level 0 (= prompt).

Access Level Attempt (Password Not Required). Assume the following conditions:

- Access Level 1 password is disabled.
- Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password is disabled, the relay does not prompt you for a password and goes directly to Access Level 1. The relay responds with the following:

```
[RID Setting]                             Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[TID Setting]                             Time Source: external
Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

The two previous examples demonstrate going from Access Level 0 to Access Level 1. The procedure to go from Access Level 1 to Access Level 2 with the **2AC** command entered at the access level screen prompt is similar. Access Level C can be accessed from Access Level 2 with the **CAL** command. The relay pulses the SALARM Relay Word bit for one second after a successful Level 2 or Level C access, or if access is denied.

ANALOG Command

Use the **ANA** command to test an analog output by temporarily assigning a value to an analog output channel (see *Table 7.8* for the command description and format). After entering the **ANA** command, the device suspends normal operation of the analog output channel and scales the output to a percentage of full scale. After assigning the specified value for the specified time, the device returns to normal operation.

Entering any character (including pressing the space key) ends the command before reaching the specified interval completion. You can test the analog output in one of the following two modes:

- Fixed percentage: Outputs a fixed percentage of the signal for a specified duration
- Ramp: Ramps the output from minimum to maximum of full scale over the time specified

Table 7.8 ANALOG Command

Command	Description	Access Level
ANA *c p t*	Temporarily assigns a value to an analog output channel.	2
Parameters		
c	Parameter *c* is the analog channel (either the channel name, e.g., A0301, or the channel number, e.g., 301).	
p	Parameter *p* is a percentage of full scale, or either the letter “R” or “r” to indicate ramp mode.	
t	Parameter *t* is the duration (in decimal minutes) of the test.	

NOTE: 0% = low span, 100% = high span. For a scaled output from 4–20 mA, 0 percent is 4 mA and 100 percent is 20 mA.

When parameter *p* is a percentage, the relay displays the following message during the test:

```
Outputting xx.xx [units] to Analog Output Port for y.y
minutes. Press any key to end test
```

where:

`xx.xx` is the calculation of percent of full scale
`[units]` is either mA or V, depending on the channel type setting
`y.y` is the time in minutes

When parameter *p* is a ramp function, the device displays the following message during the test:

```
Ramping Analog Output at xx.xx [units]/min; full scale in
y.y minutes. Press any key to end test
```

where:

`xx.xx` is the calculation based upon range/time t
`[units]` is either mA or V, depending on the channel type setting
`y.y` is the time in minutes

For either mode of operation (percentage or ramp), when the time expires, or upon pressing a key, the analog output port returns to normal operation and the device displays the following message:

```
Analog Output Port Test Complete
```

Example 1

The following is an example of the device response to the **ANA** command in the percentage mode. For this example, we assume the analog output signal type is 4–20 mA, and we want to test the analog output at 75 percent of rating for 5.5 minutes. To check the device output, calculate the expected mA output as follows:

$$\text{Output} = \left[(20.00\text{ mA} - 4.00\text{ mA}) \bullet \frac{75}{100}\right] + 4.00\text{ mA} = 16.00\text{ mA}$$

To start the test, enter **ANA A0301 75 5.5** at the Access Level 2 prompt:

```
=>>ANA A0301 75 5.5 <Enter>
Outputting 16.00 mA to Analog Output Port for 5.5 minutes.
Press any key to end test
```

Example 2

The following is an example of the ramp mode when the analog output signal type is 4–20 mA for a 9.0 minute test. To check the device output, calculate the current/time (mA/min) output as follows:

$$\text{Output} = \left[\frac{20.00\text{ mA} - 4.00\text{ mA}}{9.0\text{ min}}\right] = 1.78\text{ mA/min}$$

To start the test, enter **ANA AO301 R 9.0** at the Access Level 2 prompt:

```
=>>ANA A0301 R 9.0 <Enter>
Ramping Analog Output at 1.78 mA/min; full scale in 9.0 minutes.
Press any key to end test
```

CEV Command

The SEL-787 provides Compressed ASCII event reports to facilitate event report storage and display. SEL communications processors and SEL-5601-2 SYNCHROWAVE Event Software take advantage of the Compressed ASCII format. Use the **CHIS** command to display Compressed ASCII event history information. Use the **CSUM** command to display Compressed ASCII event summary information. Use the **CEVENT** (**CEV**) command to display Compressed ASCII event reports. See *Table C.2* for further information. Compressed ASCII Event Reports contain all of the Relay Word bits. **CEV R** command gives the raw Compressed ASCII event report.

CLOSE n Command (Close Breaker n, where n = 1 or 2)

The **CLO *n*** (CLOSE *n*) command asserts Relay Word bit CC*n* for 1/4 cycle when it is executed. Relay Word bit CC*n* can then be programmed into the CL*n* SELOGIC control equation to assert the CLOSE *n* Relay Word bit, which in turn asserts an output contact (e.g., OUT102 = CLOSE1) to close circuit breaker *n* (see *Table 4.26* and *Figure 4.48* for factory-default settings CL1 and CL2 and close logic).

To issue the **CLO 1** command, enter the following.

```
=>>CLO 1 <Enter>
Close Breaker1 (Y,N)? Y <Enter>
=>>
```

Typing **N <Enter>** after the above prompt will abort the command.

The **CLO *n*** commands are supervised by the main board breaker control jumper (see *Table 2.12*). If the breaker control jumper is not in place (breaker control jumper = OFF), the relay does not execute the **CLO *n*** command and responds with the following.

```
=>>CLO 1 <Enter>
Command Aborted: No Breaker Jumper
=>>
```

COMMUNICATIONS Command

The **COM *x*** command (see *Table 7.9*) displays communications statistics for the MIRRORED BITS communications channels. For more information on MIRRORED BITS communications, see *Appendix H: MIRRORED BITS Communications*. The summary report includes information on the failure of ROKA or ROKB. The `Last error` field displays the reason for the most recent channel error, even if the channel was already failed. We define failure reasons as one of the following error types:

- Device disabled
- Framing error
- Parity error
- Overrun
- Re-sync
- Data error
- Loopback
- Underrun

Table 7.9 COM Command

Command	Description	Access Level
COM S A or **COM S B**	Return a summary report of the last 255 records in the communications buffer for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	1
COM A	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1
COM B	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1
COM L B	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1
COM C	Clears all communications records. If both MIRRORED BITS channels are enabled, omitting the channel specifier (A or B) clears both channels.	1
COM C A	Clears all communications records for Channel A.	1
COM C B	Clears all communications records for Channel B.	1

CONTROL Command (Control Remote Bit)

Use the **CON** command (see *Table 7.10*) to control remote bits (Relay Word bits RB01–RB32). You can use the **CON** function from the front panel (`Control > Outputs`) to pulse the outputs. Remote bits are device variables that you set via serial port communication only; you cannot navigate Remote Bits via the front-panel HMI. You can select the control operation from three states: set, clear, or pulse, as described in *Table 7.10*.

Table 7.10 CONTROL Command

Command	Description	Access Level
CON RB*nn k*	Set a remote bit to set, clear, or pulse.	2
Subcommand		
S	Set remote bit (ON position)	2
C	Clear remote bit (OFF position)	2
P	Pulse remote bit for 1/4 cycle (MOMENTARY position)	2
Parameters		
nn	A number from 01 to 32, representing RB01 through RB32	
k	S, C, or P	

For example, use the following command to set Remote bit RB05:

```
=>>CON RB05 S <Enter>
```

COPY Command

Use the **COPY *m n*** command (see *Table 7.11*) to copy the settings of settings Group *m* to the settings of settings Group *n*. The settings of settings Group *m* effectively overwrite the settings of settings Group *n*. Parameters *m* and *n* can be any available settings group number 1 through 4.

Table 7.11 COPY Command

Command	Description	Access Level
COPY *m n*	Copy settings in Group *m* to settings in Group *n*.	2
Parameters		
m	1, 2, 3, or 4	
n	1, 2, 3, or 4	

For example when you enter the **COPY 1 3** command, the relay responds, `Are you sure (Y/N)?` Answer **Y <Enter>** (for yes) to complete copying. The resultant settings in Group 3 are overwritten by the settings in Group 1.

COUNTER Command (Counter Values)

The device generates the values of the 32 counters in response to the **COU** command (see *Table 7.12*).

Table 7.12 COUNTER Command

Command	Description	Access Level
COU *n*	Display current state of device counters *n* times, with a 1/2-second delay between each display	1

DATE Command (View/Change Date)

Use the **DATE** command (see *Table 7.13*) to view and set the relay date.

Table 7.13 DATE Command

Command	Description	Access Level
DATE	Display the internal clock date.	1
DATE ***mm/dd/yyyy***, ***yyyy/mm/dd***, or ***dd/mm/yyyy***	Set the internal clock date (DATE_F set to MDY, YMD, or DMY).	1

The relay can overwrite the date entered by using other time sources such as IRIG. Enter the **DATE** command with a date to set the internal clock date.

Separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons. Set the year in 4-digit form (for dates 2000–2099). Global setting DATE_F sets the date format.

ETH Command

The **ETH** command (Access Level 1) may be used to display the Ethernet port (Port 1) status as shown in *Figure 7.16* for the redundant fiber-optic (FX) Ethernet Port 1A and Port 1B configuration. Copper Ethernet port is labeled as TX. The non-redundant port response is similar.

```
=>ETH <Enter>

SEL-787                                   Date: 04/04/2008   Time: 08:08:45
TRNSFRMR RELAY                            Time Source: Internal

 MAC: 00-30-A7-00-64-EA
 IP ADDRESS: 10.10.52.252
 SUBNET MASK: 255.255.255.0
 DEFAULT GATEWAY: 10.10.52.1

 PRIMARY PORT:  PORT 1A
 ACTIVE PORT:      PORT 1B

                     LINK   SPEED  DUPLEX   MEDIA
PORT 1A                Down    --       --      FX
PORT 1B                Up     100M    Full    FX

=>
```

Figure 7.16 Ethernet Port (PORT 1) Status Report

The non-redundant port response is as shown in the example below.

```
=>ETH <Enter>

SEL-787                                   Date: 04/04/2008   Time: 08:08:45
TRNSFRMR RELAY                            Time Source: Internal

 MAC: 00-30-A7-00-64-EA
 IP ADDRESS: 10.10.52.252
 SUBNET MASK: 255.255.255.0
 DEFAULT GATEWAY: 10.10.52.1

                     LINK   SPEED  DUPLEX   MEDIA
PORT 1A                Up     100M    Full    TX

=>
```

Figure 7.17 Non-Redundant Port Response

EVENT Command (Event Reports)

Use the **EVE** command (see *Table 7.14*) to view event reports. See *Section 9: Analyzing Events* for further details on retrieving and analyzing event reports. See the *HISTORY Command on page 7.28* for details on clearing event reports.

Table 7.14 EVENT Command (Event Reports)

Command	Description	Access Level
EVE *n*	Return the *n* event report with 4-samples/cycle data.	1
EVE *n* R or **EVE R *n***	Return the *n* event report with raw (unfiltered) 16 samples/cycle analog data and 4 samples/cycle digital data.	1
EVE D *n*	Return the n digital data event report with 4-samples/cycle data.	1
EVE D *n* **R**	Return the n digital data event report with 16-samples/cycle data.	1
EVE DIF1 *n*	Return the n differential element 1 event report, with 4-samples/cycle data.	1
EVE DIF2 *n*	Return the n differential element 2 event report, with 4-samples/cycle data.	1
EVE DIF3 *n*	Return the n differential element 3 event report, with 4-samples/cycle data.	1
Parameter		
n	Parameter *n* specifies the event report number to be returned. Use the **HIS** command to determine the event report number of the event you want to display. If *n* is not specified, the relay will display event report 1 by default.	

FILE Command

The **FIL** command (see *Table 7.15*) is intended to be a safe and efficient means of transferring files between intelligent electronic devices (IEDs) and external support software (ESS). The **FIL** command ignores the hide rules and transfers visible as well as hidden settings, except the settings hidden by a part number. Use FTP or Telnet over Ethernet to transfer files.

Table 7.15 FILE Command

Command	Description	Access Level
FIL DIR	Return a list of files.	1
FIL READ *filename*	Transfer settings file *filename* from the relay to the PC.	1
FIL WRITE *filename*	Transfer settings file *filename* from the PC to the relay.	2
FIL SHOW *filename*	Filename 1 displays contents of the file *filename*.	1

GOOSE Command

Use the **GOOSE** command to display transmit and receive GOOSE messaging information, which can be used for troubleshooting. The **GOOSE** command variants and options are shown in *Table 7.16*.

Table 7.16 GOOSE Command Variants

Command Variant	Description	Access Level
GOOSE	Display GOOSE information.	1
GOOSE ***count***	Display GOOSE information *count* times.	1

The following table describes the information displayed for each GOOSE IED.

IED	Description
Transmit GOOSE Control Reference	This field represents the GOOSE control reference information that includes the IED name, ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and GSEControl name (GSE Control Block Name) (e.g., SEL_787_1CFG/LLN0GOGooseDSet13).
Receive GOOSE Control Reference	This field represents the goCbRef (GOOSE Control Block Reference) information that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and cbName (GSE Control Block Name) (e.g., SEL_787_1CFG/LLN0GOGooseDSet13).
MultiCastAddr (Multicast Address)	This hexadecimal field represents the GOOSE multicast address.
Ptag	This three-bit decimal field represents the priority tag value, where spaces are used if the priority tag is unknown.
Vlan	This 12-bit decimal field represents the virtual LAN (Local Area Network) value, where spaces are used if the virtual LAN is unknown.
StNum (State Number)	This hexadecimal field represents the state number that increments with each state change.
SqNum (Sequence Number)	This hexadecimal field represents the sequence number that increments with each GOOSE message sent.
TTL (Time to Live)	This field contains the time (in ms) before the next message is expected.
Code	This text field contains warning or error condition text when appropriate that is abbreviated as follows: **Code Abbreviation** — **Explanation** OUT OF SEQUENC — Out of sequence error CONF REV MISMA — Configuration Revision mismatch NEED COMMISSIO — Needs Commissioning TEST MODE — Test Mode MSG CORRUPTED — Message Corrupted TTL EXPIRED — Time to live expired HOST DISABLED — Optional code for when the host is disabled or becomes unresponsive after the **GOOSE** command has been issued
Transmit Data Set Reference	This field represents the DataSetReference (Data Set Reference) that includes the IED name, LN0 lnClass (Logical Node Class), and GSEControl datSet (Data Set Name) (e.g., SEL_787_1/LLN0$DSet13).
Receive Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and datSet (Data Set Name) (e.g., SEL_787_1CFG/LLN0$DSet13).

An example response to the **GOOSE** commands is shown in *Figure 7.18*.

```
#>GOOSE <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------
SEL_787_2CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-04  4:1     2          20376      50
   Data Set: SEL_787_2CFG/LLN0$DSet13
GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------
SEL_787_1CFG/LLN0$GO$NewGOOSEMessage5
   01-0C-CD-01-00-05  4:0     1          100425     160
   Data Set: SEL_787_1CFG/LLN0$DSet10

SEL_787_1CFG/LLN0$GO$NewGOOSEMessage3
   01-0C-CD-01-00-03  4:0     1          98531      120
   Data Set: SEL_787_1CFG/LLN0$DSet05


GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------
SEL_787_1CFG/LLN0$GO$NewGOOSEMessage5
   01-0C-CD-01-00-05  4:0     1          100425     160
   Data Set: SEL_787_1CFG/LLN0$DSet10

SEL_787_1CFG/LLN0$GO$NewGOOSEMessage3
   01-0C-CD-01-00-03  4:0     1          98531      120
   Data Set: SEL_787_1CFG/LLN0$DSet05

SEL_787_1CFG/LLN0$GO$NewGOOSEMessage2
   01-0C-CD-01-00-02  4:0     1          97486      200
   Data Set: SEL_787_1CFG/LLN0$DSet04

SEL_787_1CFG/LLN0$GO$NewGOOSEMessage1
   01-0C-CD-01-00-01  4:0     1          96412      190
   Data Set: SEL_787_1CFG/LLN0$DSet03

SEL_387E_1CFG/LLN0$GO$NewGOOSEMessage5
   01-0C-CD-01-00-06  4:0     1          116156     140
   Data Set: SEL_387E_1CFG/LLN0$DSet10

SEL_387E_1CFG/LLN0$GO$NewGOOSEMessage4
   01-0C-CD-01-00-05  4:0     1          116041     130
   Data Set: SEL_387E_1CFG/LLN0$DSet06

SEL_387E_1CFG/LLN0$GO$NewGOOSEMessage2
   01-0C-CD-01-00-02  4:0     1          115848     120
   Data Set: SEL_387E_1CFG/LLN0$DSet04

SEL_387E_1CFG/LLN0$GO$NewGOOSEMessage1
   01-0C-CD-01-00-01 4:0     1          115798     150
   Data Set: SEL_387E_1CFG/LLN0$DSet03

=>
```

Figure 7.18 GOOSE Command Response

GROUP Command

Use the **GROUP** command (see *Table 7.17*) to display the active settings group or try to force an active settings group change.

Table 7.17 GROUP Command

Command	Description	Access Level
GROUP	Display the active settings group.	1
GROUP *n*	Change the active group to Group *n*.	2
Parameter		
n	Parameter *n* indicates group numbers 1–4.	

When you change the active group, the relay responds with a confirmation prompt: `Are you sure (Y/N)?` Answer **Y <Enter>** to change the active group. The relay asserts the Relay Word bit SALARM for one second when you change the active group.

If any of the SELOGIC control equations SS1–SS3 are set when you issue the **GROUP *n*** command, the group change will fail. The relay responds: `Command Unavailable: Active setting group SELOGIC equations have priority over the GROUP command`.

HELP Command

The **HELP** command (see *Table 7.18*) gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for help on each command.

Table 7.18 HELP Command

Command	Description	Access Level
HELP	Display a list of each command available at the present access level with a one-line description.	1
HELP *command*	Display information on the command *command*.	1

HISTORY Command

Use the **HIS** command (see *Table 7.19*) to view a list of one-line descriptions of relay events or clear the list (and corresponding event reports) from nonvolatile memory. For more information on event reports, see *Section 9: Analyzing Events*.

Table 7.19 HISTORY Command

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1
HIS *n*	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list, beginning at Event *n*.	1
HIS C or **R**	Clear/reset the event history and all corresponding event reports from nonvolatile memory.	1

IDENTIFICATION Command

Use the **ID** command (see *Table 7.20*) to extract device identification codes.

Table 7.20 IDENTIFICATION Command

Command	Description	Access Level
ID	Return a list of device identification codes.	0

IRIG Command

Use the **IRIG** command to direct the relay to read the demodulated IRIG-B time code at the serial port or IRIG-B input (see *Table 7.21*).

Table 7.21 IRIG Command

Command	Description	Access Level
IRIG	Force synchronization of internal control clock to IRIG-B time-code input.	1

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

```
=>IRI <Enter>
```

If the relay successfully synchronizes to IRIG-B, it sends the following header and access level prompt:

```
SEL-787                  Date: 12/10/2007 Time: 08:56:03.190
TRNSFRMR RELAY             Time Source: External
=>
```

If no IRIG-B code is present at the serial port input or if the code cannot be read successfully, the relay responds with `IRIG-B DATA ERROR`.

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

L_D Command (Load Firmware)

Use the **L_D** command (see *Table 7.22*) to load firmware. See *Appendix A: Firmware, ICD, and Manual Versions* for information on changes to the firmware and instruction manual. See *Appendix B: Firmware Upgrade Instructions* for further details on downloading firmware.

Table 7.22 L_D Command (Load Firmware)

Command	Description	Access Level
L_D	Loads new firmware.	2

Only download firmware to the front port.

LDP Command (Load Profile Report)

Use the **LDP** commands (see *Table 7.23*) to view and manage the Load Profile report (see *Figure 5.15*). If there is no stored data and an **LDP** command is issued, the relay responds with `No data available`.

Table 7.23 LDP Commands

Command	Description	Access Level
LDP *row1 row2* **LDP *date1 date2***	Use the **LDP** command to display a numeric progression of all load profile report rows. Use the **LDP** command with parameters to display a numeric or reverse numeric subset of the load profile rows.	1
LDP C	Use this command to clear the load profile report from nonvolatile memory.	1
Parameters		
row1 row2	Append *row1* to return a chronological progression of the first *row1* rows. Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row1* and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows.	
date1 date 2	Append *date1* to return all rows with this date. Append *date1* and *date2* to return all rows between *date1* and date beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting DATE_F.	

LOOPBACK Command

The **LOO** command (see *Table 7.24*) is used for testing the MIRRORED BITS communications channel for proper communication. For more information on MIRRORED BITS, see *Appendix H: MIRRORED BITS Communications*. With the transmitter of the communications channel physically looped back to the receiver, the MIRRORED BITS addressing will be wrong and ROK will be deasserted. The **LOO** command tells the MIRRORED BITS software to temporarily expect to see its own data looped back as its input. In this mode, LBOK will assert if error-free data are received. The **LOO** command with just the channel specifier, enables looped back mode on that channel for five minutes, while the inputs are forced to the default values.

Table 7.24 LOO Command

Command	Description	Access Level
LOO	Enable loopback testing of MIRRORED BITS channels.	2
LOO A	Enable loopback on MIRRORED BITS Channel A for the next 5 minutes.	2
LOO B	Enable loopback on MIRRORED BITS Channel B for the next 5 minutes.	2

```
=>>LOO A <Enter>
Loopback will be enabled on Mirrored Bits channel A for the next 5 minutes.
The RMB values will be forced to default values while loopback is enabled.
Are you sure (Y/N)?
=>>
```

If only one MIRRORED BITS port is enabled, the channel specifier (A or B) may be omitted. To enable loopback mode for other than the 5-minute default, enter the desired number of minutes (1–5000) as a command parameter. To allow the loopback data to modify the RMB values, include the DATA parameter.

```
=>>LOO 10 DATA <Enter>
Loopback will be enabled on Mirrored Bits channel A for the next 10 minutes.
The RMB values will be allowed to change while loopback is enabled.
Are you sure (Y/N)? N <Enter>
Canceled.
=>>
```

To disable loopback mode before the selected number of minutes, re-issue the **LOO** command with the R parameter. The R parameter returns the device to normal operation. If both MIRRORED BITS channels are enabled, omitting the channel specifier in the disable command will cause both channels to be disabled.

```
=>>LOO R <Enter>
Loopback is disabled on both channels.
=>>
```

MAC Command

Use the **MAC** command to display the MAC addresses of PORT 1, as shown below.

```
=>MAC <Enter>
Port 1 MAC Address:  00-30-A7-00-00-00
=>
```

MET Command (Metering Data)

The **MET** command (see *Table 7.25* and *Table 7.26*) provides access to the relay metering data.

Table 7.25 METER Command

Command	Description	Access Level
MET *c n*	Display metering data.	1
MET *c* R	Reset metering data.	2
Parameters		
c	Parameter for identifying meter class.	
n	Parameter used to specify the number of times (1–32676) to repeat the meter response.	

Table 7.26 Meter Class (Sheet 1 of 2)

c	Meter Class
F	Fundamental Metering
E[a]	Energy Metering
M[a]	Maximum/Minimum Metering
RMS	RMS Metering
T	Thermal and RTD Metering

Table 7.26 Meter Class (Sheet 2 of 2)

c	Meter Class
AI	Analog Input (transducer) Metering
MV	SELOGIC Math Variable Metering
DEM[a]	Demand Metering
PEA[a]	Peak Demand Metering
PM	Synchrophasor Metering
H	Harmonic Metering
DIF	Differential Metering

[a] Reset metering available.

For more information on metering and example responses for each meter class, see *Section 5: Metering and Monitoring*.

On issuing the **MET *c* R** command for resetting metering quantities in class *c*, the relay responds: `Reset Metering Quantities (Y,N)?` Upon confirming (pressing **Y**), the metering quantities will be reset and the relay responds with `Reset Complete`.

OPEN n Command (Open Breakern, where n = 1 or 2)

The **OPE** *n* (OPEN) command asserts Relay Word bit OC*n* for 1/4 cycle when it is executed. Relay Word bit OC*n* can then be programmed into the TR*n* SELOGIC control equation to assert the TRIP*n* Relay Word bit, which in turn asserts an output contact (e.g., OUT301 = TRIP*n*) to open circuit breaker *n* (see *Table 4.26* and *Figure 4.47* for factory-default setting TR*n* and trip logic).

To issue the **OPE 1** command, enter the following.

```
=>>OPE 1 <Enter>
Open Breaker1 (Y,N)? Y <Enter>
=>>
```

Typing **N <Enter>** after the prompt will abort the command.

The **OPE** *n* command is supervised by the main board breaker control jumper (see *Table 2.12*). If the breaker control jumper is not in place (breaker control jumper = OFF), the relay does not execute the **OPE** *n* command and responds with the following.

```
=>>OPE 1 <Enter>
Command Aborted: No Breaker Jumper
=>>
```

PASSWORD Command (Change Passwords)

Use the **PAS** command (see *Table 7.27*) to change existing passwords.

Table 7.27 PASSWORD Command

Command	Description	Access Level
PAS ***level***	Change password for Access Level *level*.	2, C
Parameter		
level	Parameter *level* represents the relay Access Levels 1 or 2.	

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

The factory-default passwords are as shown in *Table 7.28*.

Table 7.28 Factory-Default Passwords for Access Levels 1, 2, and C

Access Level	Factory-Default Password
1	OTTER
2	TAIL
C	CLARKE

To change the password for Access Level 1 to #Ot3579!ijd7, enter the following command sequence:

```
=>>PAS 1 <Enter>
New PW: ? *********** <Enter>
Confirm PW: ? *********** <Enter>
Password Changed
=>>
```

Similarly, use **PAS 2** to change Level 2 passwords and PAS C to change Level C passwords.

Table 7.29 Valid Password Characters

Alpha	A B C D E F G H I J K L M N O P Q R S T U V W X Y Z a b c d e f g h i j k l m n o p q r s t u v w x y z
Numeric	0 1 2 3 4 5 6 7 8 9
Special	! " # $ % & ' ( ) * + , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

Passwords can contain as many as 12 characters. Upper- and lowercase letters are treated as different characters. Strong passwords consist of 12 characters, with at least one special character or digit and mixed-case sensitivity, but do not form a name, date, acronym, or word. Passwords formed in this manner are less susceptible to password guessing and automated attacks.

Examples of valid, distinct, and strong passwords are shown below:

- #0t3579!ijd7
- $A24.68&,mvj
- (Ih2dcs)36dn
- *4u-Iwg+?lf-

PING Command

When you are setting up or testing substation networks, it is helpful to determine if the network is connected properly and if the other devices are powered up and configured properly. The **PING** command (Access Level 2) allows you to determine if a host is reachable across an IP network and/or if the Ethernet port (Port 1) is functioning and configured correctly. A typical **PING** command response is shown in *Figure 7.19*.

The command structure is:

PING *x.x.x.x t*

where:

x.x.x.x is the Host IP address and

t is the PING interval in seconds, with a 2 to 255 second range.

The default PING interval is one second when *t* is not specified. The relay sends ping messages to the remote node until you stop the PING test by pressing the **Q** key.

```
=>>PING 10.201.7.52 <Enter>

Press the Q key to end the ping test.

Pinging 10.201.7.52 every 1 second(s):

Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Reply from 10.201.7.52
Ping test stopped.

Ping Statistics for 10.201.7.52
   Packets: Sent = 7, Received = 6, Lost = 1
   Duplicated = 0

=>>
```

Figure 7.19 PING Command Response

PULSE Command

Use the **PULSE** command (see *Table 7.30*) to pulse any of the relay control outputs for a specified time. This function aids you in relay testing and commissioning. When a **PUL** command is issued, the selected contact will close or open depending on the output contact type (a or b). The **PUL** command energizes the coil and does not have any effect if the coil is already energized. The control outputs are OUT*nnn*, where *nnn* represents 101–103 (standard), 301–304 (optional), 401–404 (optional), or 501–504 (optional).

Table 7.30 PUL OUTnnn Command

Command	Description	Access Level
PUL OUT*nnn*	Pulse output OUT*nnn* for 1 second.	2
PUL OUT*nnn s*	Pulse output OUT*nnn* for *s* seconds.	2
Parameters		
nnn	A control output number	
s	Time in seconds, with a range of 1–30.	

QUIT Command

Use the **QUIT** command (see *Table 7.31*) to revert to Access Level 0.

Table 7.31 QUIT Command

Command	Description	Access Level
QUIT	Go to Access Level 0.	0

Access Level 0 is the lowest access level; the SEL-787 performs no password check to descend to this level (or to remain at this level).

R_S Command (Restore Factory Defaults)

Use the **R_S** command (see *Table 7.32*) to restore factory-default settings.

Table 7.32 R_S Command (Restore Factory Defaults)

Command	Description	Access Level
R_S	Restore the factory-default settings and passwords, and reboot the system.[a]	2

[a] Only available after a settings or critical RAM failure.

SER Command (Sequential Events Recorder Report)

Use the **SER** commands (see *Table 7.33*) to view and manage the Sequential Events Recorder report. If there is no SER report row stored, the relay responds with `No data available`. See *Section 9: Analyzing Events* for further details on SER reports.

Table 7.33 SER Command (Sequential Events Recorder Report)

Command	Description	Access Level
SER	Use the **SER** command to display a chronological progression of all available SER rows (as many as 1024 rows). Row 1 is the most recently triggered row, and row 1024 is the oldest.	1
SER C or **R**	Use this command to clear/reset the SER records.	1
Parameters		
row1	Append *row1* to return a chronological progression of the first *row1* rows. For example, use **SER 5** to return the first five rows.	
row1 row2	Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row1* and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows. For example, use **SER 1 10** to return the first 10 rows in numeric order or **SER 10 1** to return these same items in reverse numeric order.	
date1	Append *date1* to return all rows with this date. For example, use **SER 1/1/2008** to return all records for January 1, 2008.	
date1 date2	Append *date1* and *date2* to return all rows between *date1* and *date2* beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting DATE_F. For example, use **SER 1/5/2008 1/7/2008** to return all records for January 5, 6, and 7, 2008.	

SER D Command

The **SER D** command shows a list of SER items that the relay has automatic-ally removed. These are "chattering" elements. You can automatically remove chattering SER elements in the SER Chatter Criteria category of the Report settings; the enable setting is ESERDEL. See *Section 4: Protection and Logic Functions*, *Report Settings (SET R Command) on page 4.103* for more information on SER automatic deletion and reinsertion.

Table 7.34 SER D Command

Command	Description	Access Level
SER D	List chattering SER elements that the relay is removing from the SER records.	1

If you issue the **SER D** command and you have not enabled automatic removal of chattering SER elements (Report setting ESERDEL), the relay responds, `Automatic removal of chattering SER elements not enabled`.

SET Command (Change Settings)

The **SET** command is for viewing or changing the relay settings (see *Table 7.35*).

Table 7.35 SET Command (Change Settings)

Command	Description	Access Level
SET *s* TERSE	Set the Group settings, beginning at the first setting.	2
SET DNP *n s* TERSE	Set DNP3 data map settings for map *n* (*n* = 1, 2, or 3)	2
SET L *s* TERSE	Set general logic settings.	2
SET G *s* TERSE	Set global settings.	2
SET P *n s* TERSE	Set serial port settings. *n* specifies the port (**1**, **2**, **3**, **4**, or **F**); *n* defaults to the active port if not listed.	2
SET R *s* TERSE	Set report settings such as Sequential Events Recorder (SER) and Event Report (ER) settings.	2
SET F *s* TERSE	Set front-panel settings.	2
SET M *s* TERSE	Set Modbus User Map settings.	2
Parameters		
s	Append ***s***, the name of the specific setting you want to view and jumps to this setting. If ***s*** is not entered, the relay starts at the first setting.	
TERSE	Append **TERSE** to skip the settings display after the last setting. Use this parameter to speed up the **SET** command. If you want to review the settings before saving, do not use the TERSE option.	

When you issue the **SET** command, the relay presents a list of settings one at a time. Enter a new setting or press **<Enter>** to accept the existing setting. Editing keystrokes are shown in *Table 7.36*.

Table 7.36 SET Command Editing Keystrokes

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

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

When all the settings are entered, the relay displays the new settings and prompts you for approval to enable them. Answer **Y <Enter>** to enable the new settings. The relay is disabled for as long as one second while it saves the new settings. The SALARM Relay Word bit is set momentarily, and the **ENABLED** LED extinguishes while the relay is disabled.

SHOW Command (Show/View Settings)

When showing settings, the relay displays the settings label and the present value from nonvolatile memory for each setting class. See *Table 7.37* for the **SHOW** command settings and the command format.

Table 7.37 SHOW Command (Show/View Settings)

Command	Description	Access Level
SHO *s*	Show group settings.	1
SHO L *s*	Show general logic settings.	1
SHO G *s*	Show global settings.	1
SHO P *n s*	Show serial port settings. *n* specifies the port (**1**, **2**, **3**, **4**, or **F**); *n* defaults to the active port if not listed.	1
SHO R *s*	Show report settings such as Sequential Events Recorder (SER) and Event Report (ER) settings.	1
SHO F *s*	Show front-panel settings.	1
SHO M *s*	Show Modbus user map settings.	1
SHO DNP *n*	Display DNP3 data map settings for Map *n* (*n* = 1, 2, or 3)	1
Parameter		
s	Append ***s***, the name of the specific setting you want to view, and jump to this setting. If ***s*** is not entered, the relay starts at the first setting.	

```
=>>SHO <Enter>

Group 1
Relay Settings

ID Settings
RID      := SEL-787
TID      := TRNSFRMR RELAY

Config Settings
W1CT     := WYE           W2CT     := WYE           CTR1     := 100
CTR2     := 1000          MVA      := 50.0          ICOM     := N
VWDG1    := 138.00        VWDG2    := 13.80         CTRN1    := 120
PTR      := 120.00        VNOM     := 13.80         DELTA_Y  := DELTA
VIWDG    := 2             SINGLEV  := N

DIFF ELEMENT
E87      := Y             TAP1     := 2.09          TAP2     := 2.09
O87P     := 0.30          87AP     := 0.15          87AD     := 5.0
SLP1     := 25            SLP2     := 50            IRS1     := 3.0
U87P     := 10.0          PCT2     := 15            PCT4     := OFF
PCT5     := 35            TH5P     := OFF           HRSTR    := Y
HBLK     := N

Restricted Earth FLT
REF1POL  := OFF
REF1TC   := 1
50REF1P  := 0.25

WDG1 Max Ph IOC
50P11P   := 10.00         50P11D   := 0.00
50P11TC  := 1
50P12P   := 10.00         50P12D   := 0.00
50P12TC  := 1

50P13P   := 10.00         50P13D   := 0.00
50P13TC  := 1
50P14P   := 10.00         50P14D   := 0.00
50P14TC  := 1
```

Figure 7.20 SHOW Command Example

```
WDG1 Res IOC
50G11P   := OFF          50G12P   := OFF

WDG1 Neg Seq IOC
50Q11P   := OFF          50Q12P   := OFF

WDG1 Max Ph TOC
51P1P    := 6.00         51P1C    := U3          51P1TD   := 3.00
51P1RS   := N            51P1CT   := 0.00        51P1MR   := 0.00
51P1TC   := 1

WDG1 Res TOC
51G1P    := 0.50         51G1C    := U3          51G1TD   := 1.50
51G1RS   := N            51G1CT   := 0.00        51G1MR   := 0.00
51G1TC   := 1

WDG1 Neg Seq TOC
51Q1P    := 6.00         51Q1C    := U3          51Q1TD   := 3.00
51Q1RS   := N            51Q1CT   := 0.00        51Q1MR   := 0.00
51Q1TC   := 1

WDG2 Max Ph IOC
50P21P   := 10.00        50P21D   := 0.00
50P21TC  := 1
50P22P   := 10.00        50P22D   := 0.00
50P22TC  := 1
50P23P   := 10.00        50P23D   := 0.00
50P23TC  := 1
50P24P   := 10.00        50P24D   := 0.00
50P24TC  := 1

WDG2 Res IOC
50G21P   := OFF          50G22P   := OFF

WDG2 Neg Seq IOC
50Q21P   := OFF          50Q22P   := OFF

WDG2 Max Ph TOC
51P2P    := 6.00         51P2C    := U3          51P2TD   := 3.00
51P2RS   := N            51P2CT   := 0.00        51P2MR   := 0.00
51P2TC   := 1


WDG2 Res TOC
51G2P    := 0.50         51G2C    := U3          51G2TD   := 1.50
51G2RS   := N            51G2CT   := 0.00        51G2MR   := 0.00
51G2TC   := 1

WDG2 Neg Seq TOC
51Q2P    := 6.00         51Q2C    := U3          51Q2TD   := 3.00
51Q2RS   := N            51Q2CT   := 0.00        51Q2MR   := 0.00
51Q2TC   := 1

Neutral IOC
50N11P   := OFF          50N12P   := OFF

Neutral TOC
51N1P    := OFF

RTD Settings
E49RTD   := NONE

Ph Undervoltage
27P1P    := OFF          27P2P    := OFF

Ph Overvoltage
59P1P    := OFF          59P2P    := OFF

NSeq Overvoltage
59Q1P    := OFF          59Q2P    := OFF

Volts per Hertz
E24      := Y            24WDG    := WYE         24D1P    := 105
24D1D    := 1.00         24CCS    := ID          24IP     := 105
24IC     := 2.0          24ITD    := 0.1         24D2P2   := 176
24D2D2   := 3.00         24CR     := 240.00
24TC     := 1
```

Figure 7.20 SHOW Command Example (Continued)

```
Power Elements
EPWR     := N

Freq Settings
81D1TP   := OFF           81D2TP   := OFF           81D3TP   := OFF
81D4TP   := OFF

Demand Mtr Set

EDEM     := OFF
Trip/Close Logic
TDURD    := 0.5           CFD1     := 0.5           CFD2     := 0.5
TR1      := 50P11T OR 51P1T OR 51Q1T OR NOT LT02 AND SV04T OR OC1
TR2      := 51P2T OR 51Q2T OR LT02 AND SV04T OR OC2
TRXFMR   := 87R OR 87U
REMTRIP  := 0
ULTRIP1  := 0
ULTRIP2  := 0
ULTRXFMR := 0
52A1     := 0
CL1      := SV03T AND NOT LT02 OR CC1
ULCL1    := TRIP1 OR TRIPXFMR
52A2     := 0
CL2      := SV03T AND LT02 OR CC2
ULCL2    := TRIP2 OR TRIPXFMR

=>>
```

Figure 7.20 SHOW Command Example (Continued)

STATUS Command (Relay Self-Test Status)

The **STA** command (see *Table 7.38*) displays the status report.

Table 7.38 STATUS Command (Relay Self-Test Status)

Command	Description	Access Level
STA *n*	Display the relay self-test information *n* times (*n* = 1–32767). Defaults to 1 if *n* is not specified.	1
STA S	Display the memory and execution utilization for the SELOGIC control equations.	1
STA C or **R**	Reboot the relay and clear self-test warning and failure status results.	2

Refer to *Section 10: Testing and Troubleshooting* for self-test thresholds and corrective actions, as well as hardware configuration conflict resolution.

Table 7.39 shows the status report definitions and message formats for each test. Refer to *Figure 1.2* and *Figure 1.3* for examples of the **STATUS** command response.

Table 7.39 STATUS Command Report and Definitions (Sheet 1 of 2)

STATUS Report Designator	Definition	Message Format
Serial Num	Serial number	Number
FID	Firmware identifier string	Text Data
CID	Firmware checksum identifier	Hex
PART NUM	Part number	Text Data
FPGA	FPGA programming unsuccessful, or FPGA failed	OK/FAIL
GPSB	General Purpose Serial Bus	OK/FAIL
HMI	Front-Panel FGPA programming unsuccessful, or Front-Panel FPGA failed	OK/WARN

Table 7.39 STATUS Command Report and Definitions (Sheet 2 of 2)

STATUS Report Designator	Definition	Message Format
RAM	Volatile memory integrity	OK/FAIL
ROM	Firmware integrity	OK/FAIL
CR_RAM	Integrity of settings in RAM and code that runs in RAM	OK/FAIL
Non_Vol	Integrity of data stored in nonvolatile memory	OK/FAIL
Clock	Clock functionality	OK/WARN
RTD	Integrity of RTD module/communications	OK/FAIL
CID_FILE	Configured IED description file	OK/FAIL
x.x V	Power supply status	Voltage/FAIL
BATT	Clock battery voltage	Voltage/WARN
CARD_C	Integrity of Card C	OK/FAIL
CARD_D	Integrity of Card D	OK/FAIL
CARD_E	Integrity of Card E	OK/FAIL
CURRENT	Integrity of current board	OK/FAIL
DN_MAC_ID	Specific DeviceNet card identification	Text Data
ASA	Manufacturers identifier for DeviceNet	Text Data
DN_Rate	DeviceNet card network communications data rate of 150, 250, or 500 kbps	Text Data
DN_Status	DeviceNet connection and fault status 000b bbbb	Text Data
Current Offset (IAW*n*, IBW*n*, ICW*n* (*n* = 1, 2), IN)	DC offset in hardware circuits of current channels	Measurement of dc offset/WARN
Voltage Offset (VA, VB, VC)	DC offset in hardware circuits of voltage channels	Measurement of dc offset/WARN

Figure 7.21 shows the typical relay output for the **STATUS S** command, showing available SELOGIC control equation capability.

NOTE: The STA S report provides the available SELOGIC capacity of the relay. For example, an Execution value of 90% means that 90% of execution capacity is still available.

```
=>STA S <Enter>

SEL-787                                Date: 03/10/2008   Time: 15:04:34
TRNSFRMR RELAY                         Time Source: Internal

Part Number = 0787EX1B0X0X7585023X

SELOGIC Equation Available Capacity

Global (%)   79
FP (%)       56
Report (%)   77

              GROUP 1  GROUP 2  GROUP 3  GROUP 4
Execution (%)   87       87       87       87
Group (%)       82       82       82       82
Logic (%)       89       89       89       89

=>
```

Figure 7.21 Typical Relay Output for STATUS S Command

SUMMARY Command

The **SUM** command (see *Table 7.40*) displays an event summary in human readable format.

Table 7.40 SUMMARY Command

Command	Description	Access Level
SUM ***n***	The command without arguments displays the latest event summary. Use *n* to display particular event summary.	1
SUM R or **C**	Use this command to clear the archive.	1

Each event summary report shows the date, time, current magnitudes (primary values), frequency, and, if the relay has the voltage option, voltage magnitudes (primary values). The relay reports the voltage and current when the largest current occurs during the event. The event summary report also shows the event type.

TARGET Command (Display Relay Word Bit Status)

The **TAR** command (see *Table 7.41*) displays the status of front-panel target LEDs or Relay Word bit, whether these LEDs or Relay Word bits are asserted or deasserted.

NOTE: The **TARGET R** command cannot reset the latched targets if a TRIP condition is present.

Table 7.41 TARGET Command (Display Relay Word Bit Status)

Command	Description	Access Level
TAR ***name k*** **TAR** ***n*** **TAR** ***n k***	Use **TAR** without parameters to display Relay Word Row 0 or last displayed target row.	1
TAR R	Clears front-panel tripping targets. Unlatches the trip logic for testing purposes (see *Figure 8.1*). Shows Relay Word Row 0.	1
Parameters		
name	Display the Relay Word row with Relay Word bit name.	
n	Show Relay Word row number *n*.	
k	Repeat ***k*** times (1–32767).	

The elements are represented as Relay Word bits and are listed in rows of eight, called Relay Word rows. The first four rows, representing the front-panel operation and target LEDs, correspond to *Table 7.42*. All Relay Word rows are described in *Table J.1* and *Table J.2*.

Relay Word bits are used in SELOGIC control equations. See *Appendix J: Relay Word Bits*.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL relays.

Table 7.42 Front-Panel LEDs and the TAR 0 Command

LEDs	7	6	5	4	3	2	1	0
TAR 0	ENABLED	TRIP_LED	TLED_01	TLED_02	TLED_03	TLED_04	TLED_05	TLED_06

TFE Command (Through-Fault Event Report)

The **TFE** command displays the following data for each individually recorded through-fault event:

- Date and time
- Duration (seconds)
- Maximum current (Amps primary) for each monitored current input

The following cumulative values (updated for each new through-fault event) are also displayed:

- Through-fault count
- Total accumulated percentage of through-fault capability used up per phase

There are various choices for the **TFE** command, listed briefly below. Refer to *Section 5: Metering and Monitoring* for a complete description of the through-fault event reports:

Table 7.43 TFE Command (Through-Fault Event Report)

Command	Description	Access Level
TFE	Displays cumulative and individual through-fault event data. The 20 most recent individual events are displayed.	1
TFE A	Displays cumulative and individual through-fault event data. All of the most recent individual events are displayed, as many as 500.	1
TFE C or **R**	Clears/resets cumulative and individual through-fault event data.	2
TFE *n*	Displays cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 500.	1
TFE P	Preloads cumulative through-fault event data.	2

TIME Command (View/Change Time)

The **TIME** command (see *Table 7.44*) returns information about the SEL-787 internal clock. You can also set the clock if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

Table 7.44 TIME Command (View/Change Time)

Command	Description	Access Level
TIME	Display the present internal clock time.	1
TIME *hh*	Set the internal clock to *hh*.	1
TIME *hh:mm*	Set the internal clock to *hh:mm*.	1
TIME *hh:mm:ss*	Set the internal clock to *hh:mm:ss*.	1

Use the **TIME *hh***, **TIME *hh:mm***, and **TIME *hh:mm:ss*** commands to set the internal clock time. The value *hh* is for hours from 0–23; the value *mm* is for minutes from 0–59; the value *ss* is for seconds from 0–59. If you enter a valid time, the relay updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the SEL-787 responds with `Invalid Time`.

TRIGGER Command (Trigger Event Report)

Use the **TRI** command (see *Table 7.45*) to trigger the SEL-787 to record data for high-resolution oscillography and event reports.

Table 7.45 TRIGGER Command (Trigger Event Report)

Command	Description	Access Level
TRI	Trigger event report data capture.	1

When you issue the **TRI** command, the SEL-787 responds with `Triggered`. If the event did not trigger within one second, the relay responds with `Did not trigger`. See *Section 9: Analyzing Events* for further details on event reports.

VEC Command (Show Diagnostic Information)

Issue the **VEC** command under the direction of SEL. The information contained in a vector report is formatted for SEL in-house use only. Your SEL application engineer or the factory may request a **VEC** command capture to help diagnose a relay or system problem.

Table 7.46 VEC Command

Command	Description	Access Level
VEC D	Displays the standard vector report.	2
VEC E	Displays the extended vector report.	2

Section 8
Front-Panel Operations

Overview

The SEL-787 Transformer Protection Relay front panel makes transformer data collection and control quick and efficient. Use the front panel to analyze operating information, view and change relay settings, and perform control functions. The SEL-787 features a straightforward menu-driven control structure presented on the front-panel liquid crystal display (LCD). Front-panel targets and other LEDs give a clear indication of the SEL-787 operation status. The features that help you operate the relay from the front panel include the following:

- ➤ Reading metering
- ➤ Inspecting targets
- ➤ Accessing settings
- ➤ Controlling relay operations
- ➤ Viewing diagnostics

Front-Panel Layout

Figure 8.1 shows and identifies the following regions:

- ➤ HMI
- ➤ **TARGET RESET** and navigation pushbuttons
- ➤ Operation and target LEDs
- ➤ Operator control pushbuttons and pushbutton LEDs
- ➤ EIA-232 Serial Port (**PORT F**). See *Section 7: Communications* for details on the serial port.

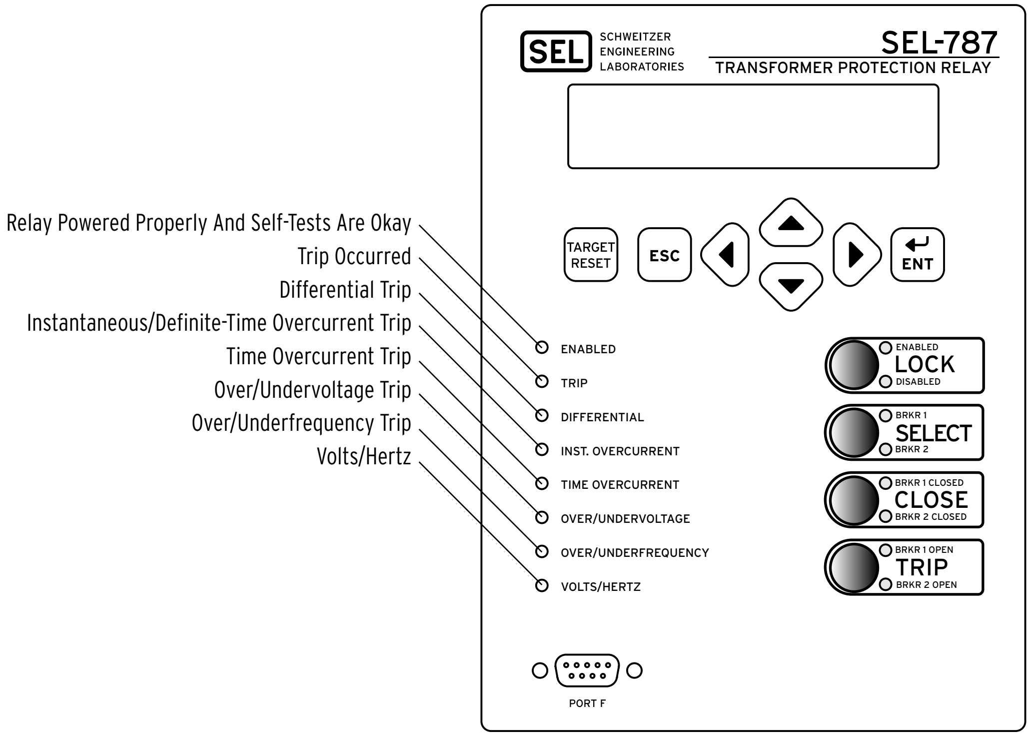


Figure 8.1 Front-Panel Overview

This versatile front panel supports the following features so you can customize it for your needs:

- Rotating display on the HMI
- Programmable target LEDs
- Programmable pushbutton LEDs
- Slide-in configurable front-panel labels to change the identification of target LEDs, pushbuttons, pushbutton LEDs and their operation.

Human-Machine Interface

Contrast

NOTE: See the Preface for an explanation of typographic conventions used to describe menus, the front-panel display, and the front-panel pushbuttons.

You can adjust the LCD screen contrast to suit your viewing angle and lighting conditions. To change screen contrast, press and hold the **ESC** pushbutton for two seconds. The SEL-787 displays a contrast adjustment box. Pressing the **Right Arrow** pushbutton increases the contrast. Pressing the **Left Arrow** pushbutton decreases the screen contrast. When you are finished adjusting the screen contrast, press the **ENT** pushbutton; this process is a shortcut for changing the LCD contrast setting FP_CONT in the front-panel settings.

Front-Panel Automatic Messages

The relay displays automatic messages, overriding the rotating display, under the conditions described in *Table 8.1*, with the relay failure having the highest priority, followed by trip and alarm when the front-panel setting FP_AUTO := OVERRIDE.

If the front-panel setting FP_AUTO := ROTATING, then the rotating display messages continue and any TRIP or ALARM message is added to the rotation. Relay failure will still override the rotating display.

Table 8.1 Front-Panel Automatic Messages (FP_AUTO := OVERRIDE)

Condition	Front-Panel Message
Relay detecting any failure	Displays the type of latest failure (see *Section 10: Testing and Troubleshooting*).
Relay trip has occurred	Displays the type or cause of the trip. Refer to *Table 9.1* for a list of trip display messages.
Relay alarm condition has occurred	Displays the type of alarm. The TRIP LED is also flashing during an alarm condition.

Front-Panel Security

Front-Panel Access Levels

The SEL-787 front panel typically operates at Access Level 1 and provides viewing of relay measurements and settings. Some activities, such as editing settings and controlling output contacts, are restricted to those operators who know the Access Level 2 passwords.

In the following figures, the padlock symbol indicates restricted activities.

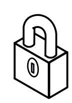


Figure 8.2 Access Level Security Padlock Symbol

Before you can perform a front-panel menu activity that is marked with the padlock symbol, you must enter the correct Access Level 2 passwords. After you have correctly entered the password, you can perform other Access Level 2 activities without reentering the password.

Access Level 2 Password Entry

When you try to perform an Access Level 2 activity, the relay determines whether you have entered the correct Access Level 2 password since the front-panel inactivity timer expired. If you have not, the relay displays the screen shown in *Figure 8.3* for you to enter the password.

Figure 8.3 Password Entry Screen

See *PASSWORD Command (Change Passwords) on page 7.33* for the list of default passwords and for more information on changing passwords.

Front-Panel Timeout

To help prevent unauthorized access to password-protected functions, the SEL-787 provides a front-panel timeout, setting FP_TO. A timer is reset every time a front-panel pushbutton is pressed. Once the timeout period has expired, the access level is reset to Access Level 1. Manually reset the access level by selecting `Quit` from the `MAIN` menu.

Front-Panel Menus and Screens

Navigating the Menus

The SEL-787 front panel gives you access to most of the information that the relay measures and stores. You can also use front-panel controls to view or modify relay settings.

All of the front-panel functions are accessible through use of the six-button keypad and LCD display. Use the keypad (shown in *Figure 8.4*) to maneuver within the front-panel menu structure, described in detail throughout the remainder of this section. *Table 8.2* describes the function of each front-panel pushbutton.

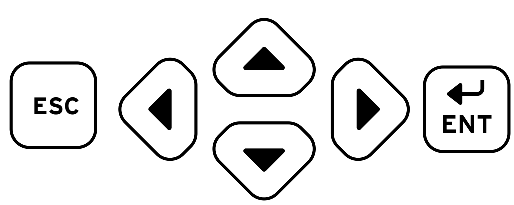
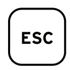
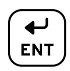


Figure 8.4 Front-Panel Pushbuttons

Table 8.2 Front-Panel Pushbutton Functions

Pushbutton		Function
	Up Arrow	Move up within a menu or data list. While editing a setting value, increase the value of the underlined digit.
	Down Arrow	Move down within a menu or data list. While editing a setting value, decrease the value of the underlined digit.
	Left Arrow	Move the cursor to the left.
	Right Arrow	Move the cursor to the right.
	ESC	Escape from the current menu or display. Displays additional information if lockout condition exists. Hold for two seconds to display contrast adjustment screen.
	ENT	Move from the rotating display to the `MAIN` menu. Select the menu item at the cursor. Select the displayed setting to edit that setting.

The SEL-787 automatically scrolls information that requires more space than provided by a 16-character LCD line. Use the **Left Arrow** and **Right Arrow** pushbuttons to suspend automatic scrolling and enable manual scrolling of this information.

MAIN Menu

Figure 8.5 shows the `MAIN` menu screen. Using the **Up Arrow** or **Down Arrow** and **ENT** pushbuttons, you can navigate to specific menu item in the `MAIN` menu. Each menu item is explained in detail in the following paragraphs.

```
MAIN
Meter
Events
Targets
Control
Set/Show
Status
```

Figure 8.5 Main Menu

Meter Menu

Select the `Meter` menu item from the `MAIN` menu as shown in *Figure 8.6* to view metering data. The `Meter` menu has menu items for viewing different types of metering data like Fundamental, Thermal, Differential, etc. Select the type of metering and view the data using the **Up Arrow** or **Down Arrow** pushbuttons. See *Metering on page 5.3* for a description of the available data fields.

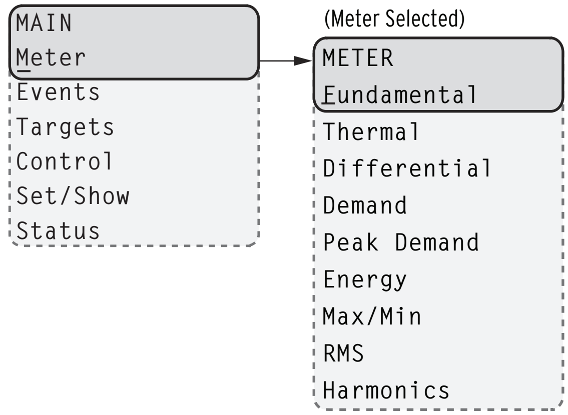


Figure 8.6 MAIN Menu and METER Submenu

For viewing Energy (or Max/Min) metering data, select the `Energy` (or `Max/Min`) menu item from the `METER` menu and select the `Display` menu item as shown in *Figure 8.7*.

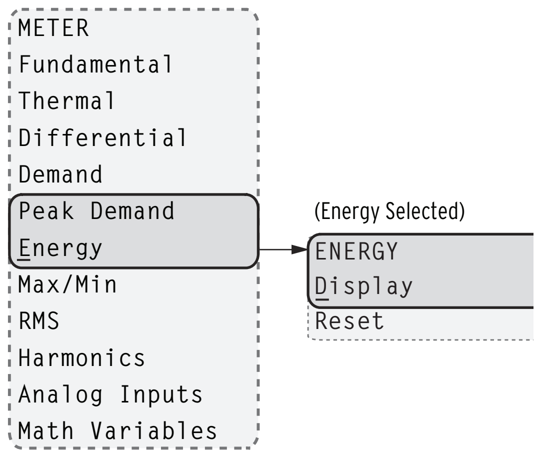


Figure 8.7 METER Menu and ENERGY Submenu

Demand, Peak Demand, Energy, or Max/Min metering data can be reset from the front-panel HMI by selecting the `Reset` menu item in the `Demand`, `Peak Demand`, `Energy` or `Max/Min` menu. After selecting `Reset` and confirming the reset, the relay displays as shown in *Figure 8.8*.

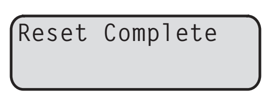


Figure 8.8 Relay Response When Demand, Peak Demand, Energy, or Max/Min Metering Is Reset

Assume the relay configuration contains no analog input cards. In response to a request for analog data (selecting `Analog Inputs`), the device displays the message as shown in *Figure 8.9*.

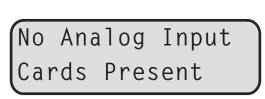


Figure 8.9 Relay Response When No Analog Cards Are Installed

Assume the math variables are not enabled. In response to a request for math variable data (selecting `Math Variables`), the device displays the message as shown in *Figure 8.10*.

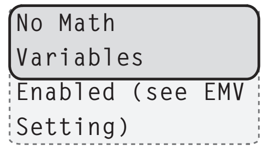


Figure 8.10 Relay Response When No Math Variables Enabled

Events Menu

Select the `Events` menu item from the `MAIN` menu as shown in *Figure 8.11*. `EVENTS` menu has `Display` and `Clear` as menu items. Select `Display` to view events and `Clear` to delete all the events data.

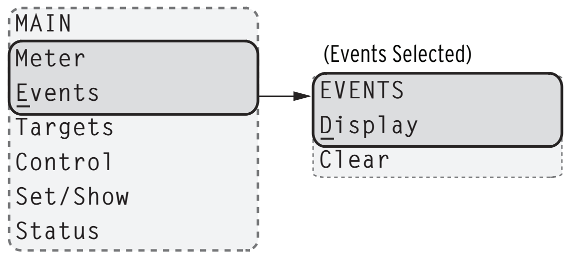


Figure 8.11 MAIN Menu and EVENTS Submenu

Figure 8.12 shows the `DISPLAY` menu when `Display` is selected from the `EVENTS` menu with events in the order of occurrence starting with the most recent. You can select an event from the `DISPLAY` menu and navigate through the event data.

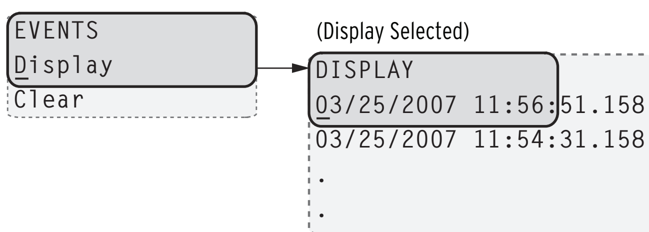


Figure 8.12 EVENTS Menu and DISPLAY Submenu

When `Display` is selected and no event data are available, the relay displays as shown in *Figure 8.13*.

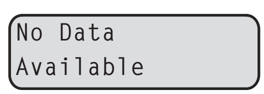


Figure 8.13 Relay Response When No Event Data Available

When `Clear` is selected from the `EVENTS` menu and confirming the selection, the relay displays as shown in *Figure 8.14* after clearing the events data.

Figure 8.14 Relay Response When Events Are Cleared

Targets Menu

Select the `Targets` menu item on the `MAIN` menu as shown in *Figure 8.15* to view the binary state of the target rows. Each target row has eight Relay Word bits as shown in *Table J.1*.

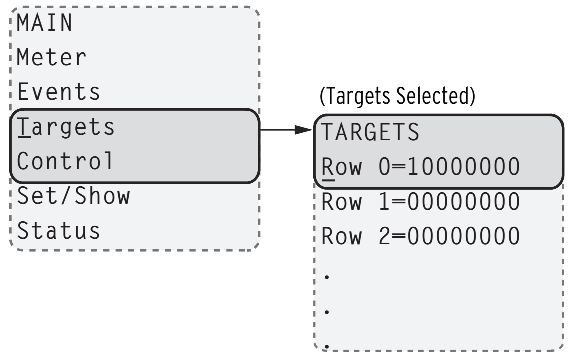


Figure 8.15 MAIN Menu and TARGETS Submenu

Select the target row to display two consecutive Relay Word bits with name and binary state as shown in *Figure 8.16*.

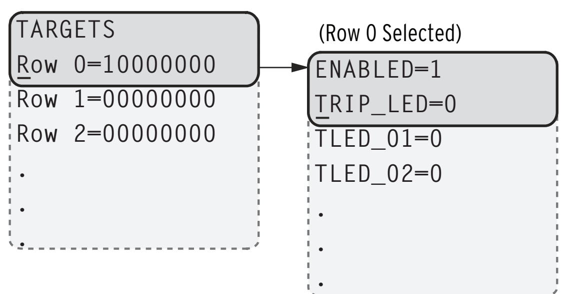


Figure 8.16 TARGETS Menu Navigation

Control Menu

Select the `Control` menu item on the `MAIN` menu as shown in *Figure 8.17* to go to the `CONTROL` menu.

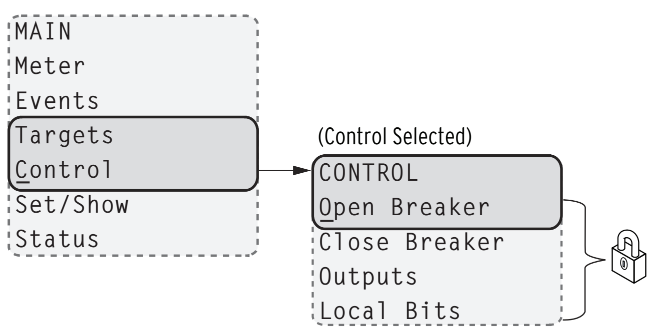


Figure 8.17 MAIN Menu and CONTROL Submenu

The `CONTROL` menu has `Open Breaker (1 or 2)`, `Close Breaker (1 or 2)`, `Outputs`, and `Local Bits` as menu items.

Select the `Open Breaker 1` or `2` menu item to assert Relay Word bits OC1 or OC2, which will open breaker 1 or 2 via SELOGIC equations TR1 or TR2. See *Table 4.26* for equations TR1 and TR2 and *Table J.2* for the definitions of Word bits OC1 and OC2. Note that this requires Level 2 access.

Select the `Close Breaker 1` or `2` menu item to assert Relay Word bits CC1 or CC2, which will close the breaker 1 or 2 via the CL1 or CL2 SELOGIC equation (see *Figure 4.48*). Note that this requires Level 2 access.

Select the `Outputs` menu item from the `CONTROL` menu as shown in *Figure 8.18* to test (pulse) SEL-787 output contacts and associated circuits. Choose the output contact by navigating through the `OUTPUT` menu and test it by pressing the **ENT** pushbutton. Note that testing the output contact requires Level 2 access and reconfirmation.

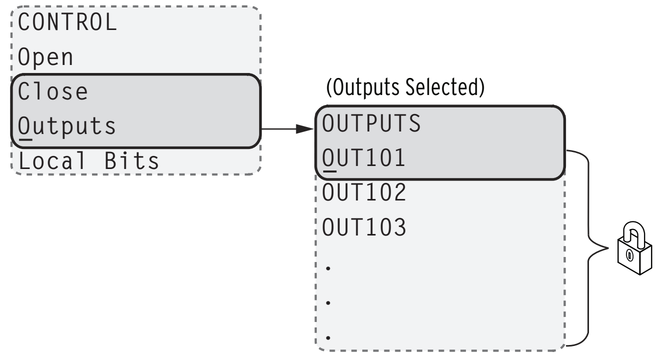


Figure 8.18 CONTROL Menu and OUTPUTS Submenu

Select the `Local Bits` menu item from the `CONTROL` menu for local control action. Local bits take the place of traditional panel switches, and perform isolation, open, close, or pulse operations.

With the settings as per the example in *Section 4* (see *Local Bits on page 4.100* for more information), local bit 1 replaces a supervisory switch. *Figure 8.19* shows the screens in closing the supervisory switch. In this operation, local bit LB01 is deasserted (SUPER SW = OPEN), and changes to asserted (SUPER SW = CLOSE) as shown in the final screen of *Figure 8.19*.

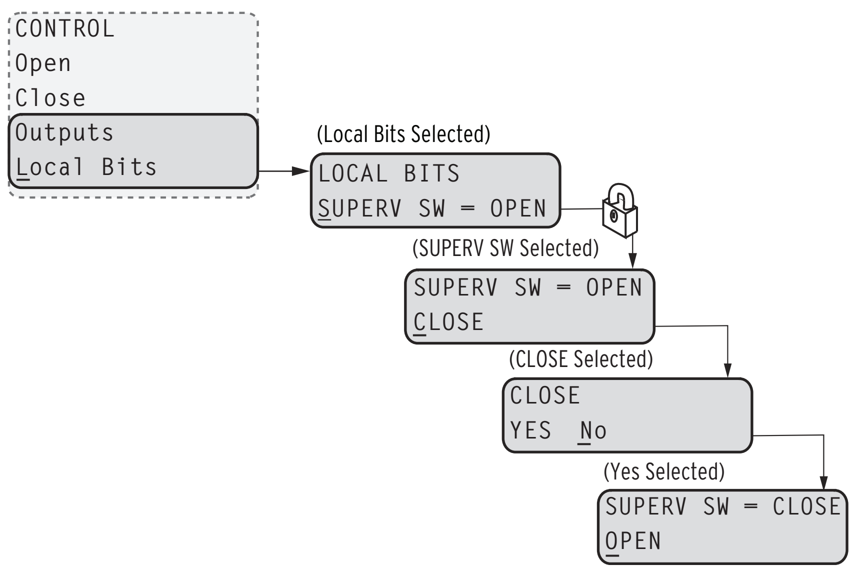


Figure 8.19 CONTROL Menu and LOCAL BITS Submenu

Set/Show Menu

Select the `Set`/`Show` menu item on the `MAIN` menu. The `Set`/`Show` menu is used to view or modify the settings (`Global`, `Group`, and `Port`), `Active Group`, `Date`, and `Time`. Note that modifying the settings requires Level 2 access.

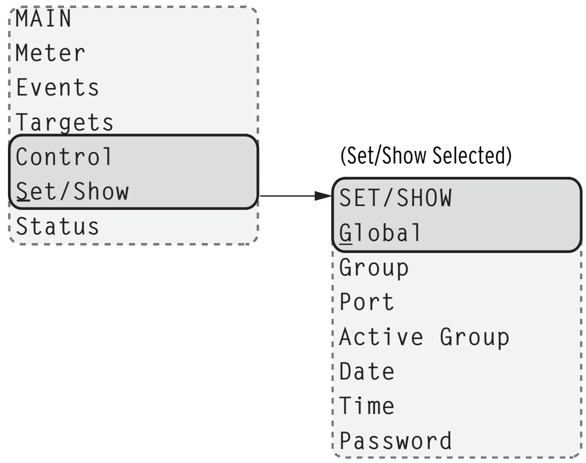


Figure 8.20 MAIN Menu and SET/SHOW Submenu

Each settings class (`Global`, `Group`, and `Port`) includes headings that create subgroups of associated settings as shown in the following illustration. Select the heading that contains the setting of interest, and then navigate to the particular setting. View or edit the setting by pressing the **ENT** pushbutton. For text settings, use the four navigation pushbuttons to scroll through the available alphanumeric and special character settings matrix. For numeric settings, use the **Left Arrow** and **Right Arrow** pushbuttons to select the digit to change and the **Up Arrow** and **Down Arrow** pushbuttons to change the value. Press the **ENT** pushbutton to enter the new setting.

Setting changes can also be made using ACSELERATOR QuickSet SEL-5030 Software or ASCII **SET** commands via a communications port.

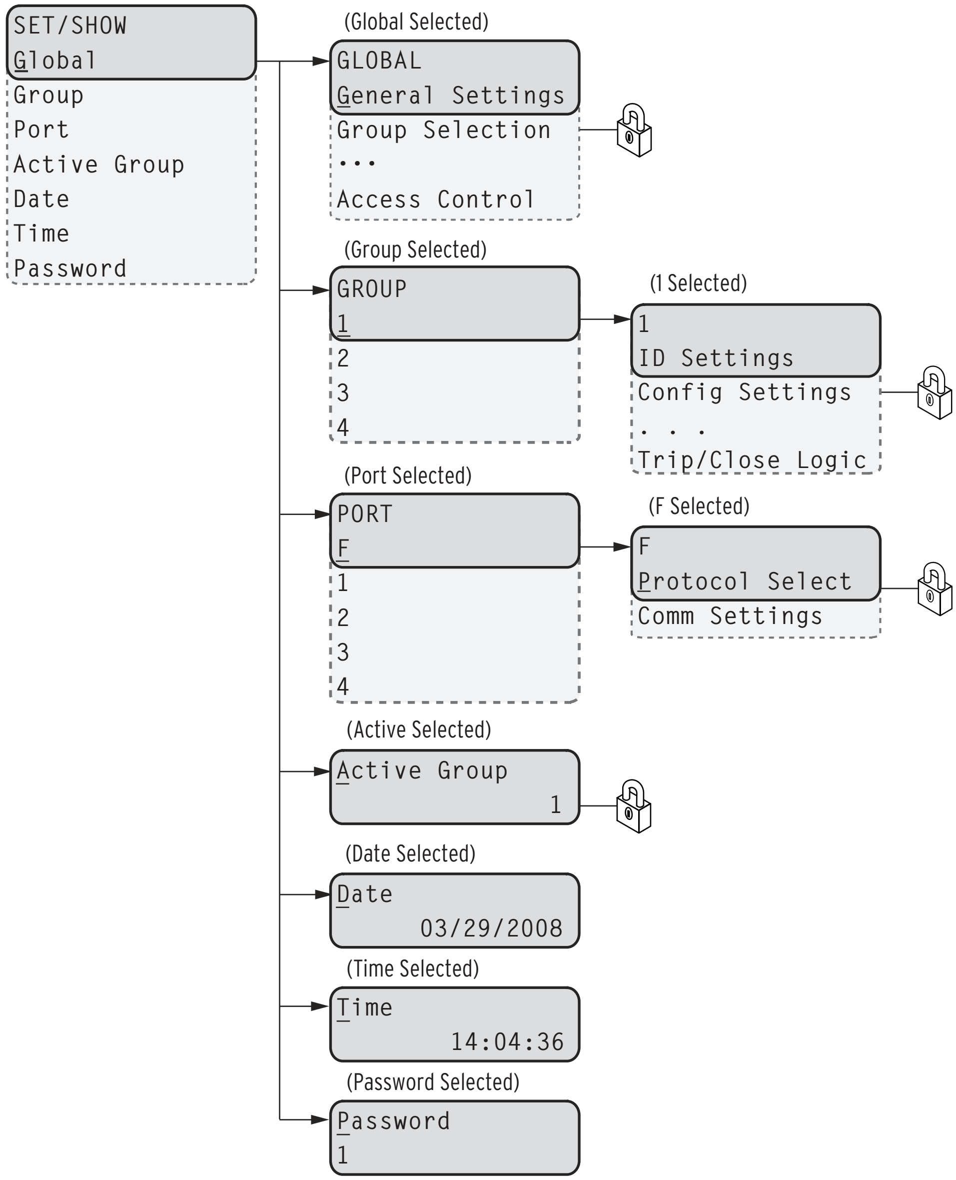


Figure 8.21 SET/SHOW Menu

Status Menu

Select the `Status` menu item on the `MAIN` menu as shown in *Figure 8.22* to access `Relay Status` data and `Reboot Relay`. See *STATUS Command (Relay Self-Test Status) on page 7.40* for the **STATUS** data field description.

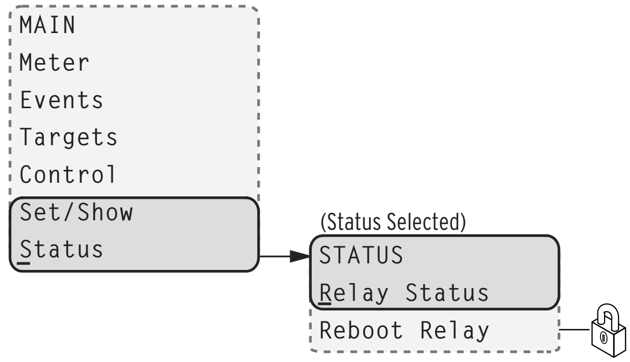


Figure 8.22 MAIN Menu and Status Submenu

Operation and Target LEDs

Programmable LEDs

The SEL-787 provides quick confirmation of relay conditions via operation and target LEDs. *Figure 8.23* shows this region with factory-default text on the front-panel configurable labels. See *Target LED Settings on page 4.101* for the SELOGIC control equations.

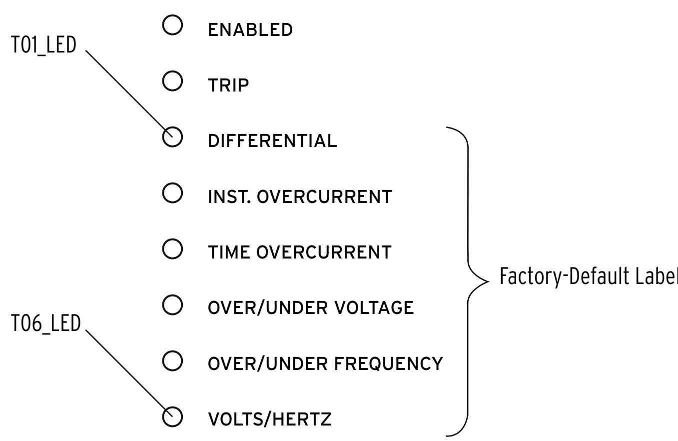


Figure 8.23 Factory-Default Front-Panel LEDs

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect operating conditions other than the factory-default programming described in this subsection.

NOTE: The target LEDs are restored to their previous state after the relay is turned off and then turned back on.

T0*n*_LED settings are SELOGIC control equations that work with the corresponding T0*n*LEDL latch settings to illuminate the LEDs shown in *Figure 8.23*. Parameter *n* is a number from 1 through 6 that indicates each LED. If the latch setting (T0*n*LEDL) for a certain LED is set to N, then the LED will follow the status of the corresponding control equation (T0*n*_LED). When the equation asserts, the LED will illuminate, and when the equation deasserts, the LED will extinguish. If the latch setting is set to Y, the LED will only assert if a trip condition occurs and the T0*n*_LED equation is asserted at the time of the trip. At this point, the LED will latch in and can be reset using the TARGET RESET pushbutton or the **TAR R** command as long as the target conditions are absent. For a concise listing of the default programming on the front-panel LEDs, see *Table 4.62*.

The SEL-787 comes with blank slide-in labels for custom LED designations that match custom LED logic. The Configurable Label Kit (includes blank labels, word processor templates, and instructions) is shipped with the SEL-787.

The ENABLED LED indicates that the relay is powered correctly, is functional, and has no self-test failures. Trip events illuminate the TRIP LED. The prominent location of the TRIP LED in the top target area aids in recognizing trip events quickly. When the TRIP LED is lit continuously, the TRIP TYPE is displayed on the LCD display. Refer to *Table 9.1*, for the list of possible trip messages.

The TRIP LED has an additional function that notifies you of warning conditions. When the TRIP LED is flashing, the warning conditions in *Table 8.3* are active when you set the corresponding relay element. For Relay Word bit definitions see *Appendix J: Relay Word Bits*.

Table 8.3 Possible Warning Conditions (Flashing TRIP LED)

HMI Message	Condition (Relay Word Bit)
RTD Warning	AMBALRM OR OTHALRM
RTD Failure	RTDFLT
Comm. Loss Warning	COMMLOSS
Comm. Idle Warning	COMMIDLE

TARGET RESET Pushbutton

Target Reset

For a trip event, the SEL-787 latches the trip-involved target LEDs except for the ENABLED LED. Press the TARGET RESET pushbutton to reset the latched target LEDs. When a new trip event occurs and the previously latched trip targets have not been reset, the relay clears the latched targets and displays the new trip targets. Pressing and holding the TARGET RESET pushbutton illuminates all the LEDs. Upon release of the TARGET RESET pushbutton, two possible trip situations can exist: the conditions that caused the relay to trip have cleared, or the trip conditions remain present at the relay inputs. If the trip conditions have cleared, the latched target LEDs turn off. If the trip event conditions remain, the relay re-illuminates the corresponding target LEDs. The TARGET RESET pushbutton also removes the trip automatic message displayed on the LCD menu screens if the trip conditions have cleared.

Figure 8.24 Target Reset Pushbutton

Lamp Test

The TARGET RESET pushbutton also provides a front-panel lamp test. Pressing and holding TARGET RESET illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as TARGET RESET is pressed. The target LEDs return to a normal operational state after release of the TARGET RESET pushbutton.

Other Target Reset Options

Use the ASCII command **TAR R** to reset the target LEDs; see *Table 7.41* for more information. Programming specific conditions in the SELOGIC control equation RSTTRGT is another method for resetting target LEDs. Access RSTTRGT in *Global Settings (SET G Command)* and see *Table 4.43* for further information.

Front-Panel Operator Control Pushbuttons

The SEL-787 features four operator-controlled pushbuttons, each with two programmable pushbutton LEDs, for local control as shown in *Figure 8.25*.

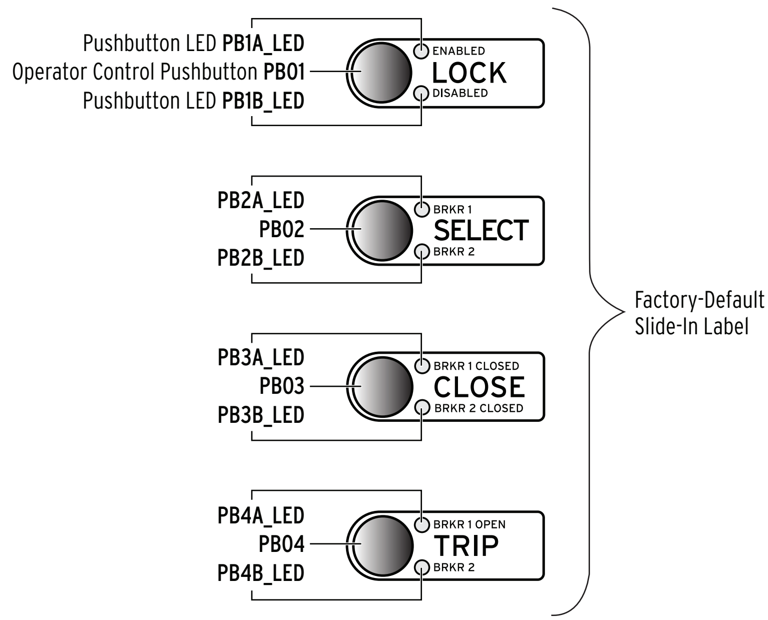


Figure 8.25 Operator Control Pushbuttons and LEDs

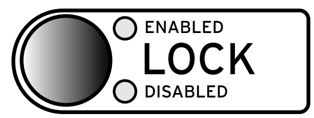
Pressing any one of these four pushbuttons asserts the corresponding PB*n* (*n* = 01 through 04) Relay Word bit, and the corresponding PB*n*_PUL Relay Word bit. The PB*n* Relay Word bit remains asserted as long as the pushbutton is pressed, but the PB*n*_PUL Relay Word bit asserts only for the initial processing interval, even if the button is still being pressed. Releasing the pushbutton, and then pressing the pushbutton again asserts the corresponding PB*n*_PUL Relay Word bit for another processing interval. The pushbutton LEDs are independent of the pushbutton.

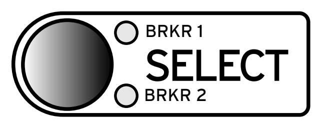
Pushbutton LEDs are programmable using front-panel settings PB*nm*_LED (where *n* = 1 through 4 and *m* = A or B). PB*nm* _LED settings are SELOGIC control equations that, when asserted, illuminate the corresponding LED for as long as the input is asserted. When the input deasserts, the LED also deasserts without latching.

Using SELOGIC control equations, you can readily change the default LED and pushbutton functions. The user-configurable slide-in labels can be used to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. Included on the SEL-787 Product Literature CD are word processor templates for printing slide-in labels. See the instructions included in the Configurable Label kit for more information on changing the slide-in labels.

Table 8.4 describes front-panel operator controls based on the factory-default settings and operator control labels.

Table 8.4 SEL-787 Front-Panel Operator Control Functions

<table>
<tr><td>
Continually press the LOCK operator control pushbutton for three (3) seconds to engage/disengage the lock function (Latch LT01 functions as Lock with the latch in reset state equivalent to the engaged lock). While this pushbutton is pressed, the corresponding LED flashes on and off, indicating a pending engagement or disengagement of the lock function. The LED illuminates constantly to indicate the engaged state. While the lock function is engaged, the following operator control is “locked in position” (assuming factory-default settings): CLOSE.
While “locked in position,” this operator control cannot change state if pressed—the corresponding LEDs remain in the same state. When the lock function is engaged, the CLOSE operator control cannot close breaker 1 or 2, but the TRIP operator control can still trip breaker 1 or 2.
</td><td>


</td></tr>
<tr><td>
Press the SELECT pushbutton to select breaker 1 or breaker 2. If breaker 1 is selected, BRKR1 LED is on and if breaker 2 is selected, BRKR2 LED is on. The SELECT pushbutton allows a breaker selection before CLOSE or TRIP pushbuttons are used.
</td><td>


</td></tr>
<tr><td>
Press the CLOSE operator control pushbutton to close the selected breaker. Corresponding BRKR CLOSED LED illuminates to indicate the breaker is closed.
Option: Set a delay, so the operator can press the CLOSE operator control pushbutton and then move a safe distance away from the breaker before the SEL-787 issues a close (the CLOSE operator control comes with no set delay in the factory settings). With a set delay, press the CLOSE operator control pushbutton momentarily, and notice that the corresponding BRKR CLOSED LED flashes on and off during the delay time, indicating a pending close. Abort the pending close by pressing the CLOSE operator control pushbutton again or by pressing the TRIP operator control pushbutton. This delay setting for the CLOSE operator control is SV03PU (range: 0 to 3000 seconds; factory set at 0—no delay). The delay is set via the SET L command. See Table 4.31 for more information.
</td><td>


</td></tr>
<tr><td>
Press the TRIP operator control pushbutton to trip the selected breaker (and take the control to the lockout state). Corresponding BRKR OPEN LED illuminates to indicate the breaker is open.
Option: Set a delay, so the operator can press the TRIP operator control pushbutton and then move a safe distance away from the breaker before the SEL-787 issues a trip (the TRIP operator control comes with no set delay in the factory settings). With a set delay, press the TRIP operator control pushbutton momentarily and notice the corresponding BRKR OPEN LED flashes on and off during the delay time, indicating a pending trip. Abort the pending trip by pressing the TRIP operator control pushbutton again or by pressing the CLOSE operator control pushbutton. This delay setting for the TRIP operator control is SV04PU (range: 0 to 3000 seconds; factory-set at 0—no delay). The delay is set via the SET L command. See Table 4.31 for more information.
</td><td>


</td></tr>
</table>

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Section 9
Analyzing Events

Overview

The SEL-787 Transformer Protection Relay provides several tools (listed below) to analyze the cause of relay operations. Use these tools to help diagnose the cause of the relay operation and more quickly restore the protected equipment to service.

- Event Reporting
  - Event Summary Reports
  - Event History Reports
  - Event Reports
- Sequential Events Recorder Report
  - Resolution: 1 ms
  - Accuracy: ±1/4 cycle

All reports are stored in nonvolatile memory, ensuring that a loss of power to the SEL-787 will not result in lost data.

Event Reporting

Analyze events with the following event reporting functions:

- Event Summaries—Enable automatic messaging to allow the relay to send event summaries out a serial port when port setting AUTO := Y. A summary provides a quick overview of an event. The summaries may also be retrieved by using the **SUMMARY** command.
- Event History—The relay keeps an index of stored nonvolatile event reports. Use the **HISTORY** command to obtain this index. The index includes some of the event summary information so that the appropriate event report can be identified and retrieved.
- Event Reports—These detailed reports are stored in nonvolatile memory for later retrieval and detailed analysis.

Each time an event occurs, a new summary, history record, and report are created. Event report information includes:

- Date and time of the event
- Individual sample analog inputs (currents and voltages)
- Digital states of selected Relay Word bits (listed in *Table J.1*)
- Event summary, including the front-panel target states at the time of tripping and fault type
- Group, Logic, Global, and Report settings (that were in service when the event was retrieved)

The SEL-787 provides Compressed ASCII event reports to facilitate event report storage and display. SEL communications processors and SEL-5601-2 SYNCHROWAVE Event Software take advantage of the Compressed ASCII format. Use the **CHIS** command to display Compressed ASCII event history information. Use the **CSUM** command to display Compressed ASCII event summary information. Use the **CEVENT** command to display Compressed ASCII event reports. See *Table C.2* for further information.

Compressed ASCII Event Reports contain *all* of the Relay Word bits.

Sequential Events Recorder (SER)

The SER report captures digital element state changes over time. Settings allow as many as 96 Relay Word bits to be monitored, in addition to the automatically generated triggers for relay power up, settings changes, and active setting group changes. State changes are time-tagged to the nearest millisecond. SER information is stored when state changes occur.

SER report data are useful in commissioning tests and during operation for system monitoring and control.

Event Reporting

Length

IMPORTANT: Changing the LER setting will clear all events in memory. Be sure to save critical event data prior to changing the LER setting.

The SEL-787 provides selectable event report length (LER) and prefault length (PRE). Event report length is either 15 or 64 cycles. Prefault length is 1–10 cycles for LER = 15 and 1–59 cycles for LER = 64. Prefault length is the first part of the total event report length and precedes the event report triggering point. Changing the PRE setting has no effect on the stored reports. The relay stores as many as 25 of the most recent 64-cycle or as many as 100 of the most recent 15-cycle event reports in nonvolatile memory. Refer to the **SET R** command in *SET Command (Change Settings) on page 7.37* and *Report Settings (SET R Command) on page SET.52*.

Triggering

The SEL-787 triggers (generates) an event report when any of the following occur:

- Relay Word bit TRIP asserts
- Programmable SELOGIC control equation setting ER asserts (in Report settings)
- **TRI** (Trigger Event Reports) serial port command executes

Relay Word Bit TRIP

Refer to *Figure 4.47*. If Relay Word bit TR asserts to logical 1, an event report is automatically generated. Thus, any Relay Word bit that causes a trip does *not* have to be entered in SELOGIC control equation setting ER.

Programmable SELOGIC Control Equation Setting ER

The programmable SELOGIC control equation event report trigger setting ER is set to trigger event reports for conditions other than trip conditions (see **SET R** in *SET Command (Change Settings) on page 7.37*). When setting ER detects a logical 0 to logical 1 transition, it generates an event report (if the SEL-787 is not already generating a report that encompasses the new transition). The factory setting is shown in *Event Report Settings on page 4.105*.

TRI (Trigger Event Report) Command

The sole function of the **TRI** serial port command is to generate event reports, primarily for testing purposes. See *TRIGGER Command (Trigger Event Report) on page 7.44* for more information on the **TRI** (Trigger Event Report) command.

Event Summaries

IMPORTANT: Clearing the HISTORY report with the **HIS C** command also clears all event data within the SEL-787 event memory.

For every triggered event, the relay generates and stores an event summary. The relay stores as many as 100 of the most recent event summaries (if event report length setting LER := 15) or as many as 25 of the most recent event summaries (if LER := 64). When the relay stores a new event summary, it discards the oldest event and event summary if the event memory is full. Event summaries contain the following information:

- ➤ Relay and Terminal Identification (RID and TID)
- ➤ Event number, date, time, event type, and frequency (see *Table 9.1*)
- ➤ The primary magnitudes of winding phase, neutral (if optional neutral CT is available), and residual currents
- ➤ The primary magnitudes of the line to neutral voltage (if DELTA_Y := WYE) or phase-to-phase voltages (if DELTA_Y := DELTA), optional Voltage Inputs card required
- ➤ Hottest RTD temperatures, SEL-2600 RTD Module or internal RTD card option required

The relay includes the event summary in the event report. The identifiers, date, and time information are at the top of the event report, and the remaining information follows at the end (See *Figure 9.3*). The example event summary in *Figure 9.1* corresponds to the standard 15-cycle event report in *Figure 9.3*.

```
=>>SUM <Enter>

SEL-787                                   Date: 02/14/2008   Time: 13:09:57.353
TRNSFRMR RELAY

Serial No = 000000000000000
FID = SEL-787-X122HR-V0-Z001001-D20080212              CID = 26FF
EVENT LOGS =  1

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0

Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)     512.0         213.8         215.0        295.00

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)    2138.8        2144.4        2141.1         36.40

Neutral Current Mag
         IN
(A)      0.60

Voltage Mag
       VAB    VBC    VCA
(V)   13501  13500  13687
=>>
```

Figure 9.1 Example Event Summary

The relay sends event summaries to all serial ports with setting AUTO := Y each time an event triggers.

Event Type

The `Event` field displays the event type. Event types and the logic used to determine event types are shown in order of priority in *Table 9.1*.

Table 9.1 Event Types

Event Type	Event Type Logic
`Diff 87 Trip`	(87U OR 87R) AND TRIP
`REF Trip`	(REF1F OR REF1P) AND TRIP
`Wdg1 Ph 50 Trip`	(50P11T OR 50P12T OR 50P13T OR 50P14T) AND TRIP
`Wdg1 Gnd 50 Trip`	(50G11T OR 50G12T) AND TRIP
`Wdg1 50Q Trip`	(50Q11T OR 50Q12T) AND TRIP
`Wdg2 Ph 50 Trip`	(50P21T OR 50P22T OR 50P23T OR 50P24T) AND TRIP
`Wdg2 Gnd 50 Trip`	(50G21T OR 50G22T) AND TRIP
`Wdg2 50Q Trip`	(50Q21T OR 50Q22T) AND TRIP
`Neutral 50 Trip`	(50N11T OR 50N12T) AND TRIP
`Wdg1 Ph 51 Trip`	51P1T AND TRIP
`Wdg1 Gnd 51 Trip`	51G1T AND TRIP
`Wdg1 51Q Trip`	51Q1T AND TRIP
`Wdg2 Ph 51 Trip`	51P2T AND TRIP
`Wdg2 Gnd 51 Trip`	51G2T AND TRIP
`Wdg2 51Q Trip`	51Q2T AND TRIP
`Neutral 51 Trip`	51N1T AND TRIP
`PowerElemnt Trip`	(3PWR1 OR 3PWR2) AND TRIP
`Undervolt Trip`	(27P1T OR 27P2T) AND TRIP
`Overvolt Trip`	(59P1T OR 59P2T OR 59Q1T OR 59Q2T) AND TRIP
`Volt/Hz 24 Trip`	(24D1T OR 24C2T) AND TRIP
`Frequency 81 Trip`	(81D1T OR 81D2T OR 81D3T OR 81D4T) AND TRIP
`RTD Trip`	RTDT AND TRIP
`RTD Fail Trip`	RTDFLT AND TRIP
`Breaker Failure Trip`	(BFT1 OR BFT2) AND TRIP
`Remote Trip`	REMTRIP AND TRIP
`CommIdleLossTrip`	(COMMIDLE OR COMMLOSS) AND TRIP
`Trigger`	Serial port **TRI** command
`ER Trigger`	ER Equation assertion
`Trip`	TRIP with no known cause

Currents, Voltages, and RTD Temperatures

The relay determines the maximum winding current during an event. The instant the maximum winding current occurs is marked by an asterisk (*) in the event report (see *Figure 9.3*). This row of data corresponds to the analogs shown in the summary report for the event.

The `Current Mag` fields display the primary current magnitudes at the instant when the maximum winding current was measured. The currents displayed are listed below:

- Winding Currents (IAW*n*, IBW*n*, ICW*n*, IGW*n* {*n* = 1 and 2})
- Neutral Current (IN)

The `Voltage Mag` fields display the primary voltage magnitudes at the instant when the maximum winding current was measured. The voltages displayed are listed below:

- DELTA_Y := WYE
  - Phase-to-Neutral Voltages (VAN, VBN, VCN)
  - Residual Voltage VG, calculated from VAN, VBN, VCN
- DELTA_Y := DELTA
  - Phase-to-Phase Voltages (VAB, VBC, VCA)

If the RTDs are connected, the hottest RTD (°C) fields display the hottest RTD reading in each RTD group. The hottest RTD temperatures in degrees centigrade (°C) are listed below:

- Ambient
- Other

Event History

The event history report gives you a quick look at recent relay activity. The relay labels each new event in reverse chronological order with `1` as the most recent event. See *Figure 9.2* for a sample event history. Use this report to view the events that are presently stored in the SEL-787.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
  - Time source (Internal or IRIG-B)
- Event number, date, time, event type (see *Table 9.1*)
- Maximum current
- Frequency (actual frequency if voltage card is available otherwise the nominal frequency)
- Target LED status

```
=>>HIS <Enter>

SEL-787                                  Date: 02/14/2008   Time: 13:25:12
TRNSFRMR RELAY                           Time Source: Internal

FID = SEL-787-X122HR-V0-Z001001-D20080212

#     DATE        TIME          EVENT        CURRENT      FREQ  TARGETS
1  02/14/2008  13:09:57.353  Diff 87 Trip     2144.4      60.0  11100000

=>>
```

Frequency

Event Number

Event Type

Maximum Current

User-Defined Target LEDs

Figure 9.2 Sample Event History

Viewing the Event History

Access the history report from the communications ports, using the **HIS** command or the analysis menu within ACSELERATOR QuickSet SEL-5030 Software. View and download history reports from Access Level 1 and higher.

Use the **HIS** command from a terminal to obtain the event history. You can specify the number of the most recent events that the relay returns. See *HISTORY Command on page 7.28* for information on the **HIS** command.

Use the front-panel `MAIN > Events > Display` menu to display event history data on the SEL-787 front-panel display.

Use the QuickSet software to retrieve the relay event history. View the **Relay Event History** dialog box via the **Analysis > Get Event Files** menu.

Clearing

Use the **HIS C** command to clear or reset history data from Access Levels 1 and higher. Clear/reset history data at any communications port. This will clear all event summaries, history records, and reports.

Event Reports

The latest event reports are stored in nonvolatile memory. The 787 relay captures the following types of data:

- ➤ Analog values
- ➤ Digital states of the protection and control elements, plus status of digital output and input states
- ➤ Event Summary
- ➤ Settings in service at the time of event retrieval, consisting of Group, Logic, Global, and Report settings classes

The SEL-787 supports the following three separate event report types:

- ➤ Standard Analog Event Report (**EVE** command)
- ➤ Digital Event Report (**EVE D** command)
- ➤ Differential Event Report (**EVE DIFz** command, where z = 1, 2, or 3 for the three 87 elements)

Analog Event Reports (EVE Command)

The Analog Event Report includes:

- ➤ Analog values of Winding 1 and 2 currents; IAW, IBW, ICW, IGW, (IGW only if voltage card is not used), neutral current IN (if available), voltages and frequency (if voltage card is used)
- ➤ Digital states of the base model digital inputs (2) and digital outputs (3)
- ➤ Event Summary
- ➤ Relay Settings

If the winding phase CTs are delta connected, the primary currents displayed are derived from the secondary values by multiplying them with CTR (CT ratio) and dividing them by the square root of 3. The phase angles shown are the same as the secondary values. If the CT connection type is known (DAB or DAC), the user can correct the phase angles. The MET response is meant to show steady-state primary values. During unbalanced conditions the primary line currents cannot be reproduced accurately because the delta-connected CTs filter out the zero-sequence component of the line current. Wye-connected CTs do not have any such issue.

Filtered and Unfiltered Analog Event Reports

The SEL-787 samples the power system measurands (ac voltage and ac current) 16 times per power system cycle. A digital filter extracts the fundamental frequency component of the measurands. The relay operates on the filtered values and reports these values in the standard, filtered event report.

To view the raw inputs to the relay, select the unfiltered event report using the **EVE R** command. Use the unfiltered event reports to observe power system conditions:

- ➤ Power system transients on current and voltage channels
- ➤ Decaying dc offset during fault conditions on current channels

Raw event reports display one extra cycle of data at the beginning of the report.

Also, unlike the filtered report, the raw event report shows the actual relay terminal voltage inputs so if the external connections are for DELTA input, VA = Vab, VB = 0, VC = –Vbc (in primary volts).

Analog Event Report Column Definitions

Refer to the example analog event report in *Figure 9.3* to view event report columns. This example event report displays rows of information each 1/4 cycle. Retrieve this report with the **EVE** command.

The columns contain analog values, including ac current, ac voltage, and frequency, followed by base model input and output information.

Table 9.2 summarizes the analog event report columns.

Table 9.2 Analog Event Report Columns Definitions

Column Heading	Column Symbols	Description
IAW1		Current measured by channel IA, Winding 1 (primary A)
IBW1		Current measured by channel IB, Winding 1 (primary A)
ICW1		Current measured by channel IC, Winding 1 (primary A)
IGW1		Residual current (IAW1 + IBW1 + ICW1, primary A), displayed only when no voltages are shown
IAW2		Current measured by channel IA, Winding 2 (primary A)
IBW2		Current measured by channel IB, Winding 2 (primary A)
ICW2		Current measured by channel IC, Winding 2 (primary A)
IGW2		Residual current (IAW2 + IBW2 + ICW2, primary A), displayed only when no voltages are shown
IN		Current measured by channel IN (primary A) when neutral CT is present
VAN or VAB		Voltage measured by channel VAN or VAB (primary V), requires voltage input
VBN or VBC		Voltage measured by channel VBN or VBC (primary V), requires voltage input
VCN or VCA		Voltage measured by channel VCN or VCA calculated from VAB and VBC (primary V), requires voltage input
In 12	1 2 b	IN101 AND NOT IN102 NOT IN101 AND IN102 IN101 AND IN102
Out 12	1 2 b	OUT101 AND NOT OUT102 NOT OUT101 AND OUT102 OUT101 AND OUT102
Out 3	3	OUT103

Note that the ac values change from plus to minus (–) values in *Figure 9.3*, indicating the sinusoidal nature of the waveforms.

Other figures help in understanding the information available in the event report current columns:

- *Figure 9.4* shows how analog event report current column data relate to the actual sampled current waveform and rms current values.
- *Figure 9.5* shows how analog event report current column data can be converted to phasor rms current values.

Example 15-Cycle Event Report

The following example of a standard analog 15-cycle event report in *Figure 9.3* also corresponds to the example SER report in *Figure 9.8*.

In *Figure 9.3*, an arrow (>) in the column following the VCA column would identify the "trigger" row. This is the row that corresponds to the Date and Time values at the top of the event report.

The asterisk (*) in the column following the VCA column identifies the row with the maximum phase current. The maximum phase current is calculated from the row identified with the asterisk and the row one quarter-cycle previous (see *Figure 9.4* and *Figure 9.5*). These currents are listed at the end of the event report in the event summary. If the trigger row (>) and the maximum phase current row (*) are the same row, the * symbol takes precedence.

```
=>>EVE <Enter>
                                                                          Date and Time of Event
SEL-787                                 Date: 02/14/2008   Time: 13:09:57.353
TRNSFRMR RELAY

Serial Number=000000000000000
FID=SEL-787-X122HR-V0-Z001001-D20080212   CID=26FF

                                                                            O
                                                                          I u
                                                                          n t
                   Currents (A Pri)                  Voltages (V Pri)     1 13
   IAW1   IBW1   ICW1   IAW2   IBW2   ICW2   IN     VAB    VBC    VCA  Freq 2 2
[1]                                                                              Optional Voltage Card Required
  -54.5  206.0 -150.5  580.0-2085.0 1460.0  -0.6  12582 -10400  -2182 60.03 . ..
 -206.5   56.0  153.0 2055.0 -505.0-1560.0   0.0   4900   8612 -13512 60.03 . ..
   54.0 -206.5  149.5 -590.0 2080.0-1465.0   0.0 -12584  10398   2186 60.03 . ..
  206.0  -56.5 -153.5-2060.0  495.0 1555.0  -1.2  -4895  -8616  13511 60.03 . ..
[2]
  -54.5  206.0 -150.5  590.0-2085.0 1460.0  -1.2  12586 -10391  -2195 60.02 . ..
 -206.5   55.5  153.5 2050.0 -500.0-1560.0   1.2   4886   8623 -13510 60.02 . ..   One Cycle of Data
   54.5 -206.5  149.5 -590.0 2080.0-1460.0   0.0 -12590  10390   2201 60.02 . ..
  206.0  -56.0 -154.0-2060.0  495.0 1555.0  -1.8  -4883  -8626  13508 60.02 . ..
[3]
  -55.5  206.0 -150.0  585.0-2085.0 1455.0  -0.6  12590 -10384  -2207 60.03 . ..
 -206.5   55.5  153.5 2050.0 -500.0-1560.0   1.2   4878   8632 -13510 60.03 . ..
   50.0 -207.0  149.5 -595.0 2080.0-1460.0   0.0 -12594  10380   2214 60.03 . ..
  294.0  -55.5 -154.0-2055.0  495.0 1560.0  -1.8  -4872  -8636  13508 60.03 . ..
[4]
  -89.0  206.5 -150.0  590.0-2085.0 1450.0  -0.6  12595 -10375  -2220 60.02 . ..
 -438.5   55.0  153.5 2055.0 -500.0-1565.0   0.6   4864   8644 -13507 60.02 . ..
  131.5 -207.0  149.5 -595.0 2080.0-1455.0   0.0 -12599  10370   2228 60.02 . ..
  493.5  -55.5 -154.5-2060.0  490.0 1560.0  -1.2  -4858  -8647  13505 60.02 . ..
[5]
 -132.5  206.5 -150.0  590.0-2085.0 1450.0  -0.6  12600 -10363  -2237 60.03 . ..
 -494.0   55.0  154.0 2055.0 -495.0-1560.0   0.6   4852   8652 -13504 60.03 . ..
  132.0 -207.0  149.0 -600.0 2080.0-1460.0   0.0 -12604  10361   2243 60.03 . ..
  493.5  -55.5 -154.5-2060.0  485.0 1560.0  -1.2  -4848  -8654  13502 60.03>. ..
[6]
 -133.0  207.0 -149.5  595.0-2085.0 1455.0  -0.6  12607 -10358  -2249 60.03 . .*
 -494.0   54.5  154.0 2050.0 -490.0-1565.0   0.0   4838   8663 -13501 60.03 . .*
  132.0 -207.5  148.5 -600.0 2080.0-1460.0   0.0 -12611  10356   2255 60.03 . .*
  493.5  -55.0 -154.0-2055.0  485.0 1560.0  -1.2  -4832  -8668  13500 60.03 . .*
[7]
 -133.0  207.0 -149.5  595.0-2085.0 1450.0  -0.6  12611 -10348  -2263 60.02 . .*
 -494.0   54.5  154.0 2050.0 -490.0-1570.0   0.6   4826   8674 -13500 60.02 . .*
  133.0 -207.5  149.0 -600.0 2080.0-1450.0   0.6 -12613  10344   2269 60.02 . .*
  493.0  -54.5 -154.5-2055.0  485.0 1560.0  -1.2  -4819  -8677  13496 60.02 . .*
[8]
 -133.5  207.0 -149.5  600.0-2085.0 1450.0  -1.2  12614 -10340  -2274 60.03 . .*
 -493.5   54.0  154.0 2050.0 -490.0-1565.0   0.6   4812   8684 -13496 60.03 . .*
  133.0 -207.0  149.5 -600.0 2085.0-1455.0   0.0 -12617  10337   2280 60.03 . .*
  493.5  -55.5 -154.5-2060.0  480.0 1560.0  -1.2  -4808  -8688  13496 60.03 . .*
[9]
 -134.0  206.5 -149.5  595.0-2085.0 1450.0  -0.6  12618 -10330  -2288 60.02 . .*
 -493.5   54.5  154.5 2050.0 -485.0-1570.0   0.6   4802   8694 -13496 60.02 . .*
  133.5 -207.5  148.5 -605.0 2080.0-1455.0   0.0 -12623  10327   2296 60.02 . .*
  493.0  -55.0 -155.0-2055.0  480.0 1565.0  -1.8  -4798  -8698  13495 60.02 . .*
[10]
 -134.5  207.0 -149.5  600.0-2090.0 1445.0  -0.6  12625 -10322  -2303 60.03 . .*
 -494.0   54.0  154.5 2050.0 -485.0-1575.0   0.6   4789   8705 -13494 60.03 . .*
  134.5 -207.5  149.0 -605.0 2085.0-1450.0   0.0 -12629  10319   2310 60.03 . .*
  493.5  -54.5 -155.0-2060.0  480.0 1570.0  -0.6  -4784  -8708  13493 60.03 . .*
[11]
 -135.5  207.0 -149.0  605.0-2090.0 1440.0  -1.2  12629 -10313  -2316 60.03 . .*
 -493.5   53.5  154.5 2050.0 -480.0-1575.0   0.0   4776   8714 -13490 60.03 . .*
  135.0 -207.5  148.5 -605.0 2085.0-1450.0   0.6 -12634  10312   2322 60.03 . .*
  492.5  -54.0 -155.5-2055.0  475.0 1570.0  -1.2  -4771  -8718  13489 60.03 . .*
[12]
 -135.5  207.0 -148.5  600.0-2090.0 1440.0  -1.2  12635 -10306  -2329 60.03 . .*
 -493.0   53.5  154.5 2050.0 -480.0-1575.0   0.6   4764   8725 -13489 60.03 . .*
  135.5 -207.5  148.0 -605.0 2085.0-1445.0   0.0 -12637  10303   2334 60.03 . .*
  492.5  -54.0 -155.5-2055.0  470.0 1575.0  -1.8  -4760  -8729  13489 60.03 . .*
```

Figure 9.3 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution

```
[13]
 -136.0  206.5 -149.0  605.0-2090.0 1440.0  -1.2  12637 -10298  -2339 60.03 . .*
 -493.0   53.5  155.0 2050.0 -475.0-1580.0   1.2   4753   8736 -13489 60.03 . .*
  136.0 -207.5  148.5 -615.0 2080.0-1445.0   0.0 -12641  10295   2346 60.03 . .*
  492.5  -54.5 -156.0-2055.0  475.0 1570.0  -1.2  -4747  -8738  13486 60.03 . .*
[14]
 -136.5  207.0 -148.5  610.0-2090.0 1445.0  -0.6  12642 -10288  -2354 60.02 . .*
 -493.5   53.5  155.5 2050.0 -480.0-1580.0   0.0   4741   8742 -13483 60.02*. .*
  136.0 -207.5  148.0 -615.0 2085.0-1450.0   0.0 -12646  10285   2360 60.02 . .*
  492.5  -54.0 -156.0-2050.0  465.0 1575.0  -0.6  -4734  -8747  13481 60.02 . .*

[15]
 -137.0  207.0 -148.0  610.0-2090.0 1440.0  -0.6  12647 -10279  -2368 60.03 . .*
 -493.0   53.0  155.5 2045.0 -470.0-1580.0   0.0   4727   8754 -13481 60.03 . .*
  136.5 -207.5  147.5 -615.0 2080.0-1440.0   0.0 -12650  10278   2372 60.03 . .*
  492.0  -53.5 -155.5-2055.0  470.0 1575.0  -1.2  -4723  -8758  13481 60.03 . .*

Serial No = 0000000000000000                                            Firmware Identifier
FID = SEL-787-X122HR-V0-Z001001-D20080212              CID = 26FF      Firmware Checksum Identifier
EVENT LOGS =  1

Event:     Diff 87 Trip
Targets    11100000
Freq (Hz)  60.0

Winding One Current Mag
       IAW1          IBW1          ICW1          IGW1
(A)     512.0         213.8         215.0        295.00

Winding Two Current Mag
       IAW2          IBW2          ICW2          IGW2
(A)    2138.8        2144.4        2141.1         36.40

Neutral Current Mag
        IN
(A)      0.60

Voltage Mag
       VAB    VBC    VCA
(V)   13501  13500  13687

Global Settings
PHROT   := ABC     FNOM    := 60      DATE_F  := MDY
FAULT   := ORED50P OR ORED51P OR TRIP
EMP     := N       TGR     := 3
SS1     := 1
SS2     := 0
SS3     := 0
SS4     := 0

EPMU    := N
52ABF   := N       BFD1    := 0.50    BFI1    := R_TRIG TRIP1 OR R_TRIG TRIPXFMR
BFD2    := 0.50    BFI2    := R_TRIG TRIP2 OR R_TRIG TRIPXFMR

THFLTD  := OFF

IN101D  := 10      IN102D  := 10

RSTTRGT := 0
RSTENRGY:= 0
RSTMXMN := 0
RSTDEM  := 0
RSTPKDEM:= 0

DSABLSET:= 0

Group Settings

RID     := SEL-787
TID     := TRNSFRMR RELAY
W1CT    := WYE     W2CT    := WYE
CTR1    := 100     CTR2    := 1000    MVA     := 50.0    ICOM    := N
VWDG1   := 138.00  VWDG2   := 13.80
CTRN1   := 120     PTR     := 120.00  VNOM    := 13.80   DELTA_Y := DELTA
VIWDG   := 2       SINGLEV := N
E87     := Y       TAP1    := 2.09    TAP2    := 2.09
O87P    := 0.30    87AP    := 0.15    87AD    := 5.0     SLP1    := 25
SLP2    := 50      IRS1    := 3.0
U87P    := 10.0    PCT2    := 15      PCT4    := OFF     PCT5    := 35
TH5P    := OFF     HRSTR   := Y       HBLK    := N

REF1POL := OFF     REF1TC  := 1
50REF1P := 0.25
```

Figure 9.3 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution (Continued)

```
50P11P  := 10.00   50P11D  := 0.00    50P11TC := 1
50P12P  := 10.00   50P12D  := 0.00    50P12TC := 1
50P13P  := 10.00   50P13D  := 0.00    50P13TC := 1
50P14P  := 10.00   50P14D  := 0.00    50P14TC := 1
50G11P  := OFF     50G12P  := OFF     50Q11P  := OFF     50Q12P  := OFF
51P1P   := 6.00    51P1C   := U3      51P1TD  := 3.00    51P1RS  := N
51P1CT  := 0.00    51P1MR  := 0.00    51P1TC  := 1


51G1P   := 0.50    51G1C   := U3      51G1TD  := 1.50    51G1RS  := N
51G1CT  := 0.00    51G1MR  := 0.00    51G1TC  := 1

51Q1P   := 6.00    51Q1C   := U3      51Q1TD  := 3.00    51Q1RS  := N
51Q1CT  := 0.00    51Q1MR  := 0.00    51Q1TC  := 1
50P21P  := 10.00   50P21D  := 0.00    50P21TC := 1
50P22P  := 10.00   50P22D  := 0.00    50P22TC := 1
50P23P  := 10.00   50P23D  := 0.00    50P23TC := 1
50P24P  := 10.00   50P24D  := 0.00    50P24TC := 1
50G21P  := OFF     50G22P  := OFF     50Q21P  := OFF     50Q22P  := OFF
51P2P   := 6.00    51P2C   := U3      51P2TD  := 3.00    51P2RS  := N
51P2CT  := 0.00    51P2MR  := 0.00    51P2TC  := 1


51G2P   := 0.50    51G2C   := U3      51G2TD  := 1.50    51G2RS  := N
51G2CT  := 0.00    51G2MR  := 0.00    51G2TC  := 1

51Q2P   := 6.00    51Q2C   := U3      51Q2TD  := 3.00    51Q2RS  := N
51Q2CT  := 0.00    51Q2MR  := 0.00    51Q2TC  := 1

50N11P  := OFF     50N12P  := OFF     51N1P   := OFF

E49RTD  := NONE
27P1P   := OFF     27P2P   := OFF
59P1P   := OFF     59P2P   := OFF
59Q1P   := OFF     59Q2P   := OFF
E24     := Y       24WDG   := WYE     24D1P   := 105
24D1D   := 1.00    24CCS   := ID      24IP    := 105     24IC    := 2.0
24ITD   := 0.1
24D2P2  := 176     24D2D2  := 3.00    24CR    := 240.00  24TC    := 1

EPWR    := N

81D1TP  := OFF     81D2TP  := OFF
81D3TP  := OFF
81D4TP  := OFF
EDEM    := OFF
EALIAS  := 4

ALIAS1  :=PB01 FP_AUX1 PICKUP DROPOUT
ALIAS2  :=PB02 FP_LOCK PICKUP DROPOUT
ALIAS3  :=PB03 FP_CLOSE PICKUP DROPOUT
ALIAS4  :=PB04 FP_TRIP PICKUP DROPOUT

ER      := R_TRIG ORED51P OR R_TRIG ORED50P
LER     := 15      PRE     := 5

LDLIST  := NA

LDAR    := 15

TDURD   := 0.5     CFD1    := 0.5     CFD2    := 0.5
TR1     := 50P11T OR 51P1T OR 51Q1T OR NOT LT02 AND SV04T OR OC1
TR2     := 51P2T OR 51Q2T OR LT02 AND SV04T OR OC2
TRXFMR  := 87R OR 87U
REMTRIP := 0
ULTRIP1 := 0
ULTRIP2 := 0
ULTRXFMR:= 0
52A1    := 0
CL1     := TRIP1 OR TRIPXFMR
ULCL1   := SV03T AND LT02 OR CC2
52A2    := SV03T AND NOT LT02 OR CC1
CL2     := 0
ULCL2   := TRIP2 OR TRIPXFMR

Report Settings

ESERDEL := N

SER1    := IN101 IN102 PB01 PB02 PB03 PB04 52A1 52A2 TRIP1 TRIP2 TRIPXFMR
SER2    := ORED51T ORED50T 87U 87R 27P1T 27P2T 59P1T 59P2T 59Q1T 59Q2T 3PWR1T
3PWR2T REF1F 24D1T 24C2T RTDT
SER3    := 81D1T 81D2T 81D3T 81D4T
SER4    := SALARM
```

Figure 9.3 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution (Continued)

```
Logic Settings

ELAT    := 4       ESV     := 5       ESC     := N       EMV     := N

SET01   := R_TRIG SV01T AND NOT LT01
RST01   := R_TRIG SV01T AND LT01
SET02   := R_TRIG SV02T AND NOT LT02 AND PB02
RST02   := R_TRIG SV02T AND LT02 AND PB02
SET03   := (PB03 AND R_TRIG SV02T) AND LT01 AND NOT (52A1 AND NOT LT02 OR 52A2 AND LT02)
RST03   := (R_TRIG SV02T OR SV03T) AND LT03
SET04   := (PB04 AND R_TRIG SV02T) AND (52A1 AND NOT LT02 OR 52A2 AND LT02)
RST04   := (R_TRIG SV02T OR SV04T) AND LT04


SV01PU  := 3.00    SV01DO  := 0.00
SV01    := PB01
SV02PU  := 0.25    SV02DO  := 0.00
SV02    := PB01 OR PB02 OR PB03 OR PB04
SV03PU  := 0.00    SV03DO  := 0.00
SV03    := LT03
SV04PU  := 0.00    SV04DO  := 0.00
SV04    := LT04
SV05PU  := 0.25    SV05DO  := 0.25
SV05    := (PB01 OR PB02 OR LT03 OR LT04) AND NOT SV05T


OUT101FS:= Y       OUT101  := HALARM OR SALARM
OUT102FS:= N       OUT102  := 0
OUT103FS:= N       OUT103  := TRIPXFMR
=>
```

Figure 9.3 Example Standard 15-Cycle Analog Event Report 1/4-Cycle Resolution (Continued)

Figure 9.4 and *Figure 9.5* look in detail at an example of one cycle of A-phase current (channel IA) data similar to what is shown in *Figure 9.3*. *Figure 9.4* shows how the event report ac current column data relate to the actual sampled waveform and rms values. *Figure 9.5* shows how the event report current column data can be converted to phasor rms values. Voltages are processed similarly.

In *Figure 9.4*, note that any two rows of current data from the analog event report, 1/4 cycle apart, can be used to calculate rms current values.

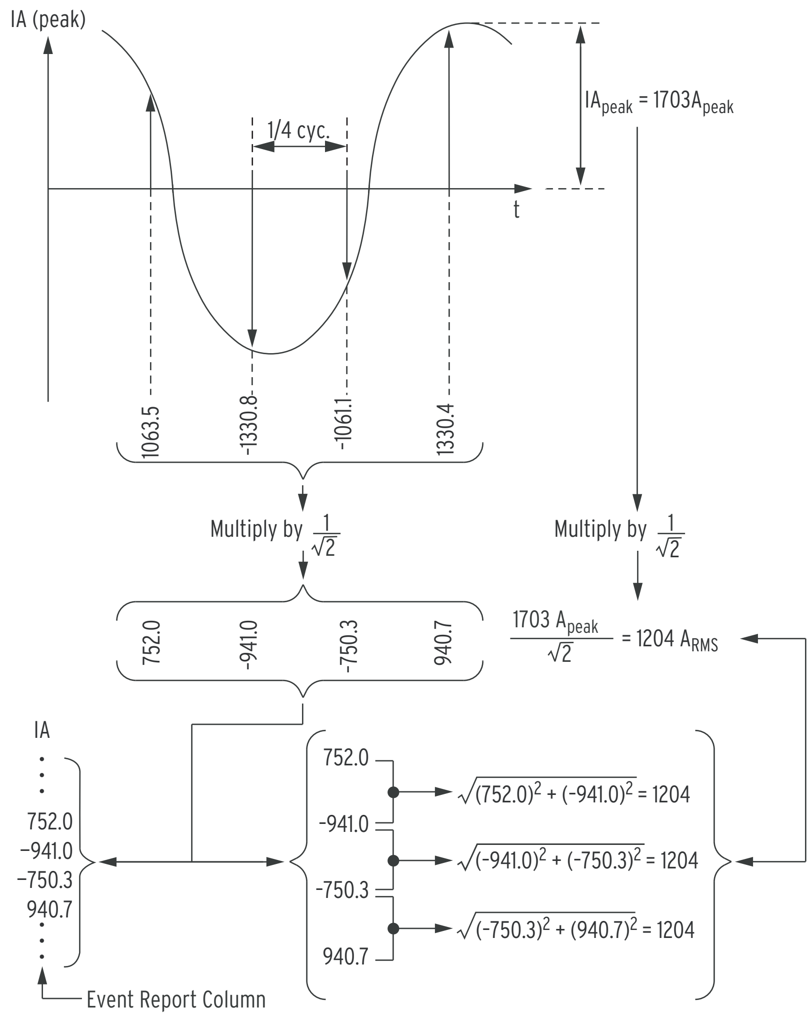


Figure 9.4 Derivation of Analog Event Report Current Values and RMS Current Values From Sampled Current Waveform

In *Figure 9.5*, note that two rows of current data from the analog event report, 1/4 cycle apart, can be used to calculate phasor rms current values. In *Figure 9.5*, at the present sample, the phasor rms current value is:

$$IA = 1204\ A\ \angle{-38.6°} \qquad \textbf{Equation 9.1}$$

The present sample (IA = 940.7 A) is a real rms current value that relates to the phasor rms current value:

$$1204\ A \bullet \cos(-38.6°) = 940.7\ A \qquad \textbf{Equation 9.2}$$

NOTE: The arctan function of many calculators and computing programs does not return the correct angle for the second and third quadrants (when X is negative). When in doubt, graph the X and Y quantities to confirm that the angle that your calculator reports is correct.

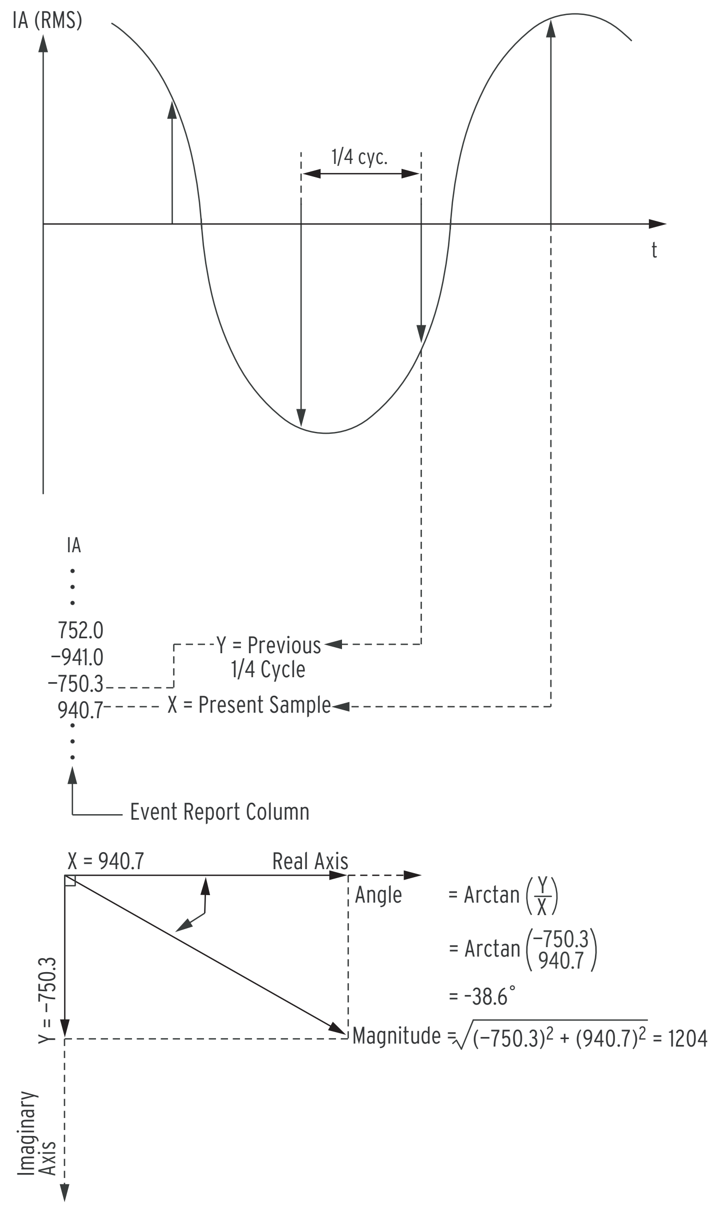


Figure 9.5 Derivation of Phasor RMS Current Values From Event Report Current Values

Digital Event Report (EVE D Command)

The digital event report includes:

- ➤ Digital states of control and protection elements, including overcurrent and voltage elements (if voltage inputs are available), plus status of digital inputs and outputs and RTD status
- ➤ Event Summary
- ➤ Relay Settings

Use the **EVE D *n*** command to view the normal digital report with 4 samples/cycle for report *n* (if not listed, *n* is assumed to be 1). **EVE D R** gives the RAW report with 16 samples/cycle.

Refer to the example event report in *Figure 9.6* to view the digital event report columns.

This example event report displays rows of information each 1/4 cycle. Retrieve this report with the **EVE D** command.

Table 9.3 gives the digital event report column definitions for the protection and control elements and the inputs and outputs.

NOTE: Active bits will depend on the options included in the relay.

Table 9.3 Digital Event Report Column Definitions (Sheet 1 of 4)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
50P11	* t	50P11P picked up 50 P11T picked up
50P12	* t	50P12P picked up 50P12T picked up
50P13	* t	50P13P picked up 50P13T picked up
50P14	* t	50P14P picked up 50P14T picked up
50G11	* t	50G11P picked up 50G11T picked up
50G12	* t	50G12P picked up 50G12T picked up
50Q11	* t	50Q11P picked up 50Q11T picked up
50Q12	* t	50Q12P picked up 50Q12T picked up
51P1	* t r	51P1P picked up 51P1T picked up 51P1R picked up
51G1	* t r	51G1P picked up 51G1T picked up 51G1R picked up
51Q1	* t r	51Q1P picked up 51Q1T picked up 51Q1R picked up
51P21	* t	51P21P picked up 51P21T picked up
51P22	* t	51P22P picked up 51P22T picked up
51P23	* t	51P23P picked up 51P23T picked up
51P24	* t	51P24P picked up 51P24T picked up
51G21	* t	51G21P picked up 51G21T picked up
51G22	* t	51G22P picked up 51G22T picked up
51Q21	* t	51Q21P picked up 51Q21T picked up
51Q22	* t	51Q22P picked up 51Q22T picked up

Table 9.3 **Digital Event Report Column Definitions** (Sheet 2 of 4)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
51P2	* t r	51P2P picked up 51P2T picked up 51P2R picked up
51G2	* t r	51G2P picked up 51G2T picked up 51G2R picked up
51Q2	* t r	51Q2P picked up 51Q2T picked up 51Q2R picked up
50N1	* t	50N1P picked up 50N1T picked up
50N2	* t	50N2P picked up 50N2T picked up
51N1	* t r	51N1P picked up 51N1T picked up 51N1R picked up
27P1	* t	27P1 picked up 27P1T picked up
27P2	* t	27P2 picked up 27P2T picked up
59P1	* t	59P1 picked up 59P1T picked up
59P2	* t	59P2 picked up 59P2T picked up
24D1	1 D	24D1 picked up 24D1T picked up
24C2	2 C r	24C2 picked up 24C2T picked up 24CR picked up
3PW1	* t	3PWR1P picked up 3PWR1T picked up
3PW2	* t	3PWR2P picked up 3PWR2T picked up
81D12	1 2 b	81D1T picked up 81D2T picked up Both 81D1T and 81D2T picked up
81D34	3 4 b	81D3T picked up 81D4T picked up Both 81D3T and 81D4T picked up.
BFI1	* t	BFI1 picked up BFT1 picked up
BFI2	* t	BFI2 picked up BFT2 picked up
TRIP	*	TRIP picked up
REF	* f r	REF1P picked up REF1F picked up REF1R picked up

Table 9.3 Digital Event Report Column Definitions (Sheet 3 of 4)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
Inputs 3012	1 2 b	IN301 picked up IN302 picked up Both IN301 and IN302 picked up
Inputs 3034	3 4 b	IN303 picked up IN304 picked up Both IN303 and IN304 picked up
Inputs 3056	5 6 b	IN305 picked up IN306 picked up Both IN305 and IN305 picked up
Inputs 3078	7 8 b	IN307 picked up IN308 picked up Both IN307 and IN308 picked up
Inputs 4012	1 2 b	IN401 picked up IN402 picked up Both IN401 and IN402 picked up
Inputs 4034	3 4 b	IN403 picked up IN404 picked up Both IN403 and IN404 picked up
Inputs 4056	5 6 b	IN405 picked up IN406 picked up Both IN405 and IN406 picked up
Inputs 4078	7 8 b	IN407 picked up IN408 picked up Both IN407 and IN408 picked up
Inputs 5012	1 2 b	IN501 picked up IN502 picked up Both IN501 and IN502 picked up
Inputs 5034	3 4 b	IN503 picked up IN504 picked up Both IN503 and IN504 picked up
Inputs5056	5 6 b	IN505 picked up IN506 picked up Both IN505 and IN506 picked up
Inputs 5078	7 8 b	IN507 picked up IN508 picked up Both IN507 and IN508 picked up
Outputs 3012	1 2 b	OUT301 picked up OUT302 picked up Both OUT301 and OUT302 picked up
Outputs 3034	3 4 b	OUT303 picked up OUT304 picked up Both OUT303 and OUT304 picked up
Outputs 4012	1 2 b	OUT401 picked up OUT402 picked up Both OUT401 and OUT402 picked up
Outputs 4034	3 4 b	OUT403 picked up OUT404 picked up Both OUT403 and OUT404 picked up
Outputs 5012	1 2 b	OUT501 picked up OUT502 picked up Both OUT501 and OUT502 picked up

Table 9.3 Digital Event Report Column Definitions (Sheet 4 of 4)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
Outputs 5034	3 4 b	OUT503 picked up OUT504 picked up Both OUT503 and OUT504 picked up
RTD Amb	a t	AMBALRM picked up AMBTRIP picked up
RTD Oth	a t	OTHALRM picked up OTHTRIP picked up
In12	1 2 b	IN101 picked up IN102 picked up Both IN101 and IN102 picked up
Out12	1 2 b	OUT101 picked up OUT102 picked up Both OUT101 and OUT102 picked up
Out3	*	OUT103 picked up

NOTE: The Event Summary and Settings are not shown here as they are the same as in Figure 9.3.

```
=>>EVE D <Enter>

SEL-787                                 Date: 02/14/2008   Time: 13:09:57.353
TRNSFRMR RELAY


Serial Number=000000000000000
FID=SEL-787-X122HR-V0-Z001001-D20080212   CID=26FF

Winding1    Winding2                             Optional I/O
                                                 Inputs       Outputs
                                                                     RTD  O
50       51 50       51 555 2255 22 33 81 BB   T 333344445555 334455    I u
PPPPGGQQPGQ PPPPGGQQPGQ 001 7799 44 PP DD FF R R 000000000000 000000 A0 n t
11111111111 22222222222 NNN PPPP DC WW 13 II E I 135713571357 131313 mt 1 13
12341212    12341212    121 1212 12 12 24 12 F P 246824682468 242424 bh 2 2
[1]
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
[2]
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
[3]
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
[4]
........rrr ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........r*r ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........r*r ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........r*r ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
[5]
........r*r ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........r*r ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........r*r ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..
........r*r ........rrr ..r .... .r .. .. .. . . ............ ...... .. . ..>
[6]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . ..
........r*r ........rrr ..r .... .r .. .. ** . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
[7]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
```

Figure 9.6 Example Standard 15-cycle Digital Event Report (EVE D Command) 1/4 Cycle Resolution

```
[8]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
[9]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*

[10]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
[11]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
[12]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*

[13]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
[14]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .**
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
[15]
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
........r*r ........rrr ..r .... .r .. .. .. . * ............ ...... .. . .*
```

Figure 9.6 Example Standard 15-cycle Digital Event Report (EVE D Command) 1/4 Cycle Resolution (Continued)

Differential Event Report (EVE DIFz Command)

The differential event report includes:

- ➤ Differential analog quantities for 87-1, 87-2 and 87-3 differential elements
- ➤ Digital states of differential and harmonic protection elements, plus status of base model digital inputs and outputs
- ➤ Event summary
- ➤ Relay settings

Use the **EVE DIF*z* *n*** command to view the normal Differential Report (*z* = 1 for 87-1 element, *z* = 2 for 87-2 element and *z* = 3 for 87-3 element) with 4 samples/cycle for report *n* (if not listed, *n* is assumed to be 1).

Refer to the example event report in *Figure 9.7* to view the differential event report columns. This example event report displays rows of information each 1/4 cycle. Retrieve this report with the **EVE DIF1** command.

Table 9.4 gives the Differential event report column definitions for the Analog Quantities IOP*z*, IRT*z*, I*z*F2 and I*z*F5 for *z* = 1, 2 and 3. *Table 9.5* gives the Differential event report digital column definitions for the Protection and Control elements and the base model inputs and outputs.

Table 9.4 Differential Event Report Column Definitions for Analog Quantities

Column Heading	Description
IOP1	Operate Current for Differential element 87-1 (multiples of TAP)
IRT1	Restraint Current for Differential element 87-1 (multiples of TAP)
I1F2	Second Harmonic current for Differential element 87-1 (multiples of TAP)
I1F5	Fifth Harmonic current for Differential element 87-1 (multiples of TAP)
IOP2	Operate Current for Differential element 87-2 (multiples of TAP)
IRT2	Restraint Current for Differential element 87-2 (multiples of TAP)
I2F2	Second Harmonic current for Differential element 87-2 (multiples of TAP)
I2F5	Fifth Harmonic current for Differential element 87-2 (multiples of TAP)
IOP3	Operate Current for Differential element 87-3 (multiples of TAP)
IRT3	Restraint Current for Differential element 87-3 (multiples of TAP)
I3F2	Second Harmonic current for Differential element 87-3 (multiples of TAP)
I3F5	Fifth Harmonic current for Differential element 87-3 (multiples of TAP)

Table 9.5 Differential Event Report Digital Column Definitions for Protection, Control, and I/O Elements (Sheet 1 of 2)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
87R	*	87R picked up
87R12	1 2 b	87R1 picked up 87R2 picked up Both 87R1 and 87R2 picked up
87R3	*	87R3 picked up
87U12	1 2 b	87U1 picked up 87U2 picked up Both 87U1 and 87U2 picked up
87U3	*	87U3 picked up
87B12	1 2 b	87BL1 picked up 87BL2 picked up Both 87BL1 and 87BL2 picked up
87B3	*	87BL3 picked up
87HR12	1 2 b	87HR1 picked up 87HR2 picked up Both 87HR1 and 87HR2 picked up
87HR3	*	87HR3 picked up
HB1	2 5 b	2_4HB1 picked up 5HB1 picked up Both 2_4HB1 and 5HB1 picked up
HB2	2 5 b	2_4HB2 picked up 5HB2 picked up Both 2_4HB2 and 5HB2 picked up
HB3	2 5 b	2_4HB3 picked up 5HB3 picked up Both 2_4HB3 and 5HB3 picked up
TH5	a t	TH5 picked up TH5T picked up

Table 9.5 Differential Event Report Digital Column Definitions for Protection, Control, and I/O Elements (Sheet 2 of 2)

Column Designation	Column Symbols	Column Symbol Relay Word Bits (RWB)
In12	1	IN101 picked up
	2	IN102 picked up
	b	Both IN101 and IN102 picked up
Out12	1	OUT101 picked up
	2	OUT102 picked up
	b	Both OUT101 and OUT102 picked up
Out3	*	OUT103 picked up

NOTE: The event summary and settings are not shown here as they are the same as in Figure 9.3.

```
=>>EVE DIF1 (Enter)

SEL-787                                   Date: 02/14/2008   Time: 13:09:57.353
TRNSFRMR RELAY
Serial Number=000000000000000
FID=SEL-787-X122HR-V0-Z001001-D20080212   CID=26FF
                              Differential         O
     Differential Quantities  8 87 87 87 87       I u
  Multiples of TAP (Amps Api) 7 R  U  B  HR HB  T n t
                              R 13 13 13 13     H 1 13
    IOP1   IRT1   I1F2   I1F5   2  2  2  2  123 5 2 2
[1]
  919.5  561.9    0.0    2.9  . .. .. .. .. ... . . ..
  919.5  561.9    5.5    5.8  . .. .. .. .. ... . . ..
  920.9  562.6    0.3    5.0  . .. .. .. .. ... . . ..
  923.4  563.6    2.6    2.4  . .. .. .. .. ... . . ..
[2]
  923.3  563.6    2.4    3.4  . .. .. .. .. ... . . ..
  918.5  561.4    2.4    5.8  . .. .. .. .. ... . . ..
  918.5  561.4    2.4    5.3  . .. .. .. .. ... . . ..
  923.3  563.6    2.6    0.2  . .. .. .. .. ... . . ..
[3]
  922.6  563.3    0.0    2.6  . .. .. .. .. ... . . ..
  917.7  561.2    3.6    5.7  . .. .. .. .. ... . . ..
  919.8  561.5    0.5    6.5  . .. .. .. .. ... . . ..
  882.0  583.2   19.1    4.8  . .. .. b* .. 2.. . . ..
[4]
  876.0  585.0   39.6    7.2  . .. .. b* .. 2.. . . ..
  809.7  618.5   19.0    7.3  . .. .. b* .. 2.. . . ..
  804.6  621.3    0.8    2.9  . .. .. .. .. ... . . ..
  781.6  635.1    2.4    0.2  . .. .. .. .. ... . . ..
[5]
  780.8  634.9    2.9    2.6  . 1. .. .. .. ... . . ..
  778.3  633.8    2.6    5.7  . 1. .. .. .. ... . . ..
  779.7  634.5    2.9    5.0  . 1. .. .. .. ... . . ..
  782.3  635.5    2.4    2.4> * 1. .. .. 1. ... . . ..
[6]
  781.4  635.2    2.6    2.4  * 1. .. .. 1. ... . . .*
  776.6  633.1    2.6    5.0  * 1. .. .. 1. ... . . .*
  777.4  633.3    2.6    5.0  * 1. .. .. 1. ... . . .*
  780.0  634.4    0.2    0.2  * 1. .. .. 1. ... . . .*
[7]
  779.1  634.1    2.6    5.0  * 1. .. .. 1. ... . . .*
  776.6  633.1    2.4    5.6  * 1. .. .. 1. ... . . .*
  777.3  633.4    2.6    2.4  * 1. .. .. 1. ... . . .*
  780.1  634.3    2.4    0.2  * 1. .. .. 1. ... . . .*
[8]
  780.0  634.3    3.4    2.6  * 1. .. .. 1. ... . . .*
  777.5  633.3    2.6    5.5  * 1. .. .. 1. ... . . .*
  777.5  633.3    0.0    4.8  * 1. .. .. 1. ... . . .*
  782.1  635.6    3.7    2.4  * 1. .. .. 1. ... . . .*
[9]
  781.3  635.3    2.4    3.4  * 1. .. .. 1. ... . . .*
  776.7  633.0    2.4    3.7  * 1. .. .. 1. ... . . .*
  778.2  633.6    0.2    2.9  * 1. .. .. 1. ... . . .*
  780.7  634.7    2.4    0.0  * 1. .. .. 1. ... . . .*
[10]
  779.9  634.4    2.6    5.3  * 1. .. .. 1. ... . . .*
  777.1  633.5    4.8    5.8  * 1. .. .. 1. ... . . .*
  777.8  633.8    2.6    3.2  * 1. .. .. 1. ... . . .*
  782.6  636.0    0.2    3.4  * 1. .. .. 1. ... . . .*
```

Figure 9.7 Example Standard 15-cycle Differential Event Report (EVE DIF1 Command) 1/4 Cycle Resolution

```
[11]
  782.5  636.1    2.6    3.6  * 1. .. .. 1. ... . . .*
  777.9  633.8    3.4    3.6  * 1. .. .. 1. ... . . .*
  777.9  633.7    0.3    2.6  * 1. .. .. 1. ... . . .*
  780.7  634.7    5.6    2.2  * 1. .. .. 1. ... . . .*
[12]
  779.9  634.4    0.2    3.4  * 1. .. .. 1. ... . . .*
  777.4  633.3    4.8    5.5  * 1. .. .. 1. ... . . .*
  778.1  633.7    3.2    4.8  * 1. .. .. 1. ... . . .*
  780.6  634.7    3.7    0.0  * 1. .. .. 1. ... . . .*
[13]
  780.6  634.7    0.2    2.6  * 1. .. .. 1. ... . . .*
  778.0  633.7    3.6    5.7  * 1. .. .. 1. ... . . .*
  779.4  634.4    2.4    5.0  * 1. .. .. 1. ... . . .*
  781.9  635.4    2.4    2.2  * 1. .. .. 1. ... . . .*

[14]
  781.2  635.1    0.2    3.4  * 1. .. .. 1. ... . . .*
  778.4  634.2    3.6    5.5* * 1. .. .. 1. ... . . .*
  779.2  634.5    2.6    4.8  * 1. .. .. 1. ... . . .*
  779.7  634.3    2.6    2.4  * 1. .. .. 1. ... . . .*
[15]
  778.8  634.0    2.4    5.6  * 1. .. .. 1. ... . . .*
  776.3  632.9    3.4    6.9  * 1. .. .. 1. ... . . .*
  777.1  633.3    2.6    4.8  * 1. .. .. 1. ... . . .*
  782.1  635.3    3.7    0.3  * 1. .. .. 1. ... . . .*
```

Figure 9.7 Example Standard 15-cycle Differential Event Report (EVE DIF1 Command) 1/4 Cycle Resolution (Continued)

Sequential Events Recorder (SER) Report

The SER report captures relay element state changes over an extended period.

SER report data are useful in commissioning tests and root-cause analysis studies. SER information is stored when state changes occur. The report records the most recent 1024 state changes if a relay element is listed in the SER trigger equations.

SER Triggering

Settings SER1 through SER4 are used to select entries in the SER report. To capture relay element state changes in the SER report, the relay element name must be programmed into one of the four SER trigger equations. Each of the four programmable trigger equations allows entry of as many as 24 relay elements; the SER report can monitor a total of 96 relay elements.

The relay adds a message to the SER to indicate power up or settings change conditions:

```
Relay Powered Up
.
.
.
Relay Settings Changed
```

Each entry in the SER includes the SER row number, date, time, element name, and element state.

SER Aliases

You may rename as many as 20 of the SER trigger conditions using the ALIAS settings. For instance, the factory-default alias setting 2 renames Relay Word bit PB02 for reporting in the SER:

```
ALIAS2:= PB02 FP_LOCK PICKUP DROPOUT
```

When Relay Word bit PB02 is asserted, the SER report will show the date and time of FP_LOCK PICKUP. When Relay Word bit PB02 is deasserted, the SER report will show the date and time of FP_LOCK DROPOUT. With this and other alias assignments, the SER record is easier for the operator to review. See *Relay Word Bit Aliases on page 4.104* for additional details.

Retrieving and Clearing SER Reports

See *SER Command (Sequential Events Recorder Report) on page 7.36* for details on the **SER** command.

Example SER Report

The example SER report in *Figure* includes records of events that occurred before the beginning of the event summary report in *Figure 9.3*.

```
=>SER <Enter>

SEL-787                                  Date: 02/14/2008   Time: 13:22:53
TRNSFRMR RELAY                           Time Source: Internal

Serial No = 000000000000000
FID = SEL-787-X122HR-V0-Z001001-D20080212              CID = 26FF

#     DATE         TIME          ELEMENT                  STATE
5  02/14/2008  13:09:57.353   87R                       Asserted
4  02/14/2008  13:09:57.353   TRIPXFMR                  Asserted
3  02/14/2008  13:09:57.615   ORED51T                   Asserted
2  02/14/2008  13:19:17.186   SALARM                    Asserted
1  02/14/2008  13:19:18.190   SALARM                    Deasserted

=>
```

Figure 9.8 Example Sequential Events Recorder (SER) Event Report

Section 10

Testing and Troubleshooting

Overview

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

Relay testing is typically divided into two categories:

➤ Tests performed at the time the relay is installed or commissioned
➤ Tests performed periodically once the relay is in service

This section provides information on both types of testing for the SEL-787 Transformer Protection Relay. Because the SEL-787 is equipped with extensive self-tests, traditional periodic test procedures may be eliminated or greatly reduced.

Should a problem arise during either commissioning or periodic tests, the section on *Troubleshooting on page 10.14* provides a guide to isolating and correcting the problem.

Testing Tools

Serial Port Commands

The following serial port commands assist you during relay testing.

The **METER** command shows the ac currents and voltages (magnitude and phase angle) presented to the relay in primary values. In addition, the command shows power system frequency. Compare these quantities against other devices of known accuracy. The **METER** command is available at the serial ports and front-panel display. See *Section 7: Communications* and *Section 8: Front-Panel Operations*.

The relay generates a 15- or 64-cycle event report in response to faults or disturbances. Each report contains current and voltage information, relay element states, and input/output contact information. If you question the relay response or your test method, use the event report for more information. The **EVENT** command is available at the serial ports. See *Section 9: Analyzing Events*.

The relay provides a Sequential Events Recorder (SER) event report that time-tags changes in relay element and input/output contact states. The SER provides a convenient means to verify the pickup/dropout of any element in the relay. The **SER** command is available at the serial ports. See *Section 9: Analyzing Events*.

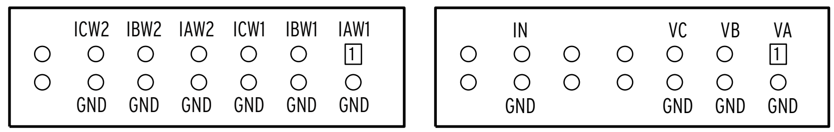
Use the **TARGET** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. The **TARGET** command is available at the serial ports and the front panel. See *Section 7: Communications* and *Section 8: Front-Panel Operations*.

Low-Level Test Interface

The SEL-787 has a low-level test interface on the 6 ACI current card (Slot Z) and 1 ACI Neutral current card or 1 ACI/3 AVI current/voltage card (Slot E). You can test the relay in either of two ways: conventionally by applying ac signals to the relay inputs or by applying low magnitude ac voltage signals to the test interface on the printed circuit boards.

NOTE: The SEL-RTS Relay Test System consists of the SEL-AMS Adaptive Multichannel Source and SEL-5401 Test System Software.

The SEL-RTS Low-Level Relay Test System can be used to provide signals to test the relay. *Figure 10.1* shows the Test Interface connectors.



(A) Connector J2 on 6 ACI Current Input Board (B) Connector J3 on 1 ACI/3 AVI Current Voltage Input Board

Figure 10.1 Low-Level Test Interface (J2 and J3)

Note that there are two options for the Slot E for low level interface:

- ➤ The 1 ACI card supports neutral current input IN only.
- ➤ The 1 ACI/3 AVI card supports the neutral current input IN and three-phase ac voltage inputs VA, VB, and VC.

Connector J3 is the same in both options.

Table 10.1 shows the signal scale factor information used by the AMS Relay Test System SEL-5401 Software for the calibrated inputs.

Table 10.1 Resultant Scale Factors for Inputs

Channel Label	Circuit Board & Connector	SEL-5401 Channel No.	Nominal Input	Scale Factor (A/V or V/V)
IAW1	6 ACI card/J2	1	5 A/1 A	106.14/21.23
IBW1	6 ACI card/J2	2	5 A/1 A	106.14/21.23
ICW1	6 ACI card/J2	3	5 A/1 A	106.14/21.23
IAW2	6 ACI card/J2	4	5 A/1 A	106.14/21.23
IBW2	6 ACI card/J2	5	5 A/1 A	106.14/21.23
ICW2	6 ACI card/J2	6	5 A/1 A	106.14/21.23
VA	1 ACI/3 AVI card/J3	7	250 V	218.4
VB	1 ACI/3 AVI card/J3	8	250 V	218.4
VC	1 ACI/3 AVI card/J3	9	250 V	218.4
IN	1 ACI/3 AVI card/J3	12	5 A/1 A	106.14/21.23

Access the low-level test interface connectors by using the following procedure.

⚠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.

Step 1. Loosen the mounting screws and the ground screw on the back and remove the back cover.

Step 2. Remove the 6 ACI board from Slot Z.

Step 3. Locate jumpers JMP1–JMP6 and change them from Pin 1–2 (normal position) to Pin 2–3 (low-level test position).

Step 4. Locate connector J2 and connect low-level signal connector (e.g., ribbon cable connector of SEL-RTS Test System).

Step 5. Insert the 6 ACI board back in its Slot Z.

Step 6. Remove the 1 ACI/3 AVI board or 1 ACI board from Slot **E**.

Step 7. Locate jumper JMP1 and change it from Pin 1-2 (normal position) to Pin 2-3 (low-level test position)

Step 8. Locate connector J3 and connect low-level signal connector (e.g., ribbon cable connector of SEL-RTS Test System).

NOTE: The 14-pin connectors of the SEL-RTS ribbon cable C750A can be used. The connectors are not keyed; make sure Pin 1 is connected to the IAW1/VA channel on the 6 ACI and 1 ACI/3 AVI boards, respectively.

Step 9. Insert the board back into Slot **E**.

Refer to the SEL-*RTS Instruction Manual* for additional detail.

When simulating a delta PT connection, DELTA_Y := DELTA, with the low-level test interface referenced in *Figure 10.1*, apply the following signals:

- Apply low-level test signal VAB to Pin VA.
- Apply low-level test signal –VBC (equivalent to VCB) to Pin VC.
- Do not apply any signal to pin VB.

Commissioning Tests

SEL performs a complete functional check and calibration of each SEL-787 before it is shipped. This helps to ensure that you receive a relay that operates correctly and accurately. Commissioning tests confirm that the relay is properly connected including the control signal inputs and outputs.

The following connection tests help you enter settings into the SEL-787 and verify that the relay is properly connected. Brief functional tests ensure that the relay settings are correct. It is unnecessary to test every element, timer, and function in these tests. Modify the procedure as necessary to conform to your standard practices. Use the procedure at initial relay installation; you should not need to repeat it unless major changes are made to the relay electrical connections.

Required Equipment

- The SEL-787, installed and connected according to your protection design
- A PC with serial port, terminal emulation software, and serial communications cable
- *SEL-787 Settings Sheets* with settings appropriate to your application and protection design
- The ac and dc elementary schematics and wiring diagrams for this relay installation
- A continuity tester
- A protective relay ac test source
  - Minimum: single-phase voltage and current with phase angle control
  - Preferred: three-phase voltage and current with phase angle control

Connection Tests

Step 1. Remove control voltage and ac signals from the SEL-787 by opening the appropriate breaker(s) or removing fuses.

Step 2. Isolate the relay contact assigned to be the **TRIP** output.

Step 3. Verify correct ac and dc connections by performing point-to-point continuity checks on the associated circuits.

Step 4. Apply ac or dc control voltage to the relay.

After the relay is energized, the front-panel green **ENABLED** LED should illuminate.

Step 5. Use the appropriate serial cable (SEL cable C234A or equivalent) to connect a PC to the relay.

Step 6. Start the PC terminal emulation software and establish communication with the relay.

Refer to *Section 7: Communications* for more information on serial port communications.

Step 7. Set the correct relay time and date by using either the front-panel or serial port commands (**TIME** *hh:mm:ss* and **DATE** *mm/dd/yy* commands).

Step 8. Using the **SET**, **SET P**, **SET G**, **SET L**, and **SET R** serial port commands, enter the relay settings from the settings sheets for your application.

Step 9. If you are connecting an external SEL-2600 RTD Module, follow the substeps below; otherwise continue with the next step.

a. Connect the fiber-optic cable to the RTD Module fiber-optic output.

b. Plug the relay end of the fiber-optic cable into the relay fiber-optic Rx input (Port 2).

Step 10. Verify the relay ac connections.

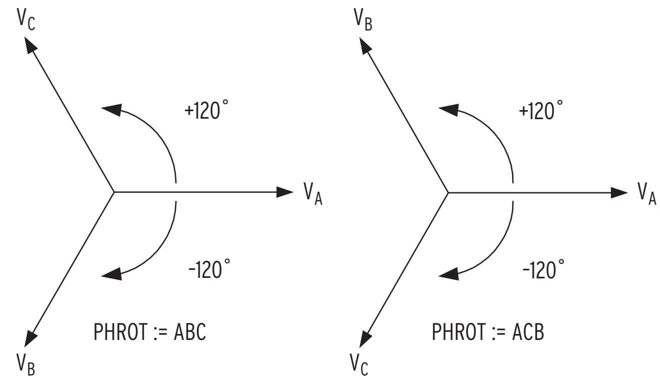
Step 11. Connect the ac test source current or voltage to the appropriate relay terminals.

NOTE: Make sure the current transformer secondary windings are shorted before they are disconnected from the relay.

a. Disconnect the current transformer and voltage transformer (if present) secondaries from the relay prior to applying test source quantities.

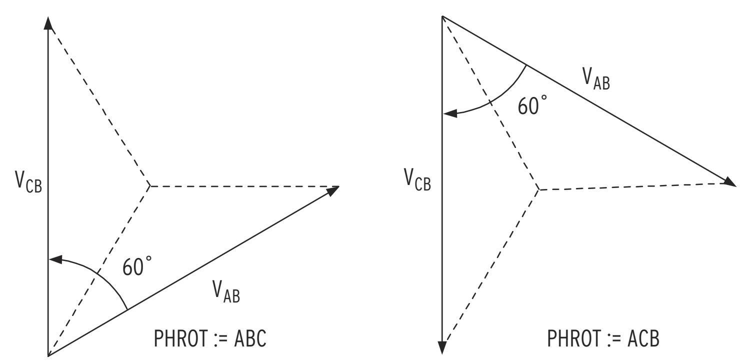
b. If you set the relay to accept phase-to-ground voltages (DELTA_Y := WYE), set the current and/or voltage phase angles as shown in *Figure 10.2*.

c. If you set the relay to accept delta voltages (DELTA_Y := DELTA), set the current and/or voltage phase angles as shown in *Figure 10.3*.



When setting PHROT := ABC,	set angle V_A = angle I_A = 0°
	set angle V_B = angle I_B = –120°
	set angle V_C = angle I_C = 120°
When setting PHROT := ACB,	set angle V_A = angle I_A = 0°
	set angle V_B = angle I_B = 120°
	set angle V_C = angle I_C = –120°

Figure 10.2 Three-Phase Wye AC Connections



When setting PHROT := ABC,	set angle I_A = 0°
	set angle I_B = –120°
	set angle I_C = 120°
	set angle V_{AB} = +30°
	set angle V_{CB} = +90°
When setting PHROT := ACB,	set angle I_A = 0°
	set angle I_B = 120°
	set angle I_C = –120°
	set angle V_{AB} = –30°
	set angle V_{CB} = –90°

Figure 10.3 Three-Phase Open-Delta AC Connections

Step 12. Apply rated current (1 A or 5 A).

Step 13. If the relay is equipped with voltage inputs, apply rated voltage for your application.

Step 14. Use the front-panel `METER > Fundamental` function or serial port **METER** command to verify that the relay is measuring the magnitude and phase angle of both voltage and current correctly, taking into account the relay PTR, CTR1, and CTR2 settings and the fact that the quantities are displayed in primary units.

Step 15. If you are using a current transformer for the neutral, apply a single-phase current to the IN1 terminal. Do not apply voltage.

Step 16. Verify that the relay is measuring the magnitude and phase angle correctly.

The expected magnitude is (applied current) • (CTRN1). The expected phase angle is zero (0).

Step 17. Verify control input connections. Using the front-panel `MAIN > Targets > Row 21` function, check the control input status in the relay (IN101 or IN102).

As you apply rated voltage to each input, the position in Row 21 corresponding to that input should change from zero (0) to one (1).

Step 18. Verify output contact operation:

a. For each output contact, set the input to logical 1. This causes the output contact to close. For example, setting OUT101 = 1 causes the output OUT101 contact to close.

b. Repeat the process for all contact outputs.

Make sure that each contact closure does what you want it to do in the annunciation, control, or trip circuit associated with that contact closure.

Step 19. Perform any desired protection element tests. Perform only enough tests to prove that the relay operates as intended; exhaustive element performance testing is not necessary for commissioning.

Step 20. Connect the relay for tripping duty.

Step 21. Verify that any settings changed during the tests performed in *Step 18* and *Step 19* are changed back to the correct values for your application.

Step 22. Use the serial port commands in *Table 10.2* to clear the relay data buffers and prepare the relay for operation.

This prevents data generated during commissioning testing from being confused with operational data collected later.

Table 10.2 Serial Port Commands That Clear Relay Data Buffers

Serial Port Command	Task Performed
LDP C	Clears Load Profile Data
SER R	Resets Sequential Events Record buffer
SUM R	Resets Event Report and Summary Command buffers

Step 23. When it is safe to do so, energize the transformer.

Step 24. Verify the following ac quantities by using the front-panel `METER > Fundamental` or serial port **METER** command.

- ➢ Phase current magnitudes should be nearly equal.
- ➢ Phase current angles should be balanced, have proper phase rotation, and have the appropriate phase relationship to the phase voltages.

Step 25. If your relay is equipped with voltage inputs, check the following:

- ➢ Phase voltage magnitudes should be nearly equal.
- ➢ Phase voltage phase angles should be balanced and have proper phase rotation.

The SEL-787 is now ready for continuous service.

Functional Tests

Phase Current Measuring Accuracy

Step 1. Connect the current source to the relay, as shown in *Figure 10.4*.

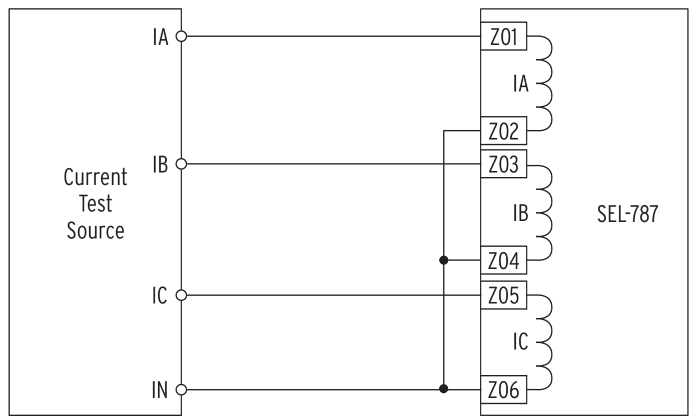


Figure 10.4 CTR1 Current Source Connections

Step 2. Using the front-panel `SET/SHOW` or the serial port **SHO** command, record the CTR1 and PHROT setting values.

Step 3. Set the phase current angles to apply balanced three-phase currents in accordance with the PHROT setting. Refer to *Figure 10.2*.

Step 4. Set each phase current magnitude equal to the values listed in Column 1 of *Table 10.3*. Use the front-panel to view the phase current values. The relay should display the applied current magnitude times the CTR1 setting.

Table 10.3 CTR1 Phase Current Measuring Accuracy

|I| Applied (A secondary)[a]	Expected Reading CTR1 x |I|	A-Phase Reading (A primary)	B-Phase Reading (A primary)	C-Phase Reading (A primary)
0.2 x I_{NOM}				
0.9 x I_{NOM}				
1.6 x I_{NOM}				

[a] I_{NOM} = rated secondary amps (1 or 5).

Step 5. Repeat *Step 1* through *Step 4* using *Figure 10.5* and *Table 10.4*.

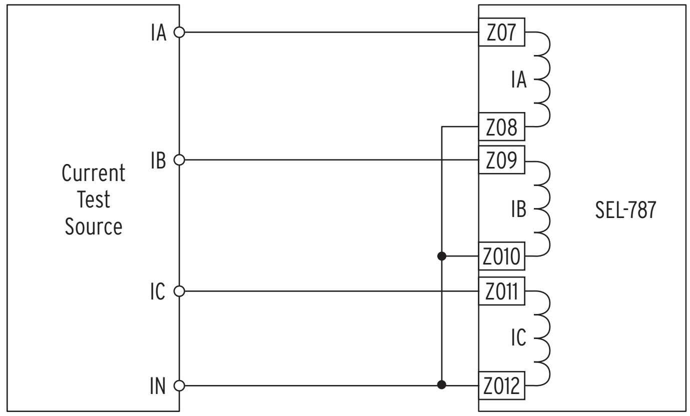


Figure 10.5 CTR2 Current Source Connections

Table 10.4 CTR2 Phase Current Measuring Accuracy

|I| Applied (A secondary)[a]	Expected Reading CTR2 x |I|	A-Phase Reading (A primary)	B-Phase Reading (A primary)	C-Phase Reading (A primary)
0.2 x I_{NOM}				
0.9 x I_{NOM}				
1.6 x I_{NOM}				

[a] I_{NOM} = rated secondary amps (1 or 5).

Power and Power Factor Measuring Accuracy

Wye-Connected Voltages

Perform the following steps to test wye-connected voltages:

Step 1. Connect the current source to the relay, as shown in *Figure 10.4* (VIWDG = 1) or *Figure 10.5* (VIWDG = 2).

Step 2. Connect the voltage source to the relay, as shown in *Figure 10.6*. Make sure that DELTA_Y := WYE.

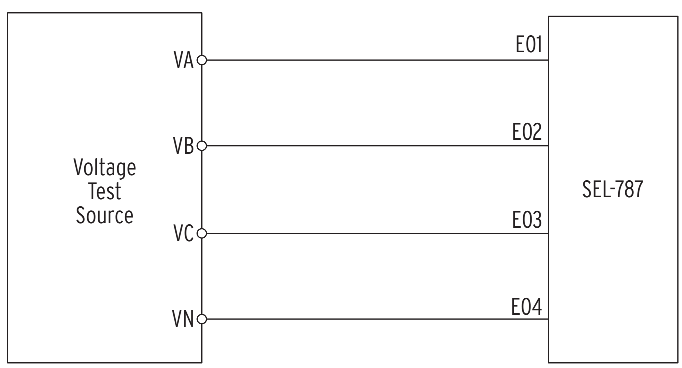


Figure 10.6 Wye Voltage Source Connections

Step 3. Using the front-panel `SET/SHOW` or the serial port **SHOW** command, record the CTR*n* (where *n* = VIWDG setting), PTR, and PHROT setting values.

Step 4. Apply the current and voltage quantities shown in Column 1 of *Table 10.5*.

Values are given for PHROT := ABC and PHROT := ACB.

Step 5. Use the front-panel METER function or the serial port **MET** command to verify the results.

Table 10.5 Power Quantity Accuracy—Wye Voltages[a]

Applied Currents and Voltages	Real Power (kW)	Reactive Power (kVAR)	Power Factor (pf)
PHROT := ABC IAW*n* = 2.5 ∠–26 IBW*n* = 2.5 ∠–146 ICW*n* = 2.5 ∠+94	**Expected:** P = 0.898 • CTR*n* • PTR	**Expected:** Q = 0.438 • CTR*n* • PTR	**Expected:** pf = 0.90 lag
VA = 67 ∠0 VB = 67 ∠–120 VC = 67 ∠+120	**Measured:**	**Measured:**	**Measured:**
PHROT := ACB IAW*n* = 2.5 ∠–26 IBW*n* = 2.5 ∠+94 ICW*n* = 2.5 ∠–146	**Expected:** P = 0.898 • CTR*n* • PTR	**Expected:** Q = 0.438 • CTR*n* • PTR	**Expected:** pf = 0.90 lag
VA = 67 ∠0 VB = 67 ∠+120 VC = 67 ∠–120	**Measured:**	**Measured:**	**Measured:**

[a] n = VIWDG setting

Delta-Connected Voltages

Perform the following steps to test delta-connected voltages:

Step 1. Connect the current source to the relay, as shown in *Figure 10.4* (VIWDG = 1) or *Figure 10.5* (VIWDG = 2).

Step 2. Connect the voltage source to the relay, as shown in *Figure 10.7*. Make sure that DELTA_Y := DELTA.

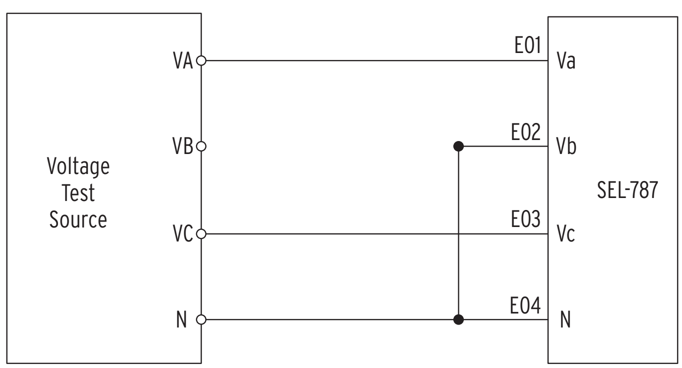


Figure 10.7 Delta Voltage Source Connections

Step 3. Using the front-panel SET/SHOW or the serial port **SHOW** command, record the CTR*n* (where n = VIWDG setting), PTR, and PHROT setting values.

Step 4. Apply the current and voltage quantities shown in Column 1 of *Table 10.6*.

Values are given for PHROT := ABC and PHROT := ACB.

Step 5. Use the front-panel METER or the serial port **MET** command to verify the results.

Table 10.6 Power Quantity Accuracy—Delta Voltages[a]

Applied Currents and Voltages	Real Power (kW)	Reactive Power (kVAR)	Power Factor (pf)
PHROT := ABC IAW*n* = 2.5 ∠–26 IBW*n* = 2.5 ∠–146 ICW*n* = 2.5 ∠+94	**Expected:** P = 0.4677 • CTR*n* • PTR	**Expected:** Q = 0.2286 • CTR*n* • PTR	**Expected** pf = 0.90 lag
VA (Vab) = 120 ∠+30 VC (Vcb) = 120 ∠+90	**Measured:**	**Measured:**	**Measured:**
PHROT := ACB IAW*n* = 2.5 ∠–26 IBW*n* = 2.5 ∠+94 ICW*n* = 2.5 ∠–146	**Expected:** P = 0.4677 • CTR*n* • PTR	**Expected:** Q = 0.2286 • CTR*n* • PTR	**Expected:** pf = 0.90 lag
VA (Vab) = 120 ∠–30 VC (Vcb)= 120 ∠–90	**Measured:**	**Measured:**	**Measured:**

[a] n = VIWDG setting

Periodic Tests (Routine Maintenance)

Because the SEL-787 is equipped with extensive self-tests, the most effective maintenance task is to monitor the front-panel messages after a self-test failure. In addition, each relay event report generated by a fault should be reviewed. Such reviews frequently reveal problems with equipment external to the relay, such as instrument transformers and control wiring.

The SEL-787 does not require specific routine tests, but your operation standards may require some degree of periodic relay verification. If you need or want to perform periodic relay verification, the following checks are recommended.

Table 10.7 Periodic Relay Checks

Test	Description
Relay Status	Use the front-panel `STATUS` or serial port **STATUS** command to verify that the relay self-tests have not detected any WARN or FAIL conditions.
Meter	Verify that the relay is correctly measuring current and voltage (if included) by comparing the relay meter readings to separate external meters.
Control Input	Using the front-panel `MAIN > Targets > Row 21` function, check the control input status in the relay. As you apply rated voltage to each input, the position in Row 21 corresponding to that input should change from zero (0) to one (1).
Contact Output	For each output contact, set the input to Logic 1. This causes the output contact to close. For example, setting OUT101 := 1 causes the output **OUT101** contact to close. Repeat the process for all contact outputs. Make sure that each contact closure does what you want it to do in the annunciation, control, or trip circuit associated with that contact closure.

Self-Test

The SEL-787 runs a variety of self-tests. The relay takes the following corrective actions for out-of-tolerance conditions (see *Table 10.8*):

- ➤ Protection Disabled: The relay disables protection and control elements and trip/close logic. All output contacts are de-energized. The ENABLED front-panel LED is extinguished.
- ➤ ALARM Output: Two Relay Word bits, HALARM and SALARM, signal self-test problems. SALARM is pulsed for software programmed conditions, such as settings changes, access level changes, unsuccessful password entry attempts, active group changes, copy commands, and password changes. HALARM is pulsed for hardware self-test warnings. HALARM is continuously asserted (set to logical 1) for hardware self-test failures. A diagnostic alarm may be configured as explained in *Section 4: Protection and Logic Functions*. In the Alarm Status column of *Table 10.8*, Latched indicates that HALARM is continuously asserted, Not Latched indicates that HALARM is pulsed for five seconds, and NA indicates that HALARM is not asserted.
- ➤ The relay generates automatic STATUS reports at the serial port for warnings and failures (ports with setting AUTO = Y).
- ➤ The relay displays failure messages on the relay LCD display for failures.
- ➤ For certain failures, the relay will automatically restart as many as three times. In many instances, this will correct the failure. The failure message might not be fully displayed before automatic restart occurs. Indication that the relay restarted will be recorded in the Sequential Events Recorder (SER).

NOTE: Refer to Access Commands (ACCESS, 2ACCESS, and CAL) for more information on when SALARM is pulsed for access level changes and unsuccessful password entry attempts.

Use the serial port **STATUS** command or front-panel to view relay self-test status. Based on the self-test type, issue the **STA C** command as directed in the Corrective Actions column. Contact SEL if this does not correct the problem.

Table 10.8 Relay Self-Tests (Sheet 1 of 4)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
Watchdog Timer Periodic Resetting	(1/32 cycle)		Yes	De-energized	No	No	
Mainboard FPGA (power up)	Fail if mainboard field programmable gate array does not accept program or the version number is incorrect		Yes	Latched	Yes	Status Fail FPGA Failure	Automatic restart. Contact SEL if failure returns.
Mainboard FPGA (run time)	Fail on lack of data acquisition interrupts or on detection of a CRC error in the FPGA code		Yes	Latched	Yes	Status Fail FPGA Failure	Automatic restart. Contact SEL if failure returns.
GPSB (back-plane) Communications	Fail if GPSB is busy on entry to processing interval		Yes	Latched	Yes	Status Fail GPSB Failure	Automatic restart. Contact SEL if failure returns.

Table 10.8 Relay Self-Tests (Sheet 2 of 4)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
Front-Panel HMI (power up)	Fail if ID registers do not match expected or if FPGA programming is unsuccessful		No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
External RAM (power up)	Performs a read/write test on system RAM		Yes	Latched	No	No	
External RAM (run time)	Performs a read/write test on system RAM		Yes	Latched	Yes	Status Fail RAM Failure	Automatic restart. Contact SEL if failure returns.
Internal RAM (power up)	Performs a read/write test on system CPU RAM		Yes	Latched	No	No	
Internal RAM (run time)	Performs a read/write test on system CPU RAM		Yes	Latched	Yes	Status Fail RAM Failure	Automatic restart. Contact SEL if failure returns.
Code Flash (power up)	SELBOOT qualifies code with a checksum		NA	NA	NA	NA	
Data Flash (power up)	Checksum is computed on critical data		Yes	Latched	Yes	Status Fail Non_Vol Failure	
Data Flash (run time)	Checksum is computed on critical data		Yes	Latched	Yes	Status Fail Non_Vol Failure	
Critical RAM (settings)	Performs a checksum test on the active copy of settings		Yes	Latched	Yes	Status Fail CR_RAM Fail-ure	Automatic restart. Contact SEL if failure returns.
Critical RAM (run time)	Verify instruction matches FLASH image		Yes	Latched	Yes	Status Fail CR_RAM Fail-ure	Automatic restart. Contact SEL if failure returns.
I/O Board Failure	Check if ID register matches part number		Yes	Latched	Yes	Status Fail Card [C|D|E] Failure	
DeviceNet Board Failure	DeviceNet card does not respond in three consecutive 300 ms time out periods		NA	NA	NA	COMMFLT Warning	
CT Board (power up)	Fail if ID register does not match part number		Yes	Latched	Yes	Status Fail CT Card Fail	
CT Board A/D Offset Warn	Measure dc offset at each input channel	–50 mV to +50 mV	No	Not Latched	No	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
VT Board (power up)	Fail if ID register does not match part number		Yes	Latched	Yes	Status Fail Card E Fail	

Table 10.8 Relay Self-Tests (Sheet 3 of 4)

Self-Test / Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
VT Board A/D Offset Warn Measure dc offset at each input channel	–50 mV to +50 mV	No	Not Latched	No	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
+0.9 V Fail Monitor +0.9 V power supply	0.855 to 0.945 V	Yes	Latched	Yes	Status Fail +0.9 V Failure	
+1.2 V Fail Monitor +1.2 V power supply	1.152 to 1.248 V	Yes	Latched	Yes	Status Fail +1.2 V Failure	
+1.5 V Fail Monitor +1.5 V power supply	1.35 to 1.65 V	Yes	Latched	Yes	Status Fail +1.5 V Failure	
+1.8 V Fail Monitor +1.8 V power supply	1.71 to 1.89 V	Yes	Latched	Yes	Status Fail +1.8 V Failure	
+3.3 V Fail Monitor +3.3 V power supply	3.07 to 3.53 V	Yes	Latched	Yes	Status Fail +3.3 V Failure	
+5 V Fail Monitor +5 V power supply	4.65 to 5.35 V	Yes	Latched	Yes	Status Fail +5 V Failure	
+2.5 V Fail Monitor +2.5 V power supply	2.32 to 2.68 V	Yes	Latched	Yes	Status Fail +2.5 V Failure	
+3.75 V Fail Monitor +3.75 V power supply	3.48 to 4.02 V	Yes	Latched	Yes	Status Fail +3.75 V Failure	
–1.25 V Fail Monitor -1.25 V power supply	–1.16 to –1.34 V	Yes	Latched	Yes	Status Fail –1.25 V Failure	
–5 V Fail Monitor -5 V power supply	–4.65 to –5.35 V	Yes	Latched	Yes	Status Fail –5 V Failure	
Clock Battery Monitor clock battery	2.3 to 3.5 V	No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
Clock Chip Unable to communicate with clock or fails time keeping test		No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
Clock Chip RAM Clock chip static RAM fails		No	Not Latched	Yes	NA	STA C, to clear the warning in the status report. Contact SEL if failure returns.
Internal/External RTD Fails if the internal RTD card or the external RTD reports that at least one enabled RTD input is open or shorted, if there is no communication, or if there is a power supply failure for the external RTD module		NA	NA	No	RTD Failure	STA C, to clear the warning in the status report. Contact SEL if failure returns.

Table 10.8 Relay Self-Tests (Sheet 4 of 4)

Self-Test	Description	Normal Range	Protection Disabled on Failure	Alarm Status	Auto Message on Failure	Front-Panel Message on Failure	Corrective Action
CID (configured IED description) File (access)	Failure to access/read CID file		No	NA	No	Status Fail CID File Failure	
Exception Vector	CPU error		Yes	Latched	NA	Vector *nn* Relay Disabled	Automatic restart. Contact SEL if failure returns.

Troubleshooting

Table 10.9 Troubleshooting

Symptom/Possible Cause	Diagnosis/Solution
The relay **ENABLED** front-panel LED is dark.	
Input power is not present or a fuse is blown.	Verify that input power is present. Check fuse continuity.
Self-test failure	View the self-test failure message on the front-panel display.
The relay front-panel display does not show characters.	
The relay front-panel has timed out.	Press the **ESC** pushbutton to activate the display.
The relay is de-energized.	Verify input power and fuse continuity.
The relay does not accurately measure voltages or currents.	
Wiring error	Verify input wiring.
Incorrect CTR1, CTR2, CTRN, or PTR setting	Verify instrument transformer ratios, connections, and associated settings.
Voltage neutral terminal (N) is not properly grounded.	Verify wiring and connections.
The relay does not respond to commands from a device connected to the serial port.	
Cable is not connected.	Verify the cable connections.
Cable is not the correct type.	Verify the cable pinout.
The relay or device is at an incorrect bps rate or has another parameter mismatch.	Verify device software setup.
The relay serial port has received an XOFF, halting communications.	Type **<Ctrl+Q>** to send the relay XON and restart communications.
The relay does not respond to faults.	
The relay is improperly set.	Verify the relay settings.
Improper test source settings	Verify the test source settings.
Current or voltage input wiring error	Verify input wiring.
Failed relay self-test	Use the front-panel RELAY STATUS function to view self-test results.

Technical Support

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

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SEL-787 Relay Commissioning Test Worksheet

System Information

System Settings

RID (Relay identification) =	
TID (Terminal identification) =	
MVA (Maximum transformer rating) =	

	Winding 1	Winding 2
Current transformer connection:	W1CT =	W2CT =
Current transformer ratio:	CTR1 =	CTR2 =
Connection compensation:	W1CTC =	W2CTC =
Nominal line-to-line voltage (kV):	VWDG1 =	VWDG2 =
TAP calculation:	TAP1 =	TAP2 =

Differential Settings

087P =	SLP1 =	SLP2 =	IRS1 =	U87P =

Metered Load (Data taken from substation panel meters, not the SEL-787)

± Readings from meters	Winding 1	Winding 2
Megawatts:	MW1 =	MW2 =
Megavars:	MVAR1 =	MVAR2 =
MVA calculation:	MVA1 =	MVA2 =

MVA calculation:

$$MVAn = \sqrt{MWn^2 + MVARn^2}$$

Calculated Relay Load

	Winding 1	Winding 2
Primary Amperes calculation:	I1pri =	I2pri =
Secondary Amperes calculation:	I1sec =	I2sec =

Primary Amperes calculation:

$$Inpri = \frac{MVAn \bullet 1000}{\sqrt{3} \bullet VWDGn}$$

Secondary Amperes calculation:

$$WnCT = Y, In\ sec = \frac{Inpri}{CTRn}$$

$$WnCT = D, In\ sec = \frac{Inpri \bullet \sqrt{3}}{CTRn}$$

Settings Check

The following check assures zero-sequence current filtering is applied to all necessary transformer windings.

It is essential to use a non-zero Winding CT Connection Compensation (W*n*CTC) setting for all grounded-WYE connected transformer windings with WYE connected CTs.

Verify that no grounded-WYE transformer windings with WYE connected CTs has setting W*n*CTC = 0. Refer to *Appendix L: Protection Application Examples* for the guidelines in determining correct compensation settings.

Note the following commissioning checks will not detect the failure to properly filter zero-sequence current. Failure to adhere to this check will result in a differential operation for external faults involving ground.

Proper zero-sequence filtering verified?

____

Connection Check

System load conditions should be higher than 0.1 A secondary. 0.5 A secondary is recommended for the best results.

Differential Connection (issue MET DIF <Enter> to serial port or front panel)

Operate Current:	IOP1 = ________	IOP2 = ________	IOP3 = ________
Restraint Current:	IRT1 = ________	IRT2 = ________	IRT3 = ________
Mismatch Calculation:	MM1 =	MM2 =	MM3 =

Check individual current magnitudes, phase angles, and operate and restraint currents in an event report if mismatch is not less than 0.10.

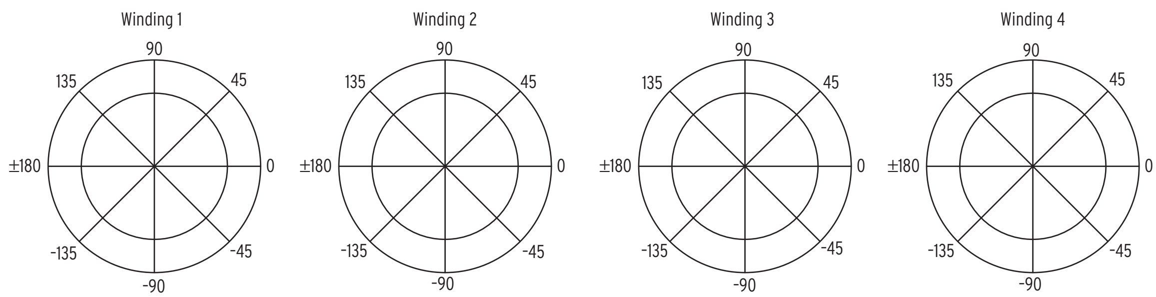
Mismatch Calculation:

$$\mathrm{MMn} = \frac{\mathrm{IOPn}}{\mathrm{IRTn}}$$

Magnitude, Angle, and Phase Rotation Check

Issue **MET <Enter>** to the serial port or front panel. If wye-connected CTs are used, then magnitudes of the currents in the MET response correspond to secondary currents seen by the relay multiplied with the corresponding CT ratio. The angles of the currents in the MET response correspond to the angles of secondary currents as seen by the relay. Refer to the *Delta-Connected CTs* for information on how the currents are reported when delta-connected CTs are used. Under balanced load conditions, the secondary amperes can be calculated by dividing the primary amperes in the MET report with the corresponding CT ratio. The secondary angles are the same as the primary angles in the MET report.

	Winding 1	Winding 2
A-Phase Secondary Amperes:	IAW1 = ________	IAW2 = ________
A-Phase Angle:	________	________
B-Phase Secondary Amperes:	IBW1 = ________	IBW2 = ________
B-Phase Angle:	________	________
C-Phase Secondary Amperes:	ICW1 = ________	ICW2 = ________
C-Phase Angle:		



1. Calculated relay amperes match MET amperes?

2. Phase rotation is as expected for each winding?

3. Do angular relationships among windings correspond to expected results? (Remember that secondary current values for load current flowing out of a winding will be 180° out-of-phase with the reference phase position for that winding in the case of standard CT connections. Refer to *Figure L.11* for an example of standard CT connections.)

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Appendix A
Firmware, ICD, and Manual Versions

Firmware

Determining the Firmware Version

To determine the firmware version, view the status report by using the serial port **STATUS** command or the front panel. The status report displays the firmware identification (FID) string.

The firmware version will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device FID string.

Existing firmware:

FID=SEL-787-**R100**-V0-Z001001-D*xxxxxxxx*

Standard release firmware:

FID=SEL-787-**R101**-V0-Z001001-D*xxxxxxxx*

A point release is identified by a change in the V-number of the device FID string.

Existing firmware:

FID=SEL-787-R100-**V0**-Z001001-D*xxxxxxxx*

Point release firmware:

FID=SEL-787-R100-**V1**-Z001001-D*xxxxxxxx*

The release date is after the D. For example, the following is firmware revision number R100, release date April 7, 2008.

FID=SEL-787-R100-V0-Z001001-**D20080407**

Table A.1 and *Table A.2* list the firmware versions, a description of the modifications, and the instruction manual date code that corresponds to the firmware version. The most recent firmware version is listed first.

Table A.1 200 Series Firmware Revision History (Sheet 1 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-R210-V0-Z004001-D20190508	➤ Added the enable port setting EPORT to each communications port to enhance port security. ➤ Addressed an issue in relays with firmware versions R203-V0 to R209-V0 and a 4 analog input (AI)/4 analog output (AO) card. When any analog input warning Relay Word bit asserted, it caused the relay to incorrectly assert the per-phase Level 1 instantaneous overcurrent element for Winding 1 (50P11*x*P).	20190508

Table A.1 200 Series Firmware Revision History (Sheet 2 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Resolved an issue with the small signal cutoff for metering magnitudes and angles. The cutoff was applied to the magnitudes, but was not applied to the angles. ➤ Resolved an issue in which the relay accepted and used the user-entered TAP*n* settings when the MVA setting was not set equal to OFF. ➤ Resolved an issue in which dual Ethernet model relays became unresponsive if the NETPORT setting was set to D. This issue affects firmware versions R208-V0 to R209-V0. ➤ Modified the General Purpose Serial Bus (GPSB) diagnostics logic to show a failure only if the GPSB diagnostics fail three consecutive times within a 24-hour period. ➤ Resolved an issue in which the relay continued to send Fast Sequential Events Recorder (SER) data to the real-time automation controller (RTAC) after the relay acknowledged an RTAC disable command. ➤ Improved the security of the resistance temperature detector (RTD) FAULT, ALARM, and TRIP indicators by adding an approximately 12-second delay to filter RTD measurements distorted by electrical noise. ➤ Addressed an issue with event type mismatch between the CHI and CEV commands that resulted in RTACs being unable to collect events with event type strings longer than 14 characters.	
SEL-787-R209-V0-Z003001-D20140714	➤ Revised the firmware to allow anonymous TCP connection from DNP masters when DNPIP*x* is set to 0.0.0.0. ➤ Added Y-MODEM over Telnet to support file transfer. ➤ Resolved an issue with port timeout when accessing SEL Fast Protocol data over Telnet. In all previous firmware revisions that supported Telnet, it was necessary to send ASCII characters regularly to keep the connection alive. ➤ Modified the default data set and report names in the IEC 61850 CID file. Added additional Logical Nodes for Local Bits and MIRRORED BITS status. ➤ Changed the storage of latch and local bits from volatile to nonvolatile memory. ➤ Revised the firmware for Trip Logic such that RSTTRGT is processed on the rising edge. ➤ Modified Real Time Clock (RTC) diagnostics logic to show a warning only if the RTC diagnostics fail three consecutive times. The self-test check is done every six hours to test the communications and the clock, including the end-of-the-year roll over capability. ➤ Addressed an issue with validating the IPADDR, SUBNETM, DEFRTR, and other IP addresses and port number settings of enabled protocols. ➤ Added a feature for Event Data registers in Modbus to always show the latest event data unless a specific event is selected by the event selection register. ➤ Improved the security of RTD ALARM and TRIP by adding an approximately six second delay to qualify the event. ➤ Resolved an issue with the DNP Binary Outputs so that they are no longer reported as OFFLINE when the Binary Output is also present in the Binary Input map and the Sequential Events Recorder (SER). ➤ Resolved an issue where the front panel showed a blank page after resetting a TRIP message.	20140714

Table A.1 200 Series Firmware Revision History (Sheet 3 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Modified the firmware to make the MATHERR Relay Word bit visible. ➤ Improved the frequency measurement and frequency element accuracy to ±0.01 Hz resolution. ➤ Implemented a firmware enhancement to preserve an existing IEC 61850 CID file while upgrading from a previous firmware version. ➤ Revised the REF element logic to improve the sensitivity for applications with different neutral and phase CT ratings. ➤ Added Flash File System support to make settings and other miscellaneous nonvolatile data storage more robust and avoid the display of NON-VOL FAIL messages. ➤ For relays configured with delta-connected CTs, resolved an issue in R207 and R208 firmware versions where power calculations in the MET report were incorrectly scaled down by $\sqrt{3}$. Protection elements were not affected by this issue. ➤ For relays configured with delta-connected CTs, resolved an issue where synchrophasor current magnitude calculations in the MET PM report were incorrectly scaled up by $\sqrt{3}$. Protection elements were not affected by this issue. ➤ For relays configured with delta-connected CTs, resolved an issue in R207 and R208 firmware versions where current harmonic calculations in the MET H report were incorrectly scaled down by $\sqrt{3}$. Protection elements were not affected by this issue. ➤ For relays configured with delta-connected CTs, resolved an issue where Through Fault (TFE) accumulated current calculations in the TFE report were incorrectly scaled up by $\sqrt{3}$. ➤ Resolved an issue that was causing small jumps in the angle calculations for analog quantities. ➤ Revised the firmware to support front-panel HMI part replacement. The function of the HMI has not changed. ➤ Resolved an issue with the settings change STSET being reported as OFFLINE via DNP. ➤ Resolved an issue with the data type "Units_0" in the IEC 61850 ICD file by changing the unit data type name to SIUnit. ➤ Resolved an initialization issue with the V/Hz (24) element after changing DELTA_Y and 24WDG settings. The element was always initialized and functioned correctly if the settings were changed from the default (DELTA_Y := DELTA and 24WDG := WYE) to any other setting combination. The element was not initialized correctly if the user started with settings DELTA_Y := WYE and 24WDG := WYE and changed to other combinations. The element was initialized correctly for any setting combination if the relay was restarted after a settings change. ➤ Resolved an issue with the V/Hz element for the settings combination DELTA_Y := DELTA and SINGLEV := Y. With this settings combination, the V/Hz did not function and the MET report showed zero for V/Hz. Firmware version R209 is for upgrading relays with R200–R208.	
SEL-787-R208-V0-Z003001-D20130426	➤ Forced RTS to high and ignored CTS when PREDLY setting is OFF to power certain fiber-optic transceivers. ➤ Corrected an Ethernet Failover Switching issue for dual Ethernet models. ➤ Corrected an issue where old packets were returned on new connections when polling Modbus at high speed.	20130426

Table A.1 200 Series Firmware Revision History (Sheet 4 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Corrected an issue with the initial Gratuitous ARP request not being sent for as long as five minutes after startup. ➤ Corrected an issue that caused port settings to not be accepted when relay settings were downloaded using ACSELERATOR QuickSet SEL-5030 Software. ACSELERATOR QuickSet reported with a message that settings files were not received. Firmware version R208 is for upgrading relays with R200–R207.	
SEL-787-R207-V0-Z003001-D20111107	➤ Enhanced firmware to make serial number visible to IEC 61850 protocol and also revised the ICD file to add serial and part number information to PhyNam DO similar to the SEL-400 series relays. ➤ Corrected an issue with the rms meter values, where in some cases the values would spike for a short time. ➤ Corrected primary current magnitude calculation for delta-connected CTs by dividing by square root of 3 factor in the meter and event report delta current quantities. ➤ Revised units for MIRRORED BITS protocol setting CBADPU to ppm (parts per million).	20111107
SEL-787-R206-V0-Z003001-D20110610	➤ Added support for Simple Network Time Protocol (SNTP) to Ethernet port (Port 1) including new settings. ➤ Added new settings for time and date management. (including daylight-saving time) under Global Settings. ➤ Corrected issue with reading Communications Counter registers (Registers 1126–1135) using the user map. ➤ Corrected DNP issue so that it allows reading delta voltages quantities even when DELTA_WYE setting is WYE. ➤ Added a squelch threshold for very low-level secondary voltages (below 0.3 V) and currents (below 3% of INOM) in the rms metering quantities command response. ➤ Corrected IEC 61850 KEMA compliance issue (Sisco library). ➤ Revised default value for IRS1 setting (Differential element) from 3.0 to 6.0. ➤ Corrected the issue of SALARM not asserting for a settings group change.	20110610
SEL-787-R205-V0-Z002001-D20110201	➤ Corrected issue with Inverse Time Overcurrent elements (did not accumulate time correctly for FNOM = 50 Hz nominal frequency). ➤ Updated firmware revision history for version R204 to show the implementation of improved diagnostics and actions in the relay self-tests.	20110201
SEL-787-R204-V0-Z002001-D20101115	➤ Corrected **LDP** command issue (relay lockup if data exceeds a threshold) in R200-203 firmware. ➤ Added a squelch threshold for very low-level secondary voltages (below 0.1 V) and currents (below 1% of INOM) in the metering quantities command response. ➤ Added calculated phase-to-phase voltages for wye-connected PTs to the analog quantities to allow selection for display points. ➤ Implemented improved diagnostics and actions in the relay self-tests. For certain failures, the relay will automatically restart as many as three times. ➤ Corrected issue with Inverse Time Overcurrent elements (did not accumulate time correctly at off-nominal frequency).	20101115

Table A.1 200 Series Firmware Revision History (Sheet 5 of 5)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-R203-V0-Z002001-D20100730	➤ Added new Winding 1 and Winding 2, level 1, Phase A, Phase B and Phase C instantaneous overcurrent elements. ➤ Added new Winding 1 and Winding 2 Phase A, Phase B and Phase C time-overcurrent elements. ➤ Updated the error messages for setting interdependency checks to match the global setting AOx0yH. ➤ Extended the CT ratio setting range to 1:10000 for 5 A CTs and 1:50000 for 1 A CTs. ➤ Enhanced REF element logic by adding 52A interlock (new setting REF52BYP). ➤ Added capability to support two Modbus TCP sessions with timeout settings on the Ethernet port. ➤ Added Select Before Operate control (SBO) to the IEC 61850 protocol. ➤ Added Access Control setting BLOCK MODBUS SET (BLKMBSET) to be able to block settings changes from a remote Modbus or DeviceNet master. ➤ Added new I/O card option of 4 DI/3 DO, which has one Form-B and two Form-C outputs. ➤ Corrected relay status reporting via Modbus when relay is disabled. ➤ Updated Ethernet port settings IPADDR, SUBNETM, and DEFRTR validation to allow addresses in the private address space. ➤ Added FASTOP setting to Port 1 (Ethernet) settings to allow breaker control using Fast Operate. ➤ Added IRIG-B input capability to fiber-optic serial Port 2 option including a new Time-Synchronization Source setting TIME_SRC. ➤ Added front-panel setting FP_AUTO to allow choice between OVERRIDE and ROTATING display messages.	20100730
SEL-787-R202-V0-Z001001-D20100215	➤ Factory calibration improvements. Only R200–R201 can be upgraded to R202 firmware.	20100215
SEL-787-R201-V0-Z001001-D20100118	➤ Corrected an occasional IEC 61850 communications defect where the firmware incorrectly reads an opcode from Flash memory and results in a vector.	20100118
SEL-787-R200-V0-Z001001-D20091015	➤ Revised firmware for processor update. Previous versions cannot be upgraded to R200. ➤ Extended event report storage capability to at least seventy-seven 15-cycle or nineteen 64-cycle event reports.	20091015

Table A.2 100 Series Firmware Revision History (Sheet 1 of 4)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-R110-V1-Z002001-D20190508	➤ Addressed an issue in relays with firmware versions R203-V0 to R209-V0 and a 4 analog input (AI)/4 analog output (AO) card. When any analog input warning Relay Word bit asserted, it caused the relay to incorrectly assert the per-phase Level 1 instantaneous overcurrent element for Winding 1 (50P11*x*P).	20190508
SEL-787-R110-V0-Z002001-D20140714	➤ For relays configured with delta-connected CTs, resolved an issue in R107–R109 firmware versions where power calculations in the MET report were incorrectly scaled down by $\sqrt{3}$. Protection elements were not affected by this issue. ➤ Revised the firmware for Trip Logic such that RSTTRGT is processed on the rising edge.	20140714

Table A.2 100 Series Firmware Revision History (Sheet 2 of 4)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
	➤ Revised the REF element logic to improve the sensitivity for applications with different neutral and phase CT ratings. ➤ Modified the firmware to make the MATHERR Relay Word bit visible. ➤ Resolved an issue where the front panel showed a blank page after resetting a TRIP message. ➤ Added a feature for Event Data registers in Modbus to always show the latest event data unless a specific event is selected by the event selection register. ➤ For relays configured with delta-connected CTs, resolved an issue in R107–R109 firmware versions where current harmonic calculations in the MET H report were incorrectly scaled down by $\sqrt{3}$. Protection elements were not affected by this issue. ➤ For relays configured with delta-connected CTs, resolved an issue where Through Fault (TFE) accumulated current calculations in the TFE report were incorrectly scaled up by $\sqrt{3}$. ➤ Resolved an initialization issue with the V/Hz (24) element after changing DELTA_Y and 24WDG settings. The element was always initialized and functioned correctly if the settings were changed from the default (DELTA_Y := DELTA and 24WDG := WYE) to any other setting combination. The element was not initialized correctly if the user started with settings DELTA_Y := WYE and 24WDG := WYE and changed to other combinations. The element was initialized correctly for any setting combination if the relay was restarted after a settings change. ➤ Resolved an issue with the V/Hz element for the settings combination DELTA_Y := DELTA and SINGLEV := Y. With this settings combination, the V/Hz did not function and the MET report showed zero for V/Hz. Firmware version R110 is for upgrading relays with R100–R109.	
SEL-787-R109-V0-Z002001-D20130426	➤ Forced RTS to high and ignored CTS when PREDLY setting is OFF to power certain fiber-optic transceivers. ➤ Corrected an Ethernet Failover Switching issue for dual Ethernet models. ➤ Corrected an issue where old packets were returned on new connections when polling Modbus at high speed. ➤ Corrected an issue with the initial Gratuitous ARP request not being sent for as long as five minutes after startup. ➤ Corrected an issue of missing SER records upon warm start. ➤ Corrected an issue that caused port settings to be rejected when relay settings were downloaded using ACSELERATOR QuickSet SEL-5030 Software. ACSELERATOR QuickSet reported with a message that settings files were not received. Firmware version R109 is for upgrading relays with R100–R108.	20130426
SEL-787-R108-V0-Z002001-D20120921	➤ Corrected an issue with the STA command response in R107 firmware. The relay was displaying incorrect values for the internal power supply level on the main board. ➤ Corrected an I/O card issue in R107 firmware. Firmware was not allowing the relay to accept an I/O card in an empty slot. ➤ Corrected a GPSB failure issue in R107 firmware.	20120921

Table A.2 100 Series Firmware Revision History (Sheet 3 of 4)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-R107-V0-Z002001-D20111107	➤ Corrected an issue with the rms meter values, where in some cases the values would spike for a short time. ➤ Corrected primary current magnitude calculation for delta-connected CTs by dividing by square root of 3 factor in the meter and event report delta current quantities.	20111107
SEL-787-R106-V0-Z002001-D20110201	➤ Corrected issue with Inverse Time Overcurrent elements (did not accumulate time correctly for FNOM = 50 Hz nominal frequency).	20110201
SEL-787-R105-V0-Z002001-D20101115	➤ Added a squelch threshold for very low-level secondary voltages (below 0.1 V) and currents (below 1% of INOM) in the metering quantities command response. ➤ Added calculated phase-to-phase voltages for wye-connected PTs to the analog quantities to allow selection for display points. ➤ Corrected issue with Inverse Time Overcurrent elements (did not accumulate time correctly at off-nominal frequency).	20101115
SEL-787-R104-V0-Z002001-D20100730	➤ Added new Winding 1 and Winding 2, level 1, Phase A, Phase B and Phase C instantaneous overcurrent elements. ➤ Added new Winding 1 and Winding 2 Phase A, Phase B and Phase C Time-Overcurrent elements. ➤ Updated the error messages for setting interdependency checks to match the global setting AOx0yH. ➤ Extended CT ratio setting range to 1:10000 for 5 A CTs and 1:50000 for 1 A CTs. ➤ Enhanced REF element logic by adding 52A interlock (new setting REF52BYP). ➤ Added capability to support two Modbus TCP sessions with timeout settings on the Ethernet port. ➤ Added Select Before Operate control (SBO) to the IEC 61850 protocol. ➤ Added Access Control setting BLOCK MODBUS SET (BLKMBSET) to be able to block settings changes from a remote Modbus or DeviceNet master. ➤ Added new I/O card option of 4 DI/3 DO, which has one Form-B and two Form-C outputs. ➤ Corrected relay status reporting via Modbus when relay is disabled. ➤ Updated Ethernet port settings IPADDR, SUBNETM, and DEFRTR validation to allow addresses in the private address space. ➤ Added FASTOP setting to Port 1 (Ethernet) settings to allow breaker control using Fast Operate. ➤ Added IRIG-B input capability to fiber-optic serial Port 2 option including a new Time-Synchronization Source setting TIME_SRC. ➤ Added front-panel setting FP_AUTO to allow choice between OVERRIDE and ROTATING display messages.	20100730
SEL-787-R103-V0-Z001001-D20090420	➤ Improved harmonic measurement accuracy.	20090420
SEL-787-R102-V0-Z001001-D20090218	➤ Corrected Power Element issue in SEL-787E models when MIRRORED BITS protocol is selected. ➤ Enhanced IEC 61850 security. ➤ Updated Modbus Register Map: revised registers 276–280 to support addition of MVA SET ENABLE and registers 291–297 to support addition of fractional PT ratio.	20090218

Table A.2 100 Series Firmware Revision History (Sheet 4 of 4)

Firmware Identification (FID) String	Summary of Revisions	Manual Date Code
SEL-787-R101-V0-Z001001-D20081022	➤ Updated IEC 61850 firmware to enhance security, streamline MMS processing and improve TCP/IP. ➤ Improved security (see selinc.com/support/security-notifications/).	20081022
SEL-787-R100-V0-Z001001-D20080407	➤ Initial version.	20080407

DeviceNet and Firmware Versions

The firmware on the DeviceNet interface has two versions as listed in *Table A.3*. The version number of this firmware is only accessible via Device Net interface. SEL-787 needs DeviceNet firmware version 1.005.

Table A.3 DeviceNet Card Versions

DeviceNet Card Software Version	Revisions	Release Date
Major Rev: 1, Minor Rev: 1 (Rev 1.001)	Base version (card defines product code = 100, fixed descriptions for DeviceNet Card parameters, etc.)	20030612
Major Rev: 1, Minor Rev: 5 (Rev 1.005)	Reads product code, DeviceNet card parameter descriptions, etc., from the relay.	20080407

The Electronic Data Sheet (EDS) file is not updated every time a firmware release is made. A new EDS file is released only when there is a change in the Modbus/DeviceNet parameters. The EDS file and an ICON file for the SEL-787 are zipped together on the SEL-787 Product Literature CD (SEL-*xxx*R*xxx*.EXE). The file can also be downloaded from the SEL website at selinc.com. *Table A.4* lists the compatibility among the EDS files and the various firmware versions of the relay.

Table A.4 EDS File Compatibility

EDS File	Firmware Revisions Supported	Release Date
SEL-787R301.EDS	R206, R207, R208, R209, and 210 (with DeviceNet version 1.005)	20110610
SEL-787R201.EDS	R104, R105, R106, R107, R108, R109, R110, R203, R204, R205 (with DeviceNet version 1.005)	20100722
SEL-787R102.EDS	R102, R103, R200, R201, R202 (with DeviceNet version 1.005)	20090226
SEL-787R100.EDS	R100, R101 (with DeviceNet version 1.005)	20080506

ICD File

Determining the ICD File Version in Your Relay

NOTE: The Z number representation is implemented with ICD File Revision R303. Previous ICD File Revisions do not provide an informative Z number.

To find the ICD revision number in your relay, view the configVersion using the **ID** command. The configVersion is the last item displayed in the information returned from the **ID** command.

configVersion=ICD-787-R303-V0-Z209004-D20140303

The ICD revision number is after the R (e.g., 100) and the release date is after the D. This revision number is not related to the relay firmware revision number. The configVersion revision displays the ICD file version used to create the CID file that is loaded in the relay.

The configVersion contains other useful information. The Z number consists of six digits. The first three digits following the Z represent the minimum IED firmware required to be used with the ICD (e.g., 209). The second three digits represent the ICD ClassFileVersion (e.g., 004). The ClassFileVersion increments when there is a major addition or change to the 61850 implementation of the relay.

Table A.5 lists the ICD file versions, a description of modifications, and the instruction manual date code that corresponds to the versions. The most recent version is listed first.

Table A.5 SEL-787 ICD File Revision History (Sheet 1 of 2)

configVersion	Summary of Revision	Relay Firmware Compatibility	ClassFile Version	ACSELERATOR Architect		Manual Date Code
				File Description	Software Version	
ICD-787-R303-V0-Z209004-D20140303	➤ Updated configVersion for new format. ➤ Modified default MMS Report and Dataset names. ➤ Updated all Report Control attributes. ➤ Corrected Report Control rptID attributes to display report name instead of dataset name. ➤ Added new PROGGIO24, LBGGIO25, MBOKGGIO26, and MISCGGIO27 Logical Nodes and attributes to ANN LDevice. ➤ Modified data types for MaxA1, MaxA2, MinA1, MinA2, MaxA, MinA, MaxPhV, MinPhV, MaxP2PV, and MinP2PV attributes in METMSTA1 Logical Node. ➤ Modified data types for DmdA and PkDmdA attributes in METMDST1 Logical Node. ➤ Added new RMS1MMXU2, RMS2MMXU3, and METMHAI1 Logical Nodes and attributes to MET LDevice. ➤ Added new PROGGIO24, LBGGIO25, MBOKGGIO26, and MISCGGIO27 Logical Nodes and attributes to ANN LDevice.	R209 and higher	004[a]	787 R209 and above	1.1.145.0 and higher	20140714

Table A.5 SEL-787 ICD File Revision History (Sheet 2 of 2)

configVersion	Summary of Revision	Relay Firmware Compatibility	ClassFile Version	ACSELERATOR Architect		Manual Date Code
				File Description	Software Version	
	➤ Modified data types for MaxA1, MaxA2, MinA1, MinA2, MaxA, MinA, MaxPhV, MinPhV, MaxP2PV, and MinP2PV attributes in METMSTA1 Logical Node. ➤ Modified data types for DmdA and PkDmdA attributes in METMDST1 Logical Node.					
ICD-787-R302-V0-Z000000-D20120404	➤ Added Serial and Model Number attributes to PhyNam DO.	R207 and higher	004[a]	787 R207 and above	1.1.145.0 and higher	20111107
ICD-787-R300-V0-Z000000-D20110623	➤ Remove UTC offset attribute. ➤ Improved IEC 61850 conformance. ➤ Correct DmdVArh data source in METMDST1 Logical Node.	R206 and higher	004[a]	787 R206	1.1.115.0 and higher	20110610
ICD-787-R200-V0-Z000000-D20100716	➤ Added select before operate (SBO) and enhanced security SBO modes to 61850 MMS.	R104 and higher R203 and higher	003[b]	Enhanced Controls R104/ R203 and above	1.1.93.0 and higher	20100730
ICD-787-R100-V0-Z002001-D20080507	➤ Initial ICD File Release.	R100–R103 R200–R202	002		1.1.73.0 and higher	20080407

[a] ICD files with ClassFileVersion 004 require R2xx series firmware and do not work with R1xx firmware.
[b] ICD files with ClassFileVersion 003 can be used with R2xx series firmware with 61850 device library 004 also. Architect will convert the ICD file to ClassFileVersion 004 and send to the relay.

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date. *Table A.6* lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.6 Instruction Manual Revision History (Sheet 1 of 8)

Revision Date	Summary of Revisions
20200715	Preface ➤ Updated the product compliance label. Section 1 ➤ Updated *Compliance* in *Specifications*.

Table A.6 Instruction Manual Revision History (Sheet 2 of 8)

Revision Date	Summary of Revisions
20190508	Preface ➤ Updated *Manual Overview* for *Appendix L: Protection Application Examples*. ➤ Updated *General Safety Marks* and *Hazardous Locations Safety Marks*. ➤ Updated *Hazardous Locations Approvals*, including the product compliance label. ➤ Updated *Other Safety Marks*. ➤ Updated *Typographic Conventions*, *Trademarks*, *Product Labels*, *LED Emitter*, *Environmental Conditions and Voltage Information*, *Wire Sizes and Insulation*, and *Technical Support*. Section 1 ➤ Updated *Monitoring Features* for Load Profile Report. ➤ Updated *Options* for a note on the discontinuation of the DeviceNet option. ➤ Updated *Powering the Relay* for the power supplies. ➤ Updated *Compliance*, *General*, *Type Tests*, and *Relay Elements* in *Specifications*. ➤ Added *Product Standards* to *Specifications*. Section 2 ➤ Updated *Physical Location*. ➤ Updated *Figure 2.2: Slot Allocations for Different Cards*. ➤ Added a note to *Analog Input/Output Card (4 AI/4 AO)* on analog output isolation. ➤ Updated *Card Configuration Procedure*. ➤ Updated *Table 2.12: Jumper Functions and Default Positions*. ➤ Updated a note for *Figure 2.13: Control I/O Connections–Internal RTD Option* for the power supply rating. ➤ Updated *Table 2.13: Typical Maximum RTD Lead Length* and added RTD wiring recommendations to *RTD Wiring*. ➤ Added a note to *Fail-Safe/Nonfail-Safe Tripping* for fast hybrid contacts. ➤ Updated *Figure 2.16: Breaker Trip Coil Connection With OUT103FS := Y and OUT103FS := N*. ➤ Added *High-Speed, High-Current Interrupting DC Tripping Outputs*. ➤ Updated *Figure 2.19: Typical Current Connections* through *Figure 2.23: SEL-787 Provides Autotransformer Differential Protection, Including REF Protection*. Section 3 ➤ Updated *Table 3.1: SEL Software Solutions* and *Table 3.4: QuickSet Help*. Section 4 ➤ Updated *Figure 4.4: Differential Element Decision Logic*, *Figure 4.5: Differential Element Harmonic Blocking Logic*, and *Figure 4.12: Internal Fault With LV Breaker Open*. ➤ Updated *Harmonic Blocking*. ➤ Updated *Connection Compensation Settings*, including adding *Table 4.5: WnCTC Setting: Corresponding Phase and Direction of Correction*. ➤ Updated *Example of Setting the SEL-787 Relay* and *Setting Descriptions and Applications*. ➤ Updated *Restricted Earth Fault Element*. ➤ Added *REF Current Pickup Level*. ➤ Added a note on short/open RTD detection to *RTD Input Function*. ➤ Added a note for trip coil current interruption and updated *Figure 4.47: Trip Logic* for *Trip/Close Logic*. ➤ Updated *Table 4.27: Enable Settings* for a note regarding math variables set to NA. ➤ Added a note to *Counter Variables* regarding counter reset on power loss. ➤ Updated *Table 4.34: Control Output Equations and Contact Behavior Settings*. ➤ Added *Table 4:43: Data Reset Setting* to *Data Reset*. ➤ Updated *PORT F*, *Table 4.46: Front-Panel Serial Port Settings*; *PORT 1*, *Table 4.47: Ethernet Port Settings*; *PORT 2*, *Table 4.49: Fiber-Optic Serial Port Settings*; *PORT 3*, *Table 4.50: Rear-Panel Serial Port Settings*; *PORT 4*, *Table 4.51: Rear-Panel Serial Port (EIA-232/EIA-485) Settings*. ➤ Added *Port Number Settings Must be Unique*, including *Table 4.48: Port Number Settings That Must be Unique*. ➤ Updated *Table 4.61: Example Settings and Displays*. Settings Sheets ➤ Updated *SET PORT p (p = F, 1, 2, 3, or 4) Command* for port access enable commands. ➤ Updated *Table SET.1: Port Number Settings That Must be Unique*.

Table A.6 Instruction Manual Revision History (Sheet 3 of 8)

Revision Date	Summary of Revisions
	Section 7 ➤ Updated *Serial (EIA-232 and EIA-485) Port*. ➤ Updated *Table 7.22: L_D Command (Load Firmware)*. ➤ Updated *OPEN n Command (Open Breaker, where n = 1 or 2)* and *PING Command*. ➤ Updated *Table 7.39: STATUS Command Report and Definitions* for current and voltage offset message formats. Section 8 ➤ Updated *Figure 8.25: Operator Control Pushbuttons and LEDs*. Section 9 ➤ Updated *Event Reporting*. Section 10 ➤ Updated *Self-Test* for a note on access commands and SALARM. ➤ Updated *Table 10.8: Relay Self-Tests*. ➤ Added the *SEL-787 Relay Commissioning Test Worksheet*. Appendix A ➤ Updated *Table A.1: 200 Series Firmware Revision History* for revision R210 and *Table A.2: 100 Series Firmware Revision History* for revision R110-V1. ➤ Updated *Table A.4: EDS File Compatibility* for firmware revision R210. Appendix B ➤ Updated *Overview*, *Upgrade Firmware Using a Terminal Emulator*, and *Technical Support*. Appendix D ➤ Updated *DNP3 in the SEL-787*, including *Table D.5: Configuring DNP3 Access Methods*. ➤ Updated *Table D.10: DNP3 Reference Data Map* for HALARM. Appendix E ➤ Added a note on the concatenation of Modbus quantities to *Modbus Register Map*. ➤ Updated *Table E.34: Modbus Register Map*. Appendix F ➤ Updated *GOOSE Processing*. Appendix G ➤ Updated *DeviceNet Card* for a note on the discontinuation of the DeviceNet option. Appendix J ➤ Updated *Table J.2: Relay Word Bit Definitions for the SEL-787* for Relay Word bit RELAY_EN and WARNING. Appendix K ➤ Updated *Table K.1: Analog Quantities* for a note on assigning RTD analog quantities to SELOGIC or variables. Appendix L ➤ Added *Appendix L: Protection Applications Examples*. Command Summary ➤ Updated *PING x.x.x.x t*, *SER*, *TFE*, and *TIME hh* and *TIME hh:mm*.
20170815	Preface ➤ Updated *Safety Marks.* ➤ Updated *Hazardous Locations Approvals*. ➤ Updated the product labels and compliance label. ➤ Updated *Wire Sizes and Insulation*. Section 1 ➤ Updated *Compliance*. ➤ Updated *AC Current Input* under *General*. ➤ Added Relay Start-Up Time in *Power Supply.* ➤ Added Fuse Ratings in *Power Supply.* ➤ Updated *Output Contacts* under *General*. Section 2 ➤ Updated hazardous locations approvals in *Physical Location* under *Relay Placement*.

Table A.6 Instruction Manual Revision History (Sheet 4 of 8)

Revision Date	Summary of Revisions
	Section 4 Updated *SELogic Control Equation Operators* to clarify how the relay rounds decimals to integers when performing math operations.
20150130	Preface ➤ Added *Safety Information* and *General Information*. ➤ Updated the product labels and compliance label. Section 1 ➤ Changed the *Certifications* section title to *Compliance* and relocated the section to the beginning of the *Specifications*. ➤ Added the applied current at which the burden is measured for I_{NOM} = 1 A and 5 A in the *Specifications*. ➤ Updated the *Type Test* compliance specifications in the *Specifications* section. Section 2 ➤ Added a note on CT circuits to applicable current card descriptions. ➤ Updated the note for *Table 2.12: Jumper Functions and Default Positions*. Section 4 ➤ Updated text for *Selecting the Correct Values of WnCTC for Each Winding*, *Example 1 for WnCTC Selection*, and *Example 2 for WnCTC Selection*. ➤ Updated *Figure 4.8: Example 1 for WnCTC Selection* and *Figure 4.9: Example 2 for WnCTC Selection*. ➤ Added *Preferred Compensation Settings* section. ➤ Added frequency tracking description to the *Volts Per Hertz Elements* section. Section 7 ➤ Updated *PULSE Command* description and added breaker control jumper note. Section 10 ➤ Added a note on CT circuits. Appendix A ➤ Added *ICD File* section including *Table A.5: ICD File Revision History*. Appendix F ➤ Updated *acSELerator Architect* and *SEL ICD File Versions* section. Appendix I ➤ Updated the RBADPU setting prompt description in *Table I.5: Mirrored Bits Protocol Settings*. Appendix K ➤ Added a note to *Table K.1: Analog Quantities* for RTDAMB and RTDOTHMX analog quantities.
20140714	Section 1 ➤ Updated the ac current inputs under *AC Current Inputs* and the input voltage range under *Power Supply* in the *Specifications*. ➤ Added RTD Trip/Alarm Time Delay to the *RTD Protection* category of the *Specifications*. ➤ Updated the accuracy specifications. Section 2 ➤ Updated *Card Configuration Procedure*. ➤ Added a note stating that the fail-safe option should not be used for fast hybrid output contacts in fail-safe/nonfail-safe tripping. Section 4 ➤ Added a note to *RTD Trip/Warning Levels*. ➤ Updated *Figure 4.49: Trip Logic*. ➤ Updated the average number of latch bit state changes per day from 70 to 5000 in *Make Latch Control Switch Settings With Care*. ➤ Revised the text for *Restricted Earth Fault Element* and *Differential Element*. Section 5 ➤ Added a note to *RTD Trip/Warning Levels*. ➤ Updated the number of time-stamp entries that the relay memory can hold for load profiling. Section 10 ➤ Updated the text for SALARM in the ALARM Output bullet of *Self-Test*. ➤ Updated *Table 10.8: Relay Self-Tests*.

Table A.6 Instruction Manual Revision History (Sheet 5 of 8)

Revision Date	Summary of Revisions
	Appendix A ➤ Updated for firmware versions R110 and R209. Appendix B ➤ Added a note to save the calibration settings before the upgrade in *Upgrade Firmware Using a Terminal Emulator*. Appendix E ➤ Revised *Reading History Data Using Modbus*. Appendix F ➤ Updated *Figure F.1:* SEL-787 *Predefined Reports* and *Figure F.2:* SEL-787 *Datasets*. ➤ Revised *Table F.7: New Logical Node Extensions*, *Table F.8: Thermal Metering Data Logical Node Class Definition*, and *Table F.9: Demand Metering Statistics Logical Node Class Definition*. ➤ Added *Table F.10: Compatible Logical Nodes With Extensions* and *Table F.11: Metering Statistics Logical Node Class Definition*. ➤ Revised *Table F.12: Logical Device: PRO (Protection)*, *Table F.13: Logical Device: MET (Metering)*, *Table F.14: Logical Device: CON (Remote Control)*, and *Table F.15: Logical Device: ANN (Annunciation)*. ➤ Added *Table F.16: Logical Device: CFG (Configuration)*. Appendix J ➤ Updated the definition for the SALARM Relay Word bit. ➤ Added the MATHERR Relay Word bit to *Table J.1:* SEL-787 *Relay Word Bits* and *Table J.2: Relay Word Bit Definitions*.
20130426	Preface ➤ Updated the product and compliance labels for the SEL-787. Section 1 ➤ Added open state leakage current for *Fast Hybrid* contacts to the *Specifications*. ➤ Added current/voltage input terminal block information under *Terminal Connections* category of the *Specifications*. Section 2 ➤ Revised the *Table 2.12: Jumper Functions and Default Positions* footnote to clarify the impact of the jumper position on breaker control. ➤ Added a note to *Figure 2.17: Voltage Connections*. Section 4 ➤ Added a note for display points stating that they are updated approximately every two seconds. ➤ Corrected *Table 4.54: Entries for the Four Strings* for set and clear strings. ➤ Revised *Figure 4.3: Differential Element (87-1) Quantities* to include the fifth-harmonic quantities. ➤ Revised *Figure 4.12: REF Protection Output (Extremely Inverse-Time O/C)* to show IN1PU. Section 7 ➤ Updated the *Fiber-Optic Serial Port* paragraph. ➤ Updated the +5 Vdc availability statement in *+5 Vdc Power Supply*. Appendix A ➤ Updated for firmware versions R208 and R109. Appendix E ➤ Added BLOCK MODBUS SET setting paragraph. Appendix G ➤ Added BLOCK MODBUS SET setting paragraph.
20120921	Appendix A ➤ Updated for firmware version R108.
20120903	Preface ➤ Updated product label examples in *Product Labels*. Section 1 ➤ Updated *Specifications*.

Table A.6 Instruction Manual Revision History (Sheet 6 of 8)

Revision Date	Summary of Revisions
20111107	Section 1 ➤ Added *Compression Plug Mounting Ear Screw Tightening Torque* specification. Section 5 ➤ Revised paragraph on small signal cutoff limits for MET and MET RMS values. ➤ Added note to MET response regarding delta-connected CTs and their impact on metered values. Settings Sheets ➤ Revised MIRRORED BITS setting CBADPU units to ppm (parts per million). Section 9 ➤ Added a note for the impact of delta-connected CTs on event report current quantities. Appendix A ➤ Updated for firmware versions R107 and R207. Appendix B ➤ Added note regarding saving data including events before firmware upgrade. Appendix J ➤ Updated with Relay Word Bits TSNTPP and TSNTPB.
20110610	Section 1 ➤ Added *SNTP Accuracy* specification. Section 2 ➤ Added *Power Supply Card* description and terminal designations. Section 4 ➤ Added *Time and Date Management* subsection. ➤ Added *SNTP Protocol* cross-reference to *Section 7: Communications*. Section 6 ➤ Updated Settings sheets for the new settings. Section 7 ➤ Added *SNTP Protocol* subsection. Appendix A ➤ Updated for firmware version R206. Appendix E Updated *Table E.32: Modbus Register Map* for new settings. Appendix J ➤ Updated for new Relay Word bits.
20110201	Section 10 ➤ Updated *Self-Test* descriptions to reflect the improvements (including automatic restarts in some cases) implemented in firmware version R204. Appendix A ➤ Updated for firmware versions R106 and R205. ➤ Addendum to R204 for the self-test firmware improvements.
20101217	Section 1 ➤ Revised Analog Output (1AO) accuracy specification to < ±1%, full scale, at 25°C in *Specifications*. ➤ Updated Dielectric (HiPot) type tests in *Specifications*.
20101115	Preface ➤ Updated product compliance label. Section 1 ➤ Updated *Specifications* for UL508 certification. Section 5 ➤ Added paragraph on *Small Signal Cutoff for Metering* in *Metering* subsection.

Table A.6 Instruction Manual Revision History (Sheet 7 of 8)

Revision Date	Summary of Revisions
	Section 8 ➤ Revised paragraph describing settings T0*n*_LED and T0*n*LEDL. Appendix A ➤ Updated for firmware versions R105 and R204.
2010730	Section 1 ➤ Updated *Analog Inputs* accuracy specifications and *Type Tests* descriptive data. Clarified fiber-optic port as ST and SEL-2812 compatible throughout sections. Section 2 ➤ Added SELECT 4DI/3 DO (2 Form C, 1 Form B) card information. Added note that digital inputs and outputs are polarity neutral. Section 4 ➤ Extended CT ratio setting range. ➤ Added 52A interlock setting to REF element. ➤ Added Level 1 individual phase overcurrent elements to *Figure 4.14: Instantaneous Overcurrent Element Logic*. ➤ Added individual phase time-overcurrent elements description and diagram. ➤ Added a description of the new Access Control setting BLOCK MODBUS SET (BLKMBSET), which blocks settings changes from remote Modbus or DeviceNet masters. ➤ Added *Time-Synchronization Source* setting description. ➤ Revised *Figure 4.40: Loss-of- Potential (LOP) Logic*. ➤ Added two Modbus sessions capability and timeout settings for the Ethernet port. Section 5 ➤ Added note for the energy meter rollover value. Settings Sheets ➤ Updated the settings sheets with settings added in *Section 4*. Section 7 ➤ Added CAL level access and password information. Section 8 ➤ Added note for the target LEDs latching with trip. Appendix A ➤ Updated for firmware versions R104 and R203. Appendix D Updated for DNP conformance requirements. Appendix F Updated for Select Before Operate (SBO) changes. Appendix J ➤ Added new Relay Word bits for phase overcurrent and phase time-overcurrent elements. Command Summary Added CAL level commands.
20100215	Appendix A ➤ Updated for firmware version R202.
20100118	Appendix A ➤ Updated for firmware version R201.
20091015	Section 1 ➤ Updated CT ratings and voltage element and metering accuracy specifications. Updated *Figure 1.2: STA Command Response—No Communications Card or EIA-232/EIA-485 Communications Card* and *Figure 1.3: STA Command Response—Communications Card/DeviceNet Protocol*. Section 2 ➤ Updated *Figure 2.7: Pins for Password Jumper, Breaker Control Jumper, and SELBOOT Jumper* to show jumper locations on updated processor card.

Table A.6 Instruction Manual Revision History (Sheet 8 of 8)

Revision Date	Summary of Revisions
	Section 4 ➤ Updated number of event reports that can be stored. ➤ Revised *Figure 4.40: Loss-of- Potential (LOP) Logic*. Section 10 ➤ Updated *Table 10.8: Relay Self-Tests* to show additional voltage checks on updated processor card. Appendix A ➤ Updated for firmware version R200.
20090420	Section 4 ➤ Corrected equation error in *Figure 4.35: Volts/Hertz Inverse-Time Characteristic, 24IC = 1* and *Figure 4.36: Volts/Hertz Inverse-Time Characteristic, 24IC = 2*. Appendix A ➤ Updated for firmware version R103. Appendix D ➤ Added information regarding default scaling and deadbands for analog quantities angles.
20090218	Section 1 ➤ Added fiber-optic port specifications, and revised 51 element response time specifications. Section 2 ➤ Revised *Figure 2.1: Relay Panel-Mount Dimensions*. ➤ Revised *Figure 2.7: Pins for Password Jumper, Breaker Control, and SELBOOT Jumper* and associated text to clarify breaker control jumper selection. Section 4 ➤ Revised *Figure 4.1: Percentage Restraint Differential Characteristic* (scaling issue). ➤ Clarified differential element IRT differences between the SEL-787 and SEL-587/SEL-387 and added differential element settings differences between the SEL-787 and SEL-587/SEL-387. Section 7 ➤ Added Ethernet network configurations figures and IRIG-connection diagrams. Section 10 ➤ Revised P, Q values in *Table 10.5: Power Quantity Accuracy-Wye Voltages*. Appendix A ➤ Updated for firmware version R102. Appendix I ➤ Corrected row numbers in *Table I.2: Positions of the MIRRORED BITS* and *Table I.3: MIRRORED BITS Values for a RXDFLT Setting of 10100111*.
20081022	Appendix A ➤ Updated for firmware version R101.
20080407	➤ Initial version.

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Appendix B
Firmware Upgrade Instructions

Overview

This instruction guides you through the process of upgrading firmware in the device. The firmware upgrade will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device firmware identification (FID) string).

Existing firmware:

FID=SEL-787-**R100**-V0-Z001001-D*xxxxxxxx*

Standard release firmware:

FID=SEL-787-**R101**-V0-Z001001-D*xxxxxxxx*

A point release is identified by a change in the V-number of the device FID string.

Existing firmware:

FID=SEL-787-R100-**V0**-Z001001-D*xxxxxxxx*

Standard release firmware:

FID=SEL-787-R100-**V1**-Z001001-D*xxxxxxxx*

These firmware upgrade instructions apply to all SEL-700 series industrial products except the SEL-701 Relay and SEL-734 Meter.

SEL occasionally offers firmware upgrades to improve the performance of your relay. Because the SEL-787 stores firmware in flash memory, changing physical components is not necessary. Upgrade the relay firmware by downloading a file from a personal computer to the relay via the front-panel serial port via ACSELERATOR QuickSet SEL-5030 Software or terminal emulator as outlined in the following sections. For relays with IEC 61850 option, verify IEC 61850 protocol after the upgrade (see Protocol Verification *for Relays With IEC 61850 Option*).

Required Equipment

Gather the following equipment before starting this firmware upgrade:

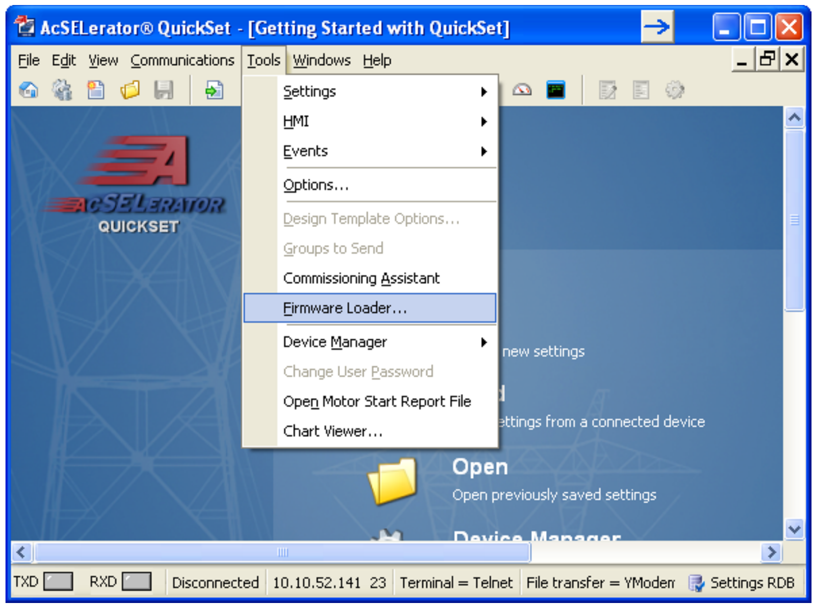
- ➤ Personal computer (PC)
- ➤ Terminal emulation software that supports Xmodem/CRC or 1k Xmodem/CRC protocol
- ➤ Serial communications cable (SEL-C234A Cable or equivalent, or a null-modem cable)

NOTE: Firmware releases are also available as zip files (.z19). Use the zip file for faster download.

- Disk containing the firmware upgrade file (for example, r1017*xx*.s19 or r1017*xx*.z19)
- QuickSet software

Upgrade Firmware Using QuickSet

Select **Tools** > **Firmware Loader** from the QuickSet menu bar to launch a wizard that walks you through the steps to load firmware into your SEL device. Refer to *Section 3: PC Software* for setup and connection procedures for QuickSet.

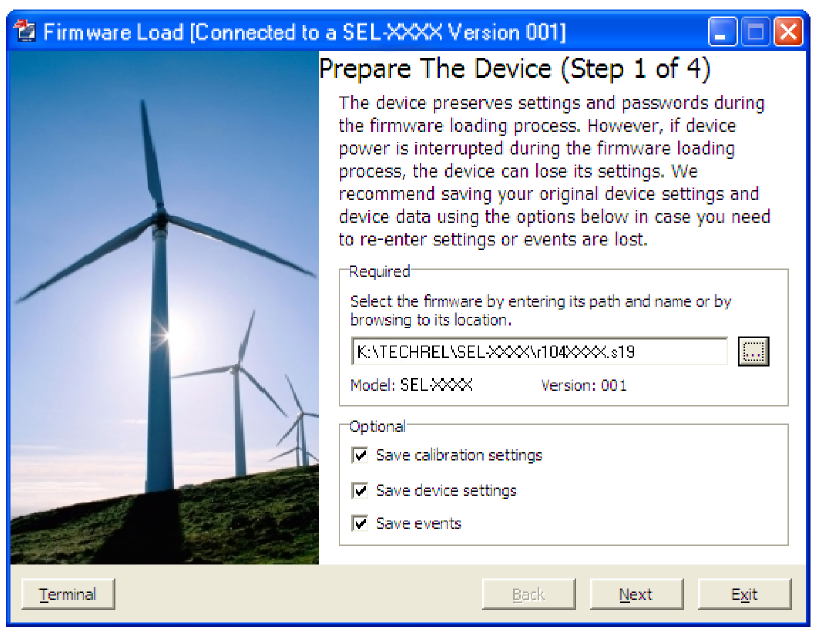


Firmware Loader will not start if:

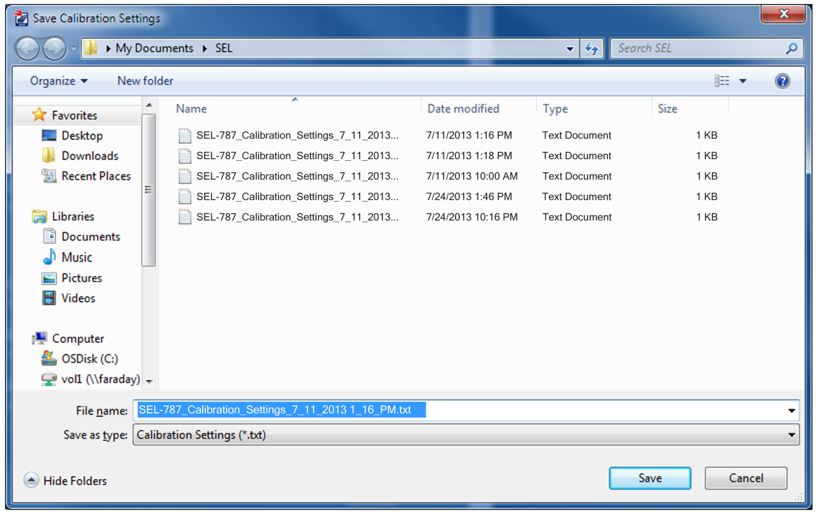
- The device is unsupported by QuickSet.
- The device is not connected to the computer with a communications cable.
- The device is disabled.

Step 1. Prepare the device.

a. Select the firmware to be loaded using the browse control and select **Save calibration settings**, **Save device settings**, and **Save events**. Select **Next** to continue the wizard.

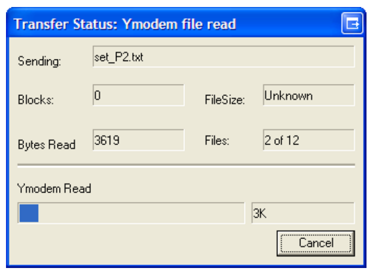


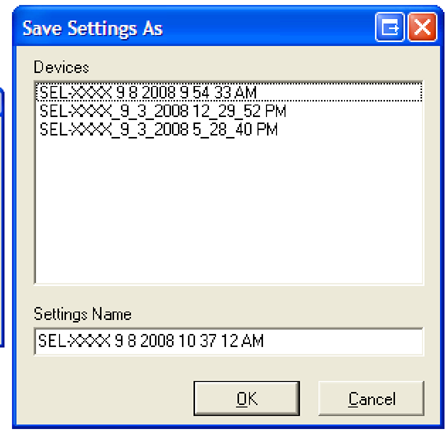
b. Select a file name to save the selected settings or accept the defaults as shown. Click **Save**.



c. The **Transfer Status**: **Ymodem file read** window shows the transfer progress of the settings file. Clicking **Cancel** will stop the transfer.

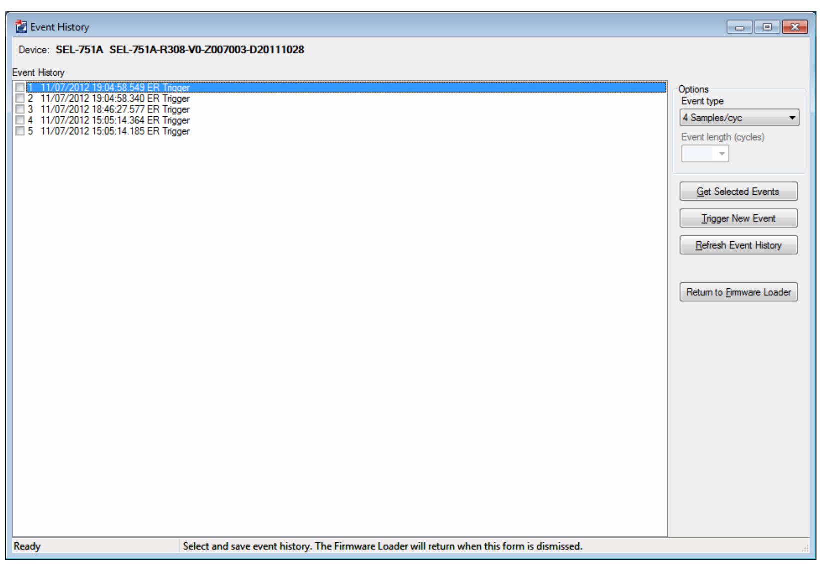
After the device settings are downloaded, select a file name and path to save the settings or accept the default, as shown.





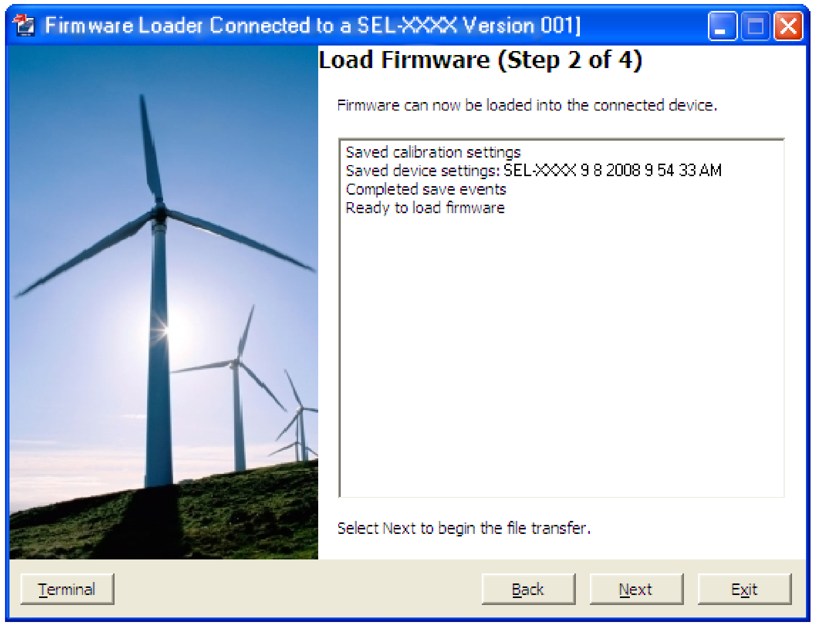
d. Click **Return to Firmware Loader** if this product does not have any event reports.

If there are any event reports to be saved, click the **Get Selected Event** button after selecting the events. After saving them, click the **Return to Firmware Loader** button.



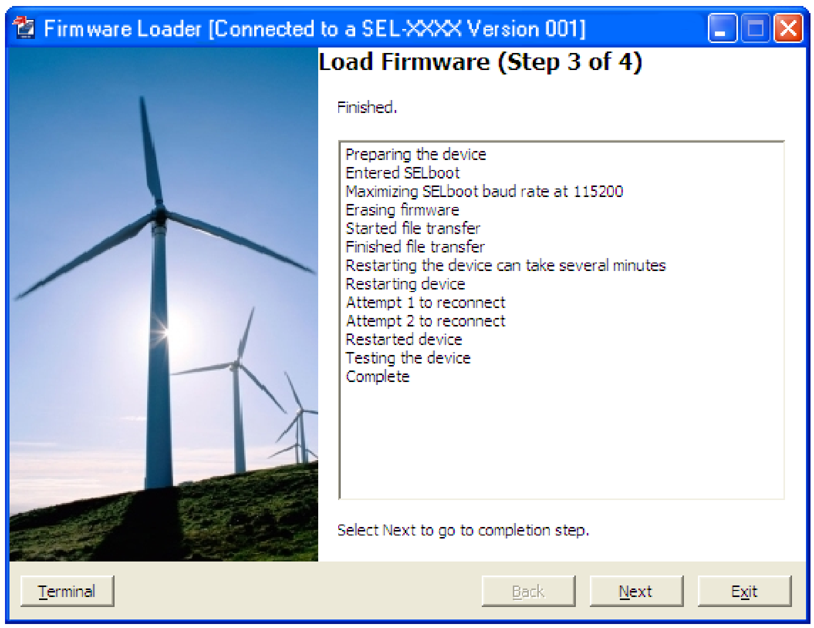
Step 2. Transfer firmware.

Click **Next** to begin the firmware transfer.

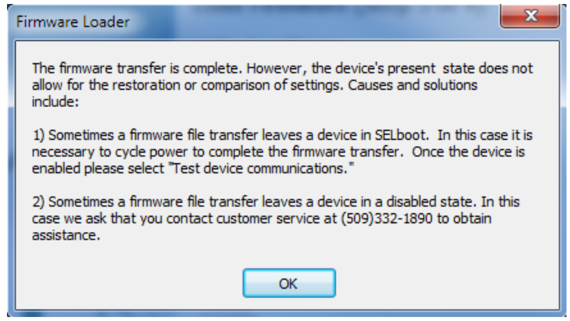


Step 3. Load firmware.

During this step, the device is put in SELBOOT. The transfer speed is maximized and the firmware transfer begins.



NOTE: The following screen can appear if you have one of the two conditions mentioned.



If the relay is disabled as mentioned in condition number 2, check for the **ENABLED** LED on the front panel of the relay. If the **ENABLED** LED is not illuminated or the front panel displays `STATUS FAIL Non_Vol Failure`, use the following procedure to restore the factory-default settings:

a. Click on the Terminal button on the Firmware Load screen of QuickSet.

b. Set the communications software settings to 9600 bps, 8 data bits, and 1 stop bit.

c. Enter Access Level 2 by issuing the **2AC** command.

d. Issue the **R_S** command to restore the factory default.

e. Enter Access Level 2.

f. Issue the **STATUS** command.

If the **STATUS** report shows option card `FAIL` and `Relay Disabled` and the message:

`Confirm Hardware Config`

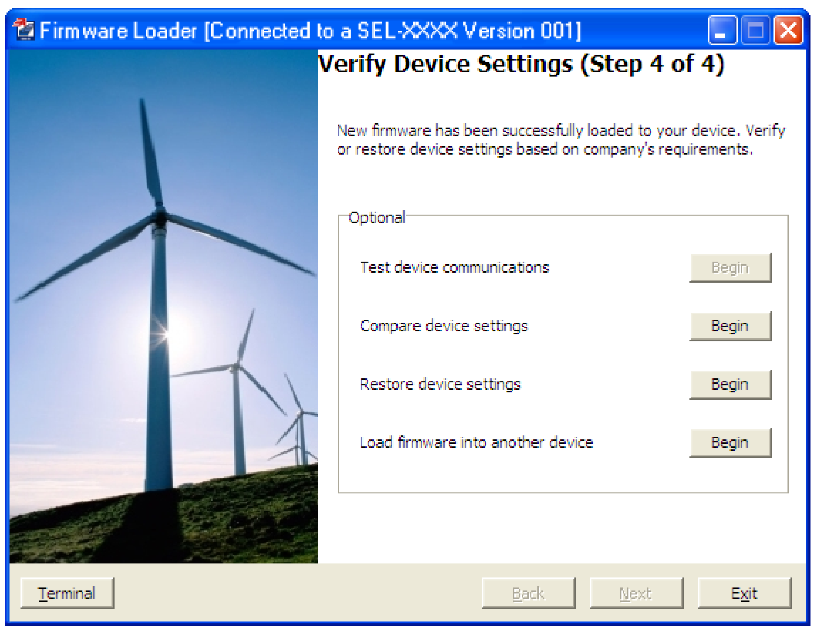
`Accept & Reboot (Y/N)?`

Enter **Y**. This will save the relay calibration settings. The relay will respond:

`Config Accepted`

The relay will reboot and come up **ENABLED**.

Step 4. Verify device.



Four verification options are provided and when enabled these options perform as follows.

Test Device Communications. If the device cannot be restarted, then turn power off and back on to restart it. Once the device is enabled, this option reconnects and re-initializes the device.

Compare Device Settings. This option verifies settings by reading them from the device and comparing them with settings saved to the database.

Restore Device Settings. This option restores settings by writing settings saved in the database to the device. Settings are converted automatically, if necessary.

Load Firmware into Another Device. Returns the wizard to *Step 1: Prepare Device* to repeat the firmware-loading process with another device.

Upgrade Firmware Using a Terminal Emulator

The following instructions assume you have a working knowledge of your personal computer terminal emulation software. In particular, you must be able to modify your serial communications parameters (bps rate, data bits, parity, etc.), select transfer protocol (Xmodem/CRC or 1k Xmodem/CRC), and transfer files (for example, send and receive binary files).

Step 1. If the relay is in service, open the relay control circuits.

Step 2. Connect the PC to the front-panel serial port and enter Access Level 2.

Step 3. Save the present relay settings.

You can use the PC software (described in the instruction manual PC software section) to save and restore settings easily. Otherwise, use the following steps.

NOTE: To save the calibration settings, perform **SHO C** from the terminal by logging into the CAL level using the CAL level password. The factory-default password for the CAL level is CLARKE.

a. Issue the following commands at the ASCII prompt:

SHO, **SHO L**, **SHO G**, **SHO P**, **SHO F**, **SHO R**, **SHO C**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

c. We recommend that you save all stored data in the relay, including EVENTS, before the upgrade.

Step 4. Start upgrading of firmware.

a. Issue the **L_D** command to the relay.

b. Type **Y <Enter>** at the following prompt:

`Disable relay to receive firmware (Y/N)?`

c. Type **Y <Enter>** at the following prompt:

`Are you sure (Y,N)?`

The relay will send the `!>` prompt.

Step 5. Change the bps rate, if necessary.

NOTE: If you have difficulty at 115200 bps, choose a slower data transfer rate (for example, 38400 bps or 57600 bps). Be sure to match the relay and PC data rates.

a. Type **BAU 115200 <Enter>**.

This will change the bps rate of the communications port to 115200.

b. Change the bps rate of the PC to 115200 to match the relay.

Step 6. Begin the transfer of new firmware to the relay by issuing the **REC** command.

Step 7. Type **Y** to erase the existing firmware or press **<Enter>** to abort.

Step 8. Press any key (for example, **<Enter>**) when the relay sends a prompt.

Step 9. Start the file transfer.

Use the Xmodem protocol and send the file that contains the new firmware (e.g., r101*xxx*.s19 or r101*xxx*.z19).

The file transfer takes less than 5–15 minutes at 115200 bps, depending on the product. After the transfer is complete, the relay will reboot and return to Access Level 0.

Figure B.1 shows the entire process.

```
=>>L_D <Enter>

Disable relay to receive firmware (Y,N)? Y <Enter>
Are you sure (Y,N)? Y <Enter>
Relay Disabled

BFID=BOOTLDR-R500-V0-Z000000-D20090925
!>BAU 115200 <Enter>
!>REC <Enter>
This command uploads new firmware.
When new firmware is uploaded successfully, IED will erase old firmware,
load new firmware and reboot.

Are you sure you want to erase the existing firmware(Y,N)? Y <Enter>
Press any key to begin transfer and then start transfer at the terminal.<Enter>
Erasing firmware.
Erase successful.
Writing new firmware.
Upload completed successfully. Attempting a restart.
```

Figure B.1 Firmware File Transfer Process

Step 10. The relay illuminates the **ENABLED** front-panel LED if the relay settings were retained through the download.

If the **ENABLED** LED is illuminated, proceed to *Step 11*.

If the **ENABLED** LED is not illuminated or the front panel displays `STATUS FAIL`, `EEPROM FAILURE`, or `Non_Vol Failure`, use the following procedure to restore the factory-default settings:

a. Set the communications software settings to 9600 bps, 8 data bits, and 1 stop bit.

b. Enter Access Level 2 by issuing the **2AC** command.

c. Issue the **R_S** command to restore the factory-default settings.

   The relay will then reboot with the factory-default settings.

d. Enter Access Level 2.

e. Issue the **STATUS** command.

   If the relay is **ENABLED** go to *Step f*.

   If the **STATUS** report shows option card `FAIL` and `Relay Disabled` and the message:

   ```
   Confirm Hardware Config
   Accept & Reboot (Y/N)?
   ```

   Enter **Y**. This will save the relay calibration settings.

   The relay will respond:

   ```
   Config Accepted
   ```

   The relay will reboot and come up **ENABLED**.

f. Restore relay settings back to the settings saved in *Step 3*.

Step 11. Change the bps rate of the PC to match that of the relay prior to *Step 5*, and enter Access Level 2.

Step 12. Issue the **STATUS** command; verify all relay self-test results are OK.

Step 13. Apply current and voltage signals to the relay.

Step 14. Issue the **METER** command; verify that the current and voltage signals are correct.

Step 15. Autoconfigure the SEL-2032, SEL-2030, or SEL-2020 port if you have a Communications Processor connected.

This step re-establishes automatic data collection between the SEL-2032, SEL-2030, or SEL-2020 Communications Processor and the SEL relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Protocol Verification for Relays With IEC 61850 Option

NOTE: A relay with optional IEC 61850 protocol requires the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or if new relay firmware does not support the current CID file version. If you transfer an invalid CID file, the relay will disable the IEC 61850 protocol, because it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

Perform the following steps to verify that the IEC 61850 protocol is still operational after a relay firmware upgrade and if not, reenable it. This procedure assumes that IEC 61850 was operational with a valid CID file immediately before initiating the relay firmware upgrade.

Step 1. Establish an FTP connection to the relay Ethernet port.

Step 2. Open the ERR.TXT file.

If the ERR.TXT file is empty, the relay found no errors during CID file processing and IEC 61850 should be enabled. Go to *Step 3* if ERR.TXT is empty.

If the ERR.TXT file contains error messages relating to CID file parsing, the relay has disabled the IEC 61850 protocol. Use ACSELERATOR Architect SEL-5032 Software to convert the existing CID file and make it compatible again.

a. Install the Architect software upgrade that supports your required CID file version.

b. Run Architect and open the project that contains the existing CID file for the relay.

c. Download the CID file to the relay.

Step 3. Upon connecting to the relay, Architect will detect the upgraded relay firmware and prompt you to allow it to convert the existing CID file to a supported version. Once converted, downloaded, and processed, the valid CID file allows the relay to reenable the IEC 61850 protocol.

Step 4. In the Telnet session, type GOO <Enter>.

Step 5. View the GOOSE status and verify that the transmitted and received messages are as expected.

The relay is now ready for your commissioning procedure.

Technical Support

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

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2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Telephone: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

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Appendix C
SEL Communications Processors

SEL Communications Protocols

The SEL-787 Transformer Protection Relay supports the SEL protocols and command sets shown in *Table C.1*.

Table C.1 Supported Serial Command Sets

Command Set	Description
SEL ASCII	Use this protocol to send ASCII commands and receive ASCII responses that are human readable with an appropriate terminal emulation program.
SEL Compressed ASCII	Use this protocol to send ASCII commands and receive Compressed ASCII responses that are comma-delimited for use with spreadsheet and database programs or for use by intelligent electronic devices.
SEL Fast Meter	Use this protocol to send binary commands and receive binary meter and target responses.
SEL Fast Operate	Use this protocol to receive binary control commands.
SEL Fast SER	Use this protocol to receive binary Sequential Events Recorder unsolicited responses.

SEL ASCII Commands

We originally designed SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands.

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 in either SEL ASCII or Compressed ASCII. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports because the compressed reports reduce blanks, tabs, and other white space between data fields to a single comma.

Table C.2 lists the Compressed ASCII commands and contents of the command responses.

Table C.2 Compressed ASCII Commands

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands	0
CEVENT	Event report	1
CHISTORY	List of events	1
CLDP	Load Profile Data	1
CMETER	Metering data, including fundamental, differential, thermal demand, peak demand, harmonic, energy, max/min, rms, analog inputs, and math variables	1
CSE	Sequence Of Events Data	1
CSTATUS	Relay status	1
CSUMMARY	Summary of an event report	1
CTFE	Through-fault event report	1
DNAME	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view through use of a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the SEL-787 communicates with an SEL communications processor. These SEL communications processors perform autoconfiguration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the SEL communications processor uses the binary data stream for Fast Meter and Fast Operate messages to populate a local database and to perform SCADA operations. At the same time, you can use the binary data stream to connect transparently to the SEL-787 and use the ASCII data stream for commands and responses.

SEL Fast Meter, Fast Operate, and Fast SER

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 SCADA or DCS functions that occur simultaneously with ASCII interaction.

SEL Communications Processor

SEL offers SEL communications processors, which are powerful tools for system integration and automation. The SEL-2030 series and the SEL-2020 communications processors are similar, except that the SEL-2030 series has two slots for network protocol cards. These devices provide a single point of contact for integration networks with a star topology, as shown in *Figure C.1*.

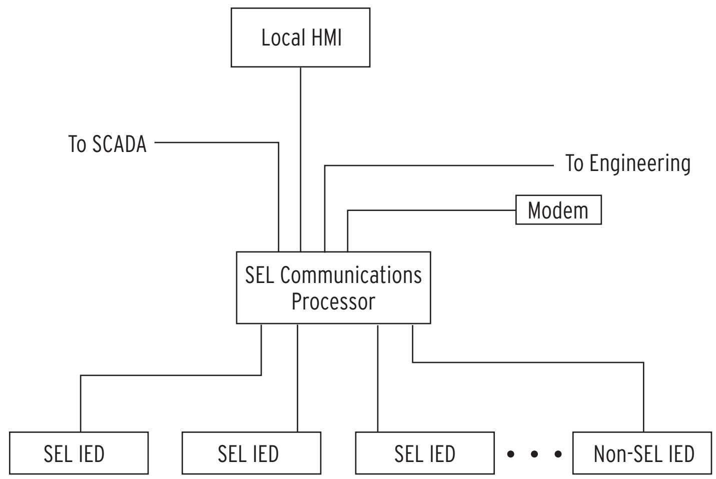

Figure C.1 SEL Communications Processor Star Integration Network

In the star topology network in *Figure C.1* the SEL communications processor uses the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Distribution of IRIG-B time synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Automated dial-out on alarms

The SEL communications processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure C.2*. In this multitiered system, the lower-tier SEL communications processors forward data to the upper-tier SEL communications processor that serves as the central point of access to substation data and substation IEDs.

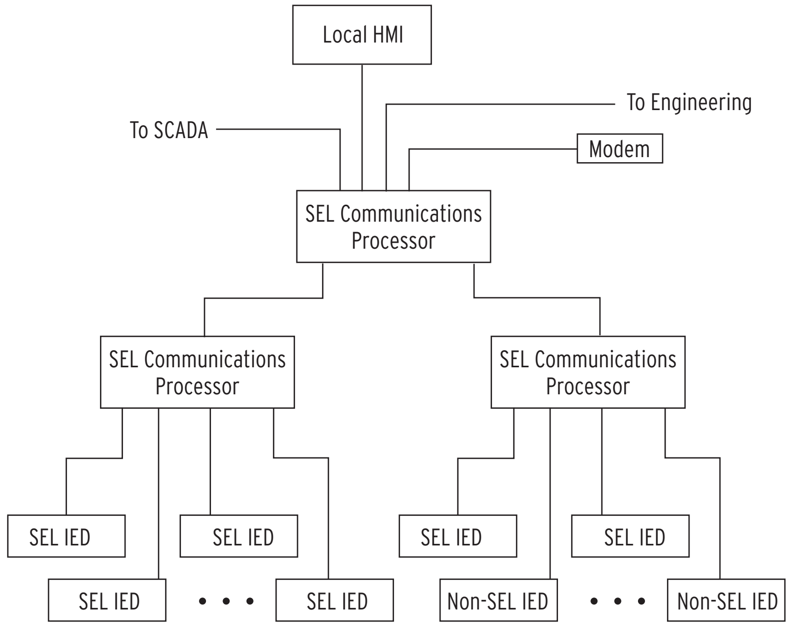

Figure C.2 Multitiered SEL Communications Processor Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. SEL communications processors provide an integration solution with a reliability comparable to that of SEL relays. In terms of MTBF (mean time between failures), SEL communications processors are 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure SEL communications processors with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. SEL communications processors offer the protocol interfaces listed in *Table C.3*.

Table C.3 SEL Communications Processors Protocol Interfaces

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters
Modbus RTU Protocol	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus[a]	Modbus Plus peers with global data and Modbus Plus masters
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol and peers

[a] Requires SEL-2711 Modbus Plus protocol card.
[b] Requires SEL-2701 Ethernet Processor.

SEL Communications Processor and Relay Architecture

You can apply SEL communications processors and SEL relays in a limitless variety of applications to integrate, automate, and improve station operation. Most system integration architectures using SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-787 and an SEL communications processor is shown in *Figure C.1*. In this architecture, the SEL communications processor collects data from the SEL-787 and other station IEDs. The SEL communications processor acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses an SEL communications processor to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting any SEL communications processor directly to the SCADA master thereby eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface, so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

SEL communications processors equipped with an SEL-2701 Ethernet Processor can provide a UCA2 interface to SEL-787 relays and other serial IEDs. The SEL-787 data appear in models in a virtual device domain. The combination of the SEL-2701 with an SEL communications processor offers a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 with an SEL communications processor, see the SEL-*2701 Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use an SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure C.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. There are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI.

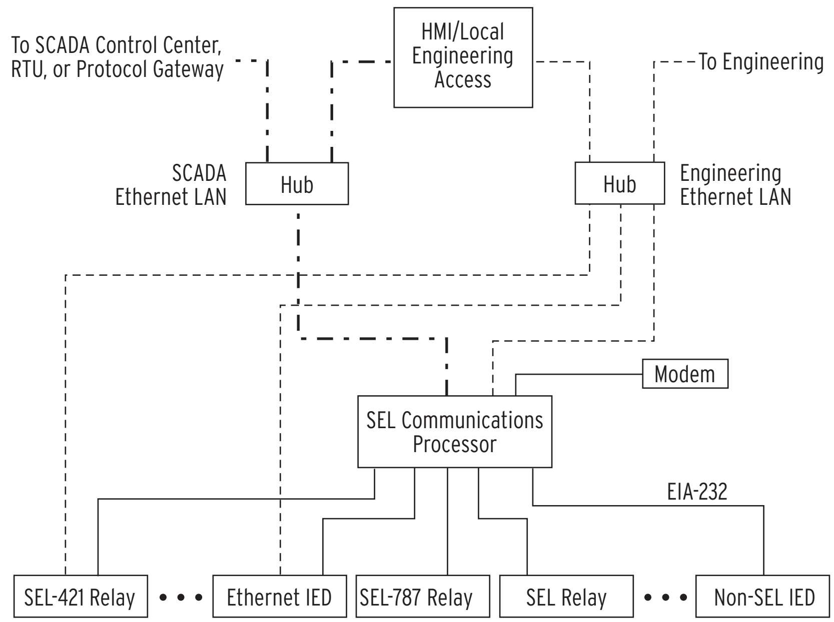

Figure C.3 Enhancing Multidrop Networks With SEL Communications Processors

In the figure, the SEL communications processor provides the following enhancements when compared to a system that employs only the multidrop network:

- Ethernet access for IEDs with serial ports
- Backup engineering access through the dial-in modem
- IRIG-B time signal distribution to all station IEDs
- Integration of IEDs without Ethernet
- Single point of access for real-time data for SCADA, HMI, and other uses
- Significant cost savings by use of existing IEDs with serial ports

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-787. The physical configuration used in this example is shown in *Figure C.4*.

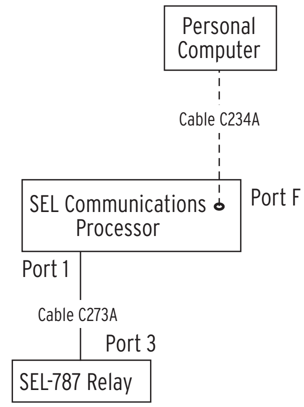

Figure C.4 Example of SEL Relay and SEL Communications Processor Configuration

Table C.4 shows the Port 1 settings for the SEL communications processor.

Table C.4 SEL Communications Processor Port 1 Settings

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	*Relay 1*	Name of connected relay[a]
BAUD	19200	Channel speed of 19200 bits per second[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit
PARITY	N	No parity
RTS_CTS	N	Hardware flow control enabled
XON_XOFF	Y	Enable XON/XOFF flow control
TIMEOUT	30	Idle timeout that terminates transparent connections of 30 seconds

[a] Automatically collected by the SEL communications processor during autoconfiguration.

Data Collection

The SEL communications processor is configured to collect data from the SEL-787 using the commands listed in *Table C.5*.

Table C.5 SEL Communications Processor Data Collection Automessages

Message	Data Collected
20METER	Power system metering data
20DEMAND	Demand metering data
20TARGET	Selected Relay Word bit elements
20HISTORY	History command (ASCII)
20STATUS	Status command (ASCII)
20EVENTS	Standard 4 sample/cycle event report (data with settings)
20EVENT	Standard 4 sample/cycle event report (data only)

Table C.6 shows the automessage (**SET A**) settings for the SEL communications processor.

Table C.6 SEL Communications Processor Port 1 Automatic Messaging Settings

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	ACC\nOTTER\n	Automatically log-in at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker bit control
REC_SER	N	Automatic sequential event recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	3	Three automessages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Relay Word bit data
ISSUE3	P00:01:00.0	Issue Message 3 every minute
MESG3	20DEMAND	Collect demand metering data
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table C.7 shows the map of regions in the SEL communications processor for data collected from the SEL-787. Use the **MAP *n*** command to view these data.

Table C.7 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Relay metering data
D2	Binary	TARGET	Relay Word bit data
D3	Binary	DEMAND[a]	Demand meter data
D4–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

[a] Demand function is available only when the setting EDEM is not set to OFF.

Relay Metering Data

Table C.8 lists the meter data available in the SEL communications processor and the location and data type for the memory areas within D1 (Data Region 1). The type field indicates the data type and size. The *int* type is a 16-bit integer. The *float* type is a 32-bit IEEE floating point number. Use the **VIE *n*:D1** command to view these data.

Table C.8 Communications Processor METER Region Map

Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME (ms)	2002h	int[2]
MONTH	2004h	char
DATE	2005h	char
YEAR	2006h	char
HOUR	2007h	char
MIN	2008h	char
SECONDS	2009h	char
MSEC	200Ah	int
IAW1	200Bh	float
IBW1	200Dh	float
ICW1	200Fh	float
IAW2	2011h	float
IBW2	2013h	float
ICW2	2015h	float
IN	2017h	float
VAB	2019h	float
VBC	201Bh	float
VCA	201Dh	float
P	201Fh	float
Q	2021h	float
S	2023h	float
PF	2025h	float
FREQ	2027h	float
V/HZ	2029h	float

Relay Word Bits Information

Table C.9 lists the Relay Word bit data available in the SEL communications processor TARGET region.

Table C.9 Communications Processor TARGET Region Map

Address	Relay Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
2804h	*	*	*	*	*	PWRUP	STSET	*
2805h	See *Table J.1*, Row 0							
2806h	See *Table J.1*, Row 1							
2807h	See *Table J.1*, Row 2							
2808h	See *Table J.1*, Row 3							
2809h	See *Table J.1*, Row 4							
280Ah	See *Table J.1*, Row 5							
280Bh	See *Table J.1*, Row 6							
280Ch	See *Table J.1*, Row 7							
280Dh	See *Table J.1*, Row 8							
280Eh	See *Table J.1*, Row 9							
280Fh	See *Table J.1*, Row 10							
2810h	See *Table J.1*, Row 11							
2811h	See *Table J.1*, Row 12							
• • •	• • •							
286Fh	See *Table J.1*, Row 106							

Control Points

The SEL communications processor can automatically pass control messages, called Fast Operate messages, to the SEL-787. You must enable Fast Operate messages by using the FASTOP setting in the SEL-787 port settings for the port connected to the SEL communications processor. You must also enable Fast Operate messages in the SEL communications processor by setting the automessage setting SEND_OPER equal to Y.

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the relay for changes in remote bits RB01–RB32 on the corresponding SEL communications processor port. In this example, if you set RB01 on **Port 1** in the SEL communications processor, it automatically sets RB01 in the SEL-787.

Breaker bits BR1 and BR2 operate differently than remote bits. There are two breaker bits in the SEL-787. For Circuit Breaker *n*, when you set BR*n*, the SEL communications processor sends a message to the SEL-787 that asserts the OC*n* bit for one processing interval. If you clear BR*n*, the SEL communications processor sends a message to the SEL-787 that asserts the CC*n* bit for one processing interval. OC*n* will open the breaker (via SELOGIC equation TR*x*) and CC*n* will close the breaker (via SELOGIC Equation CL*x*). See *Figure 4.47* and *Figure 4.48* for the breaker trip and breaker close logic diagrams, respectively.

Demand Data

Table C.10 lists the demand data available in the SEL Communications Processor and the location and data type for the memory areas within D3 (Data Region 3). The type field indicates the data type and size. The type "int" is a 16-bit integer. The type "float" is a 32-bit IEEE floating point number.

Table C.10 Communications Processor DEMAND Region Map

Item	Starting Address	Type
_YEAR	3000h	int
DAY_OF_YEAR	3001h	int
TIME(ms)	3002h	int[2]
MONTH	3004h	char
DATE	3005h	char
YEAR	3006h	char
HOUR	3007h	char
MIN	3008h	char
SECONDS	3009h	char
MSEC	300Ah	int
IAD(A)	300Bh	float
IBD(A)	300Dh	float
ICD(A)	300Fh	float
IGD(A)	3011h	float
3I2D(A)	3013h	float

Appendix D
DNP3 Communications

Overview

The SEL-787 Transformer Protection Relay provides a Distributed Network Protocol Version 3.0 (DNP3) Level 2 Outstation interface for direct serial and LAN/WAN network connections to the device.

This section covers the following topics:

- *Introduction to DNP3 on page D.1*
- *DNP3 in the SEL-787 on page D.6*
- *DNP3 Documentation on page D.13*

Introduction to DNP3

A Supervisory Control and Data Acquisition (SCADA) manufacturer developed the first versions of DNP from the lower layers of IEC 60870-5. Originally designed for use in telecontrol applications, Version 3.0 of the protocol has also become popular for local substation data collection. DNP3 is one of the protocols included in the IEEE Recommended Practice for Data Communication between Remote Terminal Units (RTUs) and Intelligent Electronic Devices (IEDs) in a Substation.

The DNP Users Group maintains and publishes DNP3 standards. See the DNP Users Group website, www.dnp.org, for more information on standards, implementers, and tools for working with DNP3.

DNP3 Specifications

DNP3 is a feature-rich protocol with many ways to accomplish tasks, defined in an eight-volume series of specifications. Volume 8 of the specification, called the Interoperability Specification, simplifies DNP3 implementation by providing four standard interoperable implementation levels. The levels are listed in *Table D.1*.

Table D.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communication requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communication requirements	Large RTUs, SCADA masters
4	Enhanced: additional data types and functionality for more complex requirements	Large RTUs, SCADA masters

Each level is a proper superset of the previous lower-numbered level. A higher-level device can act as a master to a lower-level device, but can only use the data types and functions implemented in the lower level device. For example, a typical SCADA master is a Level 3 device and can use Level 2 (or lower) functions to poll a Level 2 (or lower) device for Level 2 (or lower) data. Similarly, a lower-level device can poll a higher-level device, but the lower level device can only access the features and data available to its level.

In addition to the eight-volume DNP3 specification, the protocol is further refined by conformance requirements, optional features, and a series of technical bulletins. The technical bulletins supplement the specifications with discussions and examples of specific features of DNP3.

Data Handling

Objects

DNP3 uses a system of data references called objects, defined by the Basic 4 standard object library. Each subset level specification requires a minimum implementation of object types and recommends several optional object types. DNP3 object types, commonly referred to as objects, are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for special operations, including collections of data, time synchronization, or even all data within the DNP3 device.

If there can be more than one instance of a type of object, then each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15.

Each object also includes multiple versions called variations. For example, Object 1 (binary inputs) has three variations: 0, 1, and 2. You can use Variation 0 to request all variations, Variation 1 to specify binary input values only, and Variation 2 to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and defines what data or control points correspond with each index.

A master initiates all DNP3 message exchanges except unsolicited data. DNP3 terminology describes all points from the perspective of the master. Binary points for control that move from the master to the outstation are called binary outputs, while binary status points within the outstation are called binary inputs.

Function Codes

Each DNP3 message includes a function code. Each object has a limited set of function codes that a master may use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table D.2*.

Table D.2 Selected DNP3 Function Codes (Sheet 1 of 2)

Function Code	Function	Description
1	Read	Request data from the outstation
2	Write	Send data to the outstation

Table D.2 Selected DNP3 Function Codes (Sheet 2 of 2)

Function Code	Function	Description
3	Select	First part of a Select Before Operate operation
4	Operate	Second part of a Select Before Operate operation
5	Direct operate	One-step operation with reply
6	Direct operate, no reply	One-step operation with no reply

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range, and the range specifies the indices of the objects of interest. DNP3 masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP3 outstation.

For example, the qualifier code 01 specifies that the request for points will include a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four hexadecimal byte range field, 00h 04h 00h 10h, which specifies points in the range 4 to 16.

Access Methods

DNP3 has many features that help obtain maximum possible message efficiency. DNP3 masters send requests with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of static (unchanging) data values. These features optimize use of bandwidth and maximize performance over a connection of any speed.

DNP3 event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are time-stamped records that show when observed measurements changed. For binary points, the remote device (DNP3 outstation) logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the outstation device logs changes that exceed a deadband. DNP3 outstation devices collect event data in a buffer that either the master can request or the device can send to the master without a request message. Data sent from the outstation to the master without a polling request are called unsolicited data.

DNP3 data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value data (static data). Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With outstations that contain great amounts of data or in large systems, the three event classes provide a framework for prioritizing different types of data. For example, you can poll once a minute for Class 1 data, once an hour for Class 2 data, and once a day for Class 3 data.

DNP3 also supports static polling: simple polling of the present value of data points within the outstation. By combining event data, unsolicited polling, and static polling, you can operate your system in one of the four access methods shown in *Table D.3*.

The access methods listed in *Table D.3* are listed in order of increasing communication efficiency. With various trade-offs, each method is less demanding of communication bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communication bandwidth than polled report-by-exception because that method does not require polling messages from the master. In order to properly evaluate which access method provides optimum performance for your application, you must also consider overall system size and the volume of data communication expected.

Table D.3 DNP3 Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data
Unsolicited report-by-exception	Outstation devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data
Quiescent	Master never polls and relies on unsolicited reports only

Binary Control Operations

DNP3 masters use Object 12, control device output block, to perform DNP3 binary control operations. The control device output block has both a trip/close selection and a code selection. The trip/close selection allows a single DNP3 index to operate two related control points such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP3 master implementations.

The control device output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP3 outstations have only a limited subset of the possible combinations of the code field. Sometimes, DNP3 outstations assign special operation characteristics to the latch and pulse selections. *Table D.12* describes control point operation for the SEL-787.

Conformance Testing

In addition to the protocol specifications, the DNP Users Group has approved conformance-testing requirements for Level 1 and Level 2 devices. Some implementers perform their own conformance specification testing, while some contract with independent companies to perform conformance testing.

Conformance testing does not always guarantee that a master and outstation will be fully interoperable (that is, work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP3 implementers toward a higher level of interoperability.

DNP3 Serial Network Issues

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (Open System Interconnection) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the Data Link Layer, includes several functions for error checking and media access control.

A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP3 device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP3 conversation. You should consider whether you require this link integrity function in your application at the expense of overall system speed and performance.

The DNP3 technical bulletin (*DNP Confirmation and Retry Guidelines 9804-002*) on confirmation processes recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single (serial) network medium, you must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your serial network as a star topology of point-to point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before transmitting. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your serial network allows for spontaneous data transmission including unsolicited event data transmissions, you also must use application confirmation to provide a retry mechanism for messages lost due to data collisions.

DNP3 LAN/WAN Overview

The main process for carrying DNP3 over an Ethernet network (LAN/WAN) involves encapsulating the DNP3 data link layer data frames within the transport layer frames of the IP suite. This allows the IP stack to deliver the DNP3 data link layer frames to the destination in place of the original DNP3 physical layer.

The DNP User Group Technical Committee has recommended the following guidelines for carrying DNP3 over a network:

NOTE: Link layer confirmations are explicitly disabled for DNP3 LAN/WAN. The IP suite provides a reliable delivery mechanism, which is backed up at the application layer by confirmations when required.

- DNP3 shall use the IP suite to transport messages over a LAN/WAN
- Ethernet is the recommended physical link, though others may be used
- TCP must be used for WANs
- TCP is strongly recommended for LANs
- UDP may be used for highly reliable single segment LANs
- UDP is necessary if broadcast messages are required
- The DNP3 protocol stack shall be retained in full
- Link layer confirmations shall be disabled

The technical committee has registered a standard port number, 20000, for DNP3 with the Internet Assigned Numbers Authority (IANA). This port is used for either TCP or UDP.

TCP/UDP Selection

The committee recommends the selection of TCP or UDP protocol as per the guidelines in *Table D.4*.

Table D.4 TCP/UDP Selection Guidelines

Use in the case of...	TCP	UDP
Most situations	X	
Non-broadcast or multicast	X	
Mesh Topology WAN	X	
Broadcast		X
Multicast		X
High-reliability single-segment LAN		X
Pay-per-byte, non-mesh WAN, for example, Cellular Digital Packet Data (CDPD)		X
Low priority data, for example, data monitor or configuration information		X

DNP3 in the SEL-787

The SEL-787 is a DNP3 Level 2 remote (outstation) device.

Data Access

Table D.5 lists DNP3 data access methods along with corresponding SEL-787 settings. You must select a data access method and configure each DNP3 master for polling as specified.

NOTE: Because unsolicited messaging is problematic in most circumstances, SEL recommends using the polled report-by-exception access method to maximize performance and minimize risk of configuration problems.

NOTE: In the settings below, the suffix n represents the DNP3 session number from 1 to 3. All settings with the same numerical suffix comprise the complete DNP3 session configuration.

Table D.5 Configuring DNP3 Access Methods

Access Method	Master Polling	SEL-787 Settings
Polled static	Class 0	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to 0; UNSOL*n* to No
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to the desired event class; UNSOL*n* to No
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently; mainly relies on unsolicited messages	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to the desired event class; set UNSOL*n* to Yes and PUNSOL*n* to Yes or No
Quiescent	Class 0, 1, 2, 3 never; relies completely on unsolicited messages	Set ECLASSB*n*, ECLASSC*n*, ECLASSA*n* to the desired event class; set UNSOL*n* and PUNSOL*n* to Yes.

The SEL-787 is an outstation device without dual end point. For a TCP connection, the relay sends out unsolicited messages only if a DNP3 master has already established a session and enabled unsolicited messaging for that session. However, for a serial/modem/UDP connection, the relay automatically dials out and sends unsolicited messages as defined by the settings.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table D.5*, you must make a selection for the PUNSOL*n* setting. This setting enables or disables unsolicited data reporting at power up. If your

DNP3 master can send a message to enable unsolicited reporting on the SEL-787, you should set PUNSOL*n* to No.

While automatic unsolicited data transmission on power up is convenient, this can cause problems if your DNP3 master is not prepared to start receiving data immediately on power up. If the master does not acknowledge the unsolicited data with an Application Confirm, the device will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several devices simultaneously begin sending data and waiting for acknowledgment messages.

The SEL-787 allows you to set the conditions for transmitting unsolicited event data on a class-by-class basis. It also allows you to assign points to event classes on a point-by-point basis (see *Configurable Data Mapping on page D.23*). You can prioritize data transmission with these event class features. For example, you might place high-priority points in event Class 1 and set it with low thresholds (NUMEVE*n* and AGEEVE*n* settings) so that changes to these points will be sent to the master quickly. You may then place low priority data in event Class 2 with higher thresholds.

If the SEL-787 does not receive an Application Confirm in response to unsolicited data, it will wait for ETIMEO*n* seconds and then repeat the unsolicited message. In order to prevent clogging of the network with unsolicited data retries, the SEL-787 uses the URETRY*n* and UTIMEO*n* settings to increase retry time when the number of retries set in URETRY*n* is exceeded. After URETRY*n* has been exceeded, the SEL-787 pauses UTIMEO*n* seconds and then transmits the unsolicited data again. *Figure D.1* provides an example with URETRY*n* = 2.

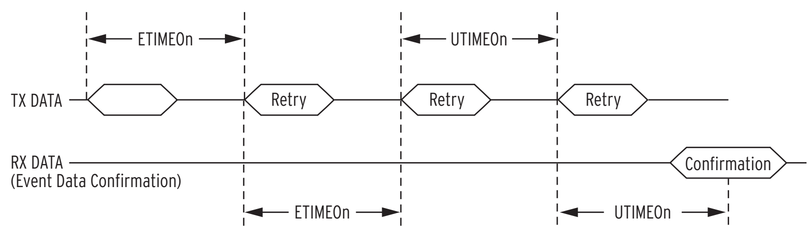

Figure D.1 Application Confirmation Timing With URETRY n = 2

Collision Avoidance

If your application uses unsolicited reporting on a serial network, you must select a half-duplex medium or a medium that includes carrier detection to avoid data collisions. EIA-485 two-wire networks are half-duplex. EIA-485 four-wire networks do not provide carrier detection, while EIA-232 systems can support carrier detection. DNP3 LAN/WAN uses features of the IP suite for collision avoidance, so does not require these settings.

The SEL-787 uses Application Confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The SEL-787 pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. For example, if you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the SEL-787 will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission (see *Figure D.2*).

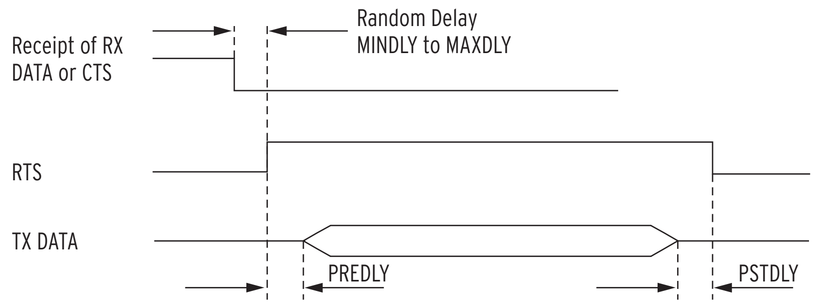

Figure D.2 Message Transmission Timing

Transmission Control

NOTE: PREDLY and POSTDLY settings are only available for EIA-232 and EIA-485 serial port sessions.

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your DNP3 network, you may need to adjust data transmission properties. Use the PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission (see *Figure D.2*). For example, an EIA-485 transceiver typically requires 10 to 20 ms to change from receive to transmit. If you set the pre-delay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

DNP3 event data objects contain change-of-state and time-stamp information that the SEL-787 collects and stores in a buffer. Points assigned in the Binary Input Map that are also assigned in the Sequential Events Recorder (SER) settings carry the time stamp of actual occurrence. Binary input points not assigned in the SER settings will carry a time stamp based on the DNP map scan time. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. The DNP map is scanned approximately once per second to generate events. You can configure the SEL-787 to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB*n*, ECLASSC*n*, and ECLASSA*n*, you can set the event class for binary, counter, and analog inputs for Session *n*. You can use the classes as a simple priority system for collecting event data. The SEL-787 does not treat data of different classes differently with respect to message scanning, but it does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. You must confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-787.

For event data collection you must also consider and enter appropriate settings for deadband and scaling operation on analog points shown in *Table D.7*. You can either:

- set and use default deadband and scaling according to data type, or
- use a custom data map to select deadbands on a point-by-point basis.

See *Configurable Data Mapping on page D.23* for a discussion of how to set scaling and deadband operation on a point-by-point basis. Deadbands for analog inputs can be modified at run-time by writing to Object 34.

The settings ANADBA*n*, ANADBV*n*, and ANADBM*n* control default deadband operation for each type of analog data. Because DNP3 Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

With no scaling, the value of 12.632 would be sent as 12. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

You can set the default analog value scaling with the DECPLA*n*, DECPLV*n*, and DECPLM*n* settings. Application of event reporting deadbands occur after scaling. For example, if you set DECPLA*n* to 2 and ANADBA*n* to 10, a measured current of 10.14 amps would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a change in magnitude of ±0.1 amps) for the device to report a new event value.

Phase angles have a default scale factor of 10, and the ANADBM deadband setting applies to them. For the angles to generate events, the corresponding magnitude also has to exceed its deadband setting (ANADBA).

The SEL-787 uses the NUMEVE*n* and AGEEVE*n* settings to decide when to send unsolicited data to the master. The device sends an unsolicited report when the total number of events accumulated in the event buffer for Master *n* reaches NUMEVE*n*. The device also sends an unsolicited report if the age of the oldest event in the master n buffer exceeds AGEEVE*n*. The SEL-787 has the buffer capacities listed in *Table D.6*.

Table D.6 SEL-787 Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	100
Counters	32

Binary Controls

The SEL-787 provides more than one way to control individual points. The SEL-787 maps incoming control points either to remote bits or to internal command bits that cause circuit breaker operations. *Table D.12* lists control points and control methods available in the SEL-787.

A DNP3 technical bulletin (*Control Relay Output Block Minimum Implementation 9701-002*) recommends that you use one point per Object 12, control block output device. You can use this method to perform Pulse On, Pulse Off, Latch On, and Latch Off operations on selected remote bits.

If your master does not support the single-point-per-index messages or single operation database points, you can use the trip/close operation or use the code field in the DNP3 message to specify operation of the points shown in *Control Point Operation on page D.22*.

Time Synchronization

The accuracy of DNP3 time synchronization is insufficient for most protection and oscillography needs. DNP3 time synchronization provides backup time synchronization in the event the device loses primary synchronization through the IRIG-B input. You can enable time synchronization with the TIMERQ*n* setting and then use Object 50, Variation 1, and Object 52, Variation 2, to set the time via the Session *n* DNP3 master (Object 50, Variation 3 for DNP3 LAN/WAN).

By default, the SEL-787 accepts and ignores time set requests (TIMERQ*n* = I for “ignore”). (This mode allows the SEL-787 to use a high accuracy, IRIG time source, but still interoperate with DNP3 masters that send time synchronization messages.) It can be set to request time synchronization periodically by setting the TIMERQ*n* setting to the desired period. It can also be set to not request, but accept time synchronization (TIMERQ*n* = M for "master").

Modem Support

The SEL-787 DNP implementation includes modem support for serial ports. Your DNP3 master can dial-in to the SEL-787 and establish a DNP3 connection. The SEL-787 can automatically dial out and deliver unsolicited DNP3 event data.

When the device dials out, it waits for the "CONNECT" message from the local modem and for assertion of the device CTS line before continuing the DNP transaction. This requires a connection from the modem DCD to the device CTS line.

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your SEL-787 to other devices.

You can either connect the modem to a computer and configure it before connecting it to the SEL-787, or program the appropriate modem setup string in the modem startup string setting MSTR. You should use the PH_NUM1 and (optional) PH_NUM2 settings to set the phone numbers that you want the SEL-787 to call. The SEL-787 will automatically send the ATDT modem dial command and then the contents of the PH_NUM1 setting when dialing the modem. If PH_NUM2 is set, the RETRY1 setting is used to configure the number of times the SEL-787 tries to dial PH_NUM1 before dialing PH_NUM2. Similarly, the RETRY2 setting is the number of attempts the SEL-787 tries to dial PH_NUM2 before trying PH_NUM1. MDTIME sets the length of time from initiating the call to declaring it failed because of no connection, and MDRET sets the time between dial-out attempts.

NOTE: RTS/CTS hardware flow control is not available for a DNP3 modem connection. You must use either X-ON/X-OFF software flow control or set the port data speed slower than the effective data rate of the modem.

The settings PH_NUM1 and PH_NUM2 must conform to the AT modem command set dialing string standard, including:

- A comma (,) inserts a four second pause
- If necessary, use a 9 to reach an outside line
- Include a 1 and the area code if the number requires long distance access
- Add any special codes your telephone service provider designates to block call waiting and other telephone line features.

DNP3 Settings

The DNP3 port configuration settings available on the SEL-787 are shown in *Table D.7*. You can enable DNP3 on Ethernet Port 1 or on any of the serial Ports 2 through 4, to a maximum of three concurrent DNP3 sessions. Each session defines the characteristics of the connected DNP3 Master, to which you assign one of the three available custom maps.

Because some settings apply only to serial DNP3, they are visible only when configuring a serial port. Likewise, settings that apply only to DNP3 LAN/WAN are visible only during Ethernet port configuration.

For example, you only have the ability to define multiple sessions on Port 1, the Ethernet port. The IP address for each session must be unique. Setting the IP address to 0.0.0.0 allows any master IP address to connect to the session, as long as that IP address is not configured for another DNP3 session. Only one connection is supported on the session at a time.

Extreme care should be observed to ensure network security, especially when setting the IP address to 0.0.0.0, as there is no limitation on the DNP3 master that may connect to the session.

Table D.7 Port DNP3 Protocol Settings (Sheet 1 of 2)

Name	Description	Range	Default
EDNP[a]	Enable DNP3 Sessions	0–3	0
DNPNUM[a]	DNP3 TCP and UDP Port	1–65534	20000
DNPADR	Device DNP3 address	0–65534	0
Session 1 Settings			
DNPIP1[a]	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR1[a b]	Transport protocol	UDP, TCP	TCP
DNPUDP1[a]	UDP response port	REQ, 1–65534	20000
REPADR1	DNP3 address of the Master to send messages to	0–65519	1
DNPMAP1	DNP3 Session Custom Map	1–3	1
DVARAI1	Analog Input Default Variation	1–6	4
ECLASSB1	Class for binary event data, 0 disables	0–3	1
ECLASSC1	Class for counter event data, 0 disables	0–3	0
ECLASSA1	Class for analog event data, 0 disables	0–3	2
DECPLA1	Decimal places scaling for Current data	0–3	1
DECPLV1	Decimal places scaling for Voltage data	0–3	1
DECPLM1	Decimal places scaling for Miscellaneous data	0–3	1
ANADBA1	Analog reporting deadband for current; hidden if ECLASSA1 set to 0	0–32767	100
ANADBV1	Analog reporting deadband for voltages; hidden if ECLASSA1 set to 0	0–32767	100
ANADBM1	Analog reporting deadband for miscellaneous analogs; hidden if ECLASSA and ECLASSC set to 0	0–32767	100
TIMERQ1	Time-set request interval, minutes (M = Disables time sync requests, but still accepts and applies time syncs from Master; I = Ignores (does not apply) time syncs from Master)	I, M, 1–32767	I
STIMEO1	Select/operate time-out, seconds	0.0–30.0	1.0
DNPINA1[a]	Send Data Link Heartbeat, seconds; hidden if DNPTR1 set to UDP	0.0–7200	120
DRETRY1[c]	Data link retries	0–15	3
DTIMEO1[c]	Data link time-out, seconds; hidden if DRETRY1 set to 0	0.0–5.0	1
ETIMEO1	Event message confirm time-out, seconds	1–50	5
UNSOL1	Enable unsolicited reporting; hidden and set to N if ECLASSB1, ECLASSC1, and ECLASSA1 set to 0	Y, N	N
PUNSOL1	Enable unsolicited reporting at power up; hidden and set to N if UNSOL1 set to N	Y, N	N
NUMEVE1[d]	Number of events to transmit on	1–200	10
AGEEVE1[d]	Oldest event to transmit on, seconds	0.0–99999.0	2.0
URETRY1[d]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO1[d]	Unsolicited messages offline timeout, seconds	1–5000	60
Session 2 Settings			
DNPIP2[a]	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR2[a]	Transport protocol	UDP, TCP	TCP
• • •			
URETRY2[a,d]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO2[a,d]	Unsolicited messages offline timeout, seconds	1–5000	60

Table D.7 Port DNP3 Protocol Settings (Sheet 2 of 2)

Name	Description	Range	Default
Session 3 Settings			
DNPIP3[a]	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR3[a]	Transport protocol	UDP, TCP	TCP
• • •			
URETRY3[a,d]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO3[a,d]	Unsolicited messages offline timeout, seconds	1–5000	60
Serial Port Settings			
MINDLY[c]	Minimum delay from DCD to TX, seconds	0.00–1.00	0.05
MAXDLY[c]	Maximum delay from DCD to TX, seconds	0.00–1.00	0.10
PREDLY[c]	Settle time from RTS on to TX; Off disables PSTDLY	OFF, 0.00–30.00	0.00
PSTDLY[c]	Settle time from TX to RTS off; hidden if PREDLY set to Off	0.00–30.00	0.00

[a] Available only on Ethernet ports. The DNP IP address of each session (DNPIP1, DNPIP2, etc.) must be unique. Set DNPIPn := 0.0.0.0 to accept connections from any DNP master.
[b] If DNPIPn is 0.0.0.0, DNPTRn must be set to TCP.
[c] Available only on serial ports.
[d] Hidden if UNSOLn set to N.

The modem settings in *Table D.8* are only available for DNP3 serial port sessions.

Table D.8 Serial Port DNP3 Modem Settings

Name	Description	Range	Default
MODEM	Modem connected to port; all following settings are hidden if MODEM set to N	Y, N	N
MSTR	Modem startup string	As many as 30 characters	“E0X0&D0S0 = 4”
PH_NUM1	Primary phone number for dial-out	As many as 30 characters	“”
PH_NUM2	Secondary phone number for dial-out	As many as 30 characters	“”
RETRY1	Retry attempts for primary dial-out; hidden and unused if PH_NUM2 set to “”	1–20	5
RETRY2	Retry attempts for secondary dial-out; hidden and unused if PH_NUM2 set to “”	1–20	5
MDTIME	Time from initiating call to failure due to no connection, seconds	5–300	60
MDRET	Time between dial-out attempts	5–3600	120

DNP3 Documentation

Object List

Table D.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-787. The list of objects conforms to the format laid out in the DNP specifications and includes supported objects for DNP3 implementation Level 2 and above and nonsupported objects for DNP3 implementation Level 2 only. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table D.9 SEL-787 DNP Object List (Sheet 1 of 5)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
0	211	Device Attributes—User-specific sets of attributes	1	0	129	0,17
0	212	Device Attributes—Master data set prototypes	1	0	129	0,17
0	213	Device Attributes—Outstation data set prototypes	1	0	129	0,17
0	214	Device Attributes—Master data sets	1	0	129	0,17
0	215	Device Attributes—Outstation data sets	1	0	129	0,17
0	216	Device Attributes—Max binary outputs per request	1	0	129	0,17
0	219	Device Attributes—Support for analog output events	1	0	129	0,17
0	220	Device Attributes—Max analog output index	1	0	129	0,17
0	221	Device Attributes—Number of analog outputs	1	0	129	0,17
0	222	Device Attributes—Support for binary output events	1	0	129	0,17
0	223	Device Attributes—Max binary output index	1	0	129	0,17
0	224	Device Attributes—Number of binary outputs	1	0	129	0,17
0	225	Device Attributes—Support for frozen counter events	1	0	129	0,17
0	226	Device Attributes—Support for frozen counters	1	0	129	0,17
0	227	Device Attributes—Support for counter events	1	0	129	0,17
0	228	Device Attributes—Max counter index	1	0	129	0,17
0	229	Device Attributes—Number of counters	1	0	129	0,17
0	230	Device Attributes—Support for frozen analog inputs	1	0	129	0,17
0	231	Device Attributes—Support for analog input events	1	0	129	0,17
0	232	Device Attributes—Max analog input index	1	0	129	0,17
0	233	Device Attributes—Number of analog inputs	1	0	129	0,17
0	234	Device Attributes—Support for double-bit events	1	0	129	0,17
0	235	Device Attributes—Max double-bit binary index	1	0	129	0,17
0	236	Device Attributes—Number of double-bit binaries	1	0	129	0,17
0	237	Device Attributes—Support for binary input events	1	0	129	0,17
0	238	Device Attributes—Max binary input index	1	0	129	0,17
0	239	Device Attributes—Number of binary inputs	1	0	129	0,17
0	240	Device Attributes—Max transmit fragment size	1	0	129	0,17
0	241	Device Attributes—Max receive fragment size	1	0	129	0,17
0	242	Device Attributes—Device manufacturer's software version	1	0	129	0,17

Table D.9 SEL-787 DNP Object List (Sheet 2 of 5)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
0	243	Device Attributes—Device manufacturer’s hardware version	1	0	129	0,17
0	245	Device Attributes—User-assigned location name	1	0	129	0,17
0	246	Device Attributes—User assigned ID code/number	1	0	129	0,17
0	247	Device Attributes—User assigned ID code/number	1	0	129	0,17
0	248	Device Attributes—Device serial number	1	0	129	0,17
0	249	Device Attributes—DNP subset and conformance	1	0	129	0,17
0	250	Device Attributes—Device manufacturer’s product name and model	1	0	129	0,17
0	252	Device Attributes—Device manufacturer's name	1	0	129	0,17
0	254	Device Attributes—Non-specific all attributes request	1	0	129	0,17
0	255	Device Attributes—List of attribute variations	1	0	129	0,17
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
1	1	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary Input Change—All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block	3, 4, 5, 6	7	129	echo of request
12	3	Pattern Mask	3, 4, 5, 6	0, 1	129	echo of request
20	0	Binary Counter—All Variations	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	2	16-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				
21	0	Frozen Counter—All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				

Table D.9 SEL-787 DNP Object List (Sheet 3 of 5)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Delta Counter Change Event With Time				
23	8	16-Bit Delta Counter Change Event With Time				
30[f]	0	Analog Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
30[f]	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	4	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30[f]	5	Short Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6	Long Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				

Table D.9 SEL-787 DNP Object List (Sheet 4 of 5)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
31	7	Short Floating Point Frozen Analog Input				
31	8	Long Floating Point Frozen Analog Input				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32[f]	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32[f]	2	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32[f]	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	5	Short Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32[f]	6	Long Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32[f]	7	Short Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
32[f]	8	Long Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
33	5	Short Floating Point Frozen Analog Event				
33	6	Long Floating Point Frozen Analog Event				
33	7	Short Floating Point Frozen Analog Event With Time				
33	8	Long Floating Point Frozen Analog Event With Time				
34	0	Analog Dead Band—All Variations				
34	1[e]	16-Bit Analog Input Reporting Dead-band Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2	32-Bit Analog Input Reporting Dead-band Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Floating Point Analog Input Reporting Dead-band Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog Output Status—All Variations	1	0, 1, 6, 7, 8	129	
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	3	Short Floating Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	4	Long Floating Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2[e]	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	3	Short Floating Point Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date—All Variations				
50	1	Time and Date	1, 2	7, 8 index=0	129	07, quantity=1
50	2	Time and Date With Interval				
50	3	Time and Date Last Recorded	2	7 quantity = 1	129	
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO			129	07, quantity=1

Table D.9 SEL-787 DNP Object List (Sheet 5 of 5)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine			129	7, quantity=1
60	0	All Classes of Data	1, 20, 21	6, 7, 8		
60	1	Class 0 Data	1, 20, 21	6, 7, 8		
60	2	Class 1 Data	1	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				
70	2	Authentication Object				
70	3	File Command Object				
70	4	File Command Status Object				
70	5	File Transport Object				
70	6	File Transport Status Object				
70	7	File Descriptor Object				
80	1	Internal Indications	2	0, 1 index=7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary-Coded Decimal				
101	2	Medium Packed Binary-Coded Decimal				
101	3	Large Packed Binary-Coded Decimal				
110	all	Octet String				
111	all	Octet String Event				
112	All	Virtual Terminal Output Block				
113	All	Virtual Terminal Event Data				
N/A		No object required for the following function codes: 13 cold start 14 warm start 23 delay measurement	13, 14, 23			

[a] Supported in requests from master.
[b] May generate in response to master.
[c] Decimal.
[d] Hexadecimal.
[e] Default variation.
[f] Default variation specified by serial port setting DVARAI (or DVARAIn for Ethernet session n [n = 1, 2, or 3]).

Device Profile

The DNP3 Device Profile document, available on the supplied CD or as a download from the SEL website, contains the standard device profile information for the SEL-787. This information is also available in XML format. Please refer to this document for complete information on DNP3 Protocol support in the SEL-787.

Reference Data Map

Table D.10 shows the SEL-787 reference data map. The reference map shows the data available to a DNP3 master. You can use the default map or the custom DNP3 mapping functions of the SEL-787 to retrieve only the points required by your application.

NOTE: Deadband changes via Object 34 are not stored in nonvolatile memory. Make sure to reissue the Object 34 deadbands after a warm (**STA C**) or cold start (power cycle).

NOTE: Although the reference maps do not include Relay Word bit labels, you can use these labels in creating custom maps.

The SEL-787 scales analog values by the indicated settings or fixed scaling indicated in the description. Analog deadbands for event reporting use the indicated settings, or ANADBM if you have not specified a setting.

Table D.10 DNP3 Reference Data Map (Sheet 1 of 2)

Object	Labels	Description
Binary Inputs		
01, 02	STFAIL	Relay Diagnostic Failure (HALARM is latched)
	STWARN	Relay Diagnostic Warning (HALARM is pulsed)
	STSET	Relay Settings Change or Relay Restart
	Enabled–T06_LED[a]	Relay Word Elements Target Row 0 (see *Table J.1*)
	50P11T–TUTCH[a]	Relay Word Elements (see *Table J.1*)
	PFL	Power Factor Leading for Three-Phase Currents
	0	Logical 0
	1	Logical 1
Binary Outputs		
10,12	RB01–RB32	Remote bits RB01–RB32
10,12	RB01:RB02 RB03:RB04 RB05:RB06 … RB29:RB30 RB31:RB32	Remote bit pairs RB01–RB32
10,12	OC1	Pulse Open Circuit Breaker 1 command
10,12	CC1	Pulse Close Circuit Breaker 1 command
10,12	OC1:CC1	Open/Close pair for Circuit Breaker 1
10,12	OC2	Pulse Open Circuit Breaker 2 command
10,12	CC2	Pulse Close Circuit Breaker 2 command
10,12	OC2:CC2	Open/Close pair for Circuit Breaker 2
Counters		
20, 22	SC*xx*	SELOGIC Counter Values (*xx* = 01–32)
	GROUP	Active Settings Group
Analog Inputs		
30, 32, 34	IAW1_MAG–SC32[b, c]	Analog Quantities from *Table K.1* with an “x” in the DNP column
	0	Numeric 0
	1	Numeric 1

Table D.10 DNP3 Reference Data Map (Sheet 2 of 2)

Object	Labels	Description
Analog Outputs		
40, 41	GROUP	Active Settings Group
	NOOP	No operation, no error

[a] Valid Relay Word bits depend on the relay model.
[b] Valid analog inputs depend on the relay model.
[c] Refer to *Default Analog Inputs* for default analog input scaling and deadbands.

Default Data Map

The default data map is an automatically generated subset of the reference map. All data maps are initialized to the default values, based on the SEL-787 part number. *Table D.11* shows the SEL-787 default data map. If the default maps are not appropriate, you can also use the custom DNP mapping commands **SET DNN** and **SHOW DNN** to create the map required for your application.

Table D.11 DNP3 Default Data Map

Object	Default Index	Point Label
01, 02	0	ENABLED
	1	TRIPXFMR
	2	TRIP1
	3	TRIP2
	4	STFAIL
	5	STSET
	6	IN101
	7	IN102
	8–99	A portion of these binary inputs can have default values as described in *Default Binary Inputs on page D.20*. Outside that scope, they contain the value NA.
10, 12	0–31	RB01–RB32 Remote Bits
20, 22	0–31	NA
30, 32, 34	0	IAW1_MAG
	1	IBW1_MAG
	2	ICW1_MAG
	3	IGW1_MAG
	4	IAW2_MAG
	5	IBW2_MAG
	6	ICW2_MAG
	7	IGW2_MAG
	8	IAVW1MAG
	9	IAVW2MAG
	10	3I2W1MAG
	11	3I2W1MAG
	12–99	A portion of these analog inputs can have default values as described in *Default Analog Inputs on page D.20*. Outside that scope, they contain the value NA.
40, 41	0–31	NA

Default Binary Inputs

The SEL-787 dynamically creates the default binary input map after you issue an **R_S** command. The SEL-787 uses the part number to determine the presence of digital input cards in Slots 3, 4, and 5. If present, each digital input point label, IN*x*0*y* (where *x* is the slot number and *y* is the point), is added to the default map in numerical order.

Default Analog Inputs

NOTE: Dead-band changes via Object 34 are stored in nonvolatile memory. Make sure to reissue the Object 34 deadbands after a warm (**STA C**) or cold start (power cycle).

The SEL-787 dynamically creates the default analog input map after you issue an **R_S** command. The SEL-787 first checks for a voltage option in the part number, and if voltages are present, adds IN_MAG, VAB_MAG, VBC_MAG, VCA_MAG, VAVE_MAG, 3V2_MAG, P, Q, S, and PF to the default DNP map. The SEL-787 then uses the part number to determine the presence of analog input cards in Slots 3, 4, and 5. If present, the SEL-787 adds each analog input point label, AI*x*0*y* (where *x* is the slot and *y* is the point number), to the default map in numerical order.

Device Attributes (Object 0)

Table D.10 includes the supported Object 0 device attributes and variations. In response to Object 0 requests, the SEL-787 will send attributes that apply to that particular DNP3 session. Because the SEL-787 supports custom DNP3 maps, these values will likely be different for each session. The SEL-787 uses its internal settings for the following variations:

- Variation 242—FID string
- Variation 243—Part Number
- Variation 245—TID setting
- Variation 246—RID setting
- Variation 247—RID setting
- Variation 248—Serial Number

Variation 249 shall contain the DNP subset and conformance, “2:2009”. Variation 250 shall contain the product model, “SEL-787” and Variation 252 shall contain “SEL”.

Binary Inputs

Binary inputs (Objects 1 & 2) are supported as defined by *Table D.11*. The default variation for both static and event inputs is 2. Only the Read function code (1) is allowed with these objects. All variations are supported. Object 2, Variation 3 will be responded to, but will contain no data.

Binary inputs 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 can be significantly delayed from the time when the original source change occurred and should not be used for sequence-of-events determination. Binary inputs registered with SER are derived from the SER and carry the time stamp of actual occurrence. Some additional binary inputs are available only to DNP. For example, STWARN and STFAIL are derived from the diagnostic task data. Another binary input, STSET, is derived from the SER and carries the time stamp of actual occurrence. Static reads of this input will always show 0.

Binary Outputs

Binary output status (Object 10, Variation 2) is supported. Static reads of points RB1–RB32, OC/CC respond with the on-line bit set and the state of the requested bit. Reads from control-only binary output points respond with the on-line bit set and a state of 0. The SEL-751 supports Control Relay Output Block objects (Object 12,Variation 1). The control relays correspond to the remote bits and other functions as shown previously. Each DNP Control message contains a Trip/Close code (TRIP, CLOSE, or NUL) and an Operation type (PULSE ON, LATCH ON, LATCH OFF, or NUL). The Trip/Close code works with the Operation Type to produce set, clear, and pulse operations.

Control operations differ slightly for single-point controls compared to paired outputs. Paired outputs correspond to the complementary two-output model, and single-point controls follow the complementary latch or activation model. In the complementary two-output model, paired points only support Trip or Close operations, which, when issued, will Pulse On the first or second point in the pair, respectively. Latch commands and Pulse operations without a Trip code are not supported. You can cancel an operation in progress by issuing a NUL Trip/Close Code with a NUL Operation Type. Single output points support both Pulse and Latch operations. See *Control Point Operation* for details on control operations.

Use of the Status field is exactly as defined. All other fields are ignored. A pulse operation is asserted for a single processing interval. You should exercise caution if sending multiple remote bit pulses in a single message (i.e., point count > 1), because this can result in some of the pulse commands being ignored and the return of an already active status message. The SEL-787 will only honor the first ten points in an Object 12, Variation 1 request. Any additional points in the request will return the DNP3 status code TOO_MANY_OBJS.

The SEL-787 also supports Pattern Control Blocks (Object 12, Variations 2 and 3) to control multiple binary output points. Variation 2 defines the control type (Trip/Close, Set/Clear, or Pulse) and the range of points to operate. Variation 3 provides a pattern mask that indicates which points in that range should be operated. Object 12, Variations 2 and 3 define the entire control command: the DNP3 master must send both for a successful control. For example, the DNP3 master sends an Object 12, Variation 2 message to request a Trip of the range of indices 0–7. The DNP3 master then sends an Object 12, Variation 3 message with a hexadecimal value of “BB” as the pattern mask (converted to binary notation: 10111011). Read right to left in increasing bit order, the Pattern Block Control command will result in a Trip of indexes 0, 1, 3 to 5, and 7. Multiple binary output point control operations are not guaranteed to occur during the same processing interval.

Control Point Operation

Use the Trip and Close, Latch On/Off and Pulse On operations with Object 12 control relay output block command messages to operate the points shown in *Table D.12*. Pulse operations provide a pulse with duration of one protection processing interval.

Table D.12 SEL-787 Object 12 Control Operations

Label	Close/Pulse On	Trip/Pulse On	Nul/Latch On	Nul/Latch Off	Nul/Pulse On
RB01–RB32	Pulse Remote Bit RB01–RB32	Pulse Remote Bit RB01–RB32	Set Remote Bit RB01–RB32	Clear Remote Bit RB01–RB32	Pulse Remote Bit RB01–RB32
RBxx:RByy	Pulse RByy RB01–RB32	Pulse RBxx RB01–RB32	Not Supported	Not Supported	Not Supported
OC1	Open Circuit Breaker 1 (Pulse OC1)	Open Circuit Breaker 1 (Pulse OC1)	Open Circuit Breaker 1 (Pulse OC1)	No action	Open Circuit Breaker 1 (Pulse OC1)
CC1	Close Circuit Breaker 1 (Pulse CC1)	Close Circuit Breaker 1 (Pulse CC1)	Close Circuit Breaker 1 (Pulse CC1)	No action	Close Circuit Breaker 1 (Pulse CC1)
OC1:CC1	Close Circuit Breaker 1 (Pulse CC1)	Open Circuit Breaker 1 (Pulse OC1)	Not Supported	Not Supported	Not Supported
OC2	Open Circuit Breaker 2 (Pulse OC2)	Open Circuit Breaker 2 (Pulse OC2)	Open Circuit Breaker 2 (Pulse OC2)	No action	Open Circuit Breaker 2 (Pulse OC2)
CC2	Close Circuit Breaker 2 (Pulse CC2)	Close Circuit Breaker 2 (Pulse CC2)	Close Circuit Breaker 2 (Pulse CC2)	No action	Close Circuit Breaker 2 (Pulse CC2)
OC2:CC2	Close Circuit Breaker 2 (Pulse CC2)	Open Circuit Breaker 2 (Pulse OC2)	Not Supported	Not Supported	Not Supported

Analog Inputs

Analog Inputs (30) and Analog Change Events (32) are supported as defined in *Table D.9* and *Table D.10*. The default variation for both static and event inputs is defined by the DVARAI1 (DVARAIn for DNP3 LAN/WAN Session *n*) setting. Only the Read function code (1) is allowed with these objects.

NOTE: Dead-band changes via Object 34 are not stored in nonvolatile memory. Be sure to reissue the Object 34 deadband changes you want to retain after changing DNP port settings, issuing a **STA C** command, or cold-starting the relay (power-cycle).

Unless otherwise indicated, analog values are reported in primary units. See *Appendix K: Analog Quantities* for a list of all available analog inputs.

For all currents, the default scaling is the DECPLA setting on magnitudes and scale factor of 100 on angles. The default deadband for currents is ANADBV on magnitudes and ANADBM on angles. For all voltages, the default scaling is the DECPLV setting on magnitudes and scale factor of 100 on angles. The default deadband for voltages is ANADBV on magnitudes and ANADBM on angles. For all powers and energies, the default scaling is the DECPLM setting and default deadband is ANADBM. For all other quantities, the default scaling is 1 and default deadband is ANADBM.

Default scaling and deadbands may be overridden by per-point scaling and deadband. See *Configurable Data Mapping on page D.23* for more information. Deadbands for analog inputs can also be modified by writing to Object 34.

A deadband check is done after any scaling has been applied. Event class messages are generated whenever an input changes beyond the value given by the appropriate deadband setting. The voltage and current phase angles will only generate an event if, in addition to their deadband check, the corresponding magnitude changes beyond its own deadband. Analog inputs are scanned at approximately a one-second rate. All events generated during a scan will use the time the scan was initiated.

Configurable Data Mapping

One of the most powerful features of the SEL-787 implementation is the ability to remap DNP3 data and, for analog values, specify per-point scaling and deadbands. Remapping is the process of selecting data from the reference map and organizing it into a data subset optimized for your application. The SEL-787 uses object and point labels, rather than point indices, to streamline the remapping process. This enables you to quickly create a custom map without having to search for each point index in a large reference map.

You may use any of the three available DNP3 maps simultaneously with as many as three unique DNP3 masters. Each map is initially populated with default data points, as described in *Default Data Map on page D.19*. You may remap the points in a default map to create a custom map with as many as:

- 100 Binary Inputs
- 32 Binary Outputs
- 100 Analog Inputs
- 32 Analog Outputs
- 32 Counters

You can use the **SHOW DNP *x* <Enter>** command to view the DNP3 data map settings, where *x* is the DNP3 map number from 1 to 3. See *Figure D.3* for an example display of Map 1.

```
=>>SHO DNP 1 <Enter>

DNP Map 1 Settings

Binary Input Map
BI_00    := ENABLED
BI_01    := T01_LED
BI_02    := T02_LED
BI_03    := T03_LED
…
BI_97    := IN101
BI_98    := IN102
BI_99    := 52A1

Binary Output Map
BO_00    := RB01
BO_01    := RB02
BO_02    := RB03
…
BO_29    := RB30
BO_30    := RB31
BO_31    := RB32

Analog Input Map
AI_00    := IAW1_MAG
AI_01    := IBW1_MAG
AI_02    := ICW1_MAG
…
AI_95    := FREQ
AI_96    := P
AI_97    := Q
AI_98    := S
AI_99    := PF

Analog Output Map
AO_00    := GROUP
AO_01    := NOOP
AO_02    := NA
…
AO_29    := NA
AO_30    := NOOP
AO_31    := NOOP

Counter Map
CO_00    := SC01
CO_01    := SC02
CO_02    := SC03
```

Figure D.3 Sample Response to SHO DNP Command

```
…
CO_29    := SC30
CO_30    := SC31
CO_31    := SC32

=>>
```

Figure D.3 Sample Response to SHO DNP Command (Continued)

You can also use the **MAP DNP *y s* <Enter>** command to display DNP3 maps, but the parameter ***y*** is the port number from 1 to 4. Because Port 1, the Ethernet port, can support multiple DNP3 sessions, it may have a different map assigned to each session selected by parameter ***s*** for Sessions 1 to 3. See *Figure D.4* for an example of a **MAP** command that shows the same map as in *Figure D.3*.

```
=>MAP DNP 1  1 <Enter>

SEL-787                                          Date: 02/14/2008   Time: 09:33:39
TRNSFRMR RELAY                                   Time Source: Internal

Map                           1
Transport                     TCP
Device IP Address             10.201.5.3
Master IP Address             10.200.0.139
Device DNP TCP and UDP Port   20000
Device DNP Address            15
Master DNP Address            0

Binary Inputs
-------------------------------------------------------------------------------
  INDEX  POINT LABEL  EVENT CLASS  SER TIMESTAMP
  0      ENABLED      1            No
  1      T01_LED      1            No
  2      T02_LED      1            No
  3      T03_LED      1            No
…
   97    IN101        1            No
   98    IN102        1            No
   99    52A1         1            No

Binary Outputs
-------------------------------------------------------------------------------
  INDEX  POINT LABEL
  0      RB01
  1      RB02
  2      RB03
…
  29     RB30
  30     RB31
  31     RB32

Counters
-------------------------------------------------------------------------------
  INDEX  POINT LABEL  EVENT CLASS  DEADBAND
  0      SC01         0            1
  1      SC02         0            1
  2      SC03         0            1
…
  29     SC30         0            1
  30     SC31         0            1
  31     SC32         0            1
```

Figure D.4 Port MAP Command

```
Analog Inputs
--------------------------------------------------------------------------------
  INDEX  POINT LABEL  EVENT CLASS  SCALE FACTOR  DEADBAND
  0      IAW1_MAG     2                 10.0000  1000
  1      IBW1_MAG     2                 10.0000  1000
  2      ICW1_MAG     2                 10.0000  1000
  3      IAW2_MAG     2                 10.0000  1000
  4      IBW2_MAG     2                 10.0000  1000
  5      ICW2_MAG     2                 10.0000  1000
  6      IGW1_MAG     2                 10.0000  1000
  7      IGW2_MAG     2                 10.0000  1000
  8      IN_MAG       2                 10.0000  1000
  9      IAVW1MAG     2                 10.0000  1000
  10     IAVW2MAG     2                 10.0000  1000
  11     3I2W1MAG     2                 10.0000  1000
  12     3I2W2MAG     2                 10.0000  1000
  13     FREQ         2                  1.0000  100
  14     VAB_MAG      2                 10.0000  2000
  15     VBC_MAG      2                 10.0000  2000
  16     VCA_MAG      2                 10.0000  2000
  17     VAVE_MAG     2                 10.0000  2000
  18     3V2_MAG      2                 10.0000  2000
…
…
  96     P            2                 10.0000  100
  97     Q            2                 10.0000  100
  98     S            2                 10.0000  100
  99     PF           2                 10.0000  100

Analog Outputs
--------------------------------------------------------------------------------

INDEX  POINT LABEL
  0      GROUP
  1      NOOP
```

Figure D.4 Port MAP Command (Continued)

You can use the command **SET DNP *x***, where *x* is the map number, to edit or create custom DNP3 data maps. You can also use ACSELERATOR QuickSet SEL-5030 Software, which is recommended for this purpose.

Scaling factors allow you to overcome the limitations imposed by the integer nature of the default variations of Objects 30 and 32. For example, the device rounds a value of 11.4 amps to 11 amps. You may use scaling to include decimal point values by multiplying by a number larger than one. If you use 10 as a scaling factor, 11.4 amps will be transmitted as 114. You must divide the value by 10 in the master to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. For example, if you have a value that can reach 157834, you cannot send it using DNP3 16-bit analog object variations. You could use a scaling factor of 0.1 so that the maximum value reported is 15783. You can then multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is rounded off in the scaling process, but you can transmit the scaled value using standard DNP3 Objects 30 and 32.

You can customize the DNP3 analog input map with per-point scaling, and deadband settings. Per-point customization is not required, but class scaling (DECPLA, DECPLV, and DECPLM) and deadband (ANADBA, ANADBV, and ANADBM) settings are applied to indices that do not have per-point entries. Unlike per-point scaling described above, class-level scaling is specified by an integer in the range 0–3 (inclusive), which indicates the number of decimal place shifts. In other words, you should select 0 to multiply by 1, 1 for 10, 2 for 100, or 3 for 1000.

If it is important to maintain tight data coherency (that is, all data read of a certain type was sampled or calculated at the same time), then you should group that data together within your custom map. For example, if you want all the Winding 1 currents to be coherent, you should group points IAW1_MAG, IBW1_MAG, ICW1_MAG, and IGW1_MAG together in the custom map. If points are not grouped together, they might not come from the same data sample.

The following example describes how to create a custom DNP3 map by point type. The example demonstrates the SEL ASCII command **SET DNP** for each point type, but the entire configuration may be completed without saving changes between point types. To do this, you simply continue entering data and save the entire map at the end. Alternately, you can use QuickSet to simplify custom data map creation.

Consider a case where you want to set the AI points in a map, as shown in *Table D.13*.

Table D.13 Sample Custom DNP3 AI Map

Desired Point Index	Description	Label	Scaling	Dead Band
0	Winding 1, IA magnitude	IAW1_MAG	default	default
1	Winding 1, IB magnitude	IBW1_MAG	default	default
2	Winding 1, IC magnitude	ICW1_MAG	default	default
3	Winding 2, IA magnitude	IAW2_MAG	default	default
4	3-Phase Real Power	P	5	default
5	AB Phase-to-Phase Voltage Magnitude	VAB_MAG	default	default
6	AB Phase-to-Phase Voltage Angle	VAB_ANG	1	15
7	Frequency	FREQ	.01	1

To set these points as part of custom map 1, you can use the command **SET DNP 1 AI_00 TERSE <Enter>** command as shown in *Figure D.5*.

```
=>>SET DNP 1 AI_00 TERSE <Enter>
Analog Input Map

DNP Analog Input Label Name (23 characters)
AI_00   := NA
? > IAW1_MAG <Enter>

AI_01   := NA
? > IBW1_MAG <Enter>

AI_02   := NA
? > ICW1_MAG <Enter>

AI_03   := NA
? > IAW2_MAG <Enter>

AI_04   := NA
? > P:5 <Enter>

AI_05   := NA
? > VAB_MAG <Enter>

AI_06   := NA
? > VAB_ANG:1:15 <Enter>

AI_07   := NA
? > FREQ:.01:1 <Enter>

AI_08   := NA
? > end <Enter>

Save changes (Y/N) ? Y <Enter>

=>>
```

Figure D.5 Sample Custom DNP3 AI Map Settings

You may also use QuickSet to enter the above AI map settings as shown in the screen capture in *Figure D.6*. You can enter scaling and deadband settings in the same pop-up dialog used to select the AI point, as shown in *Figure D.7*.

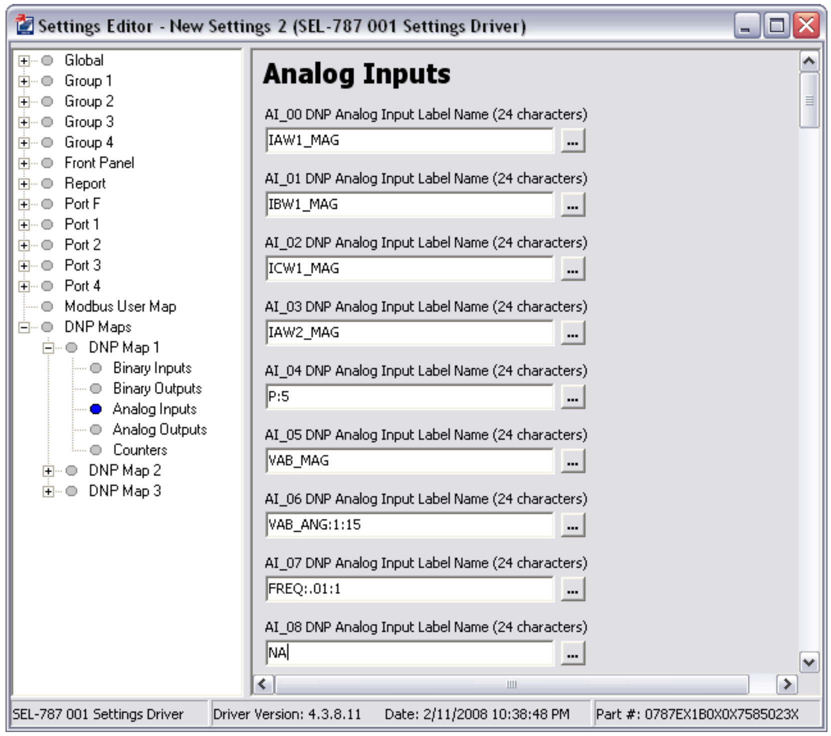

Figure D.6 Analog Input Map Entry in QuickSet Software

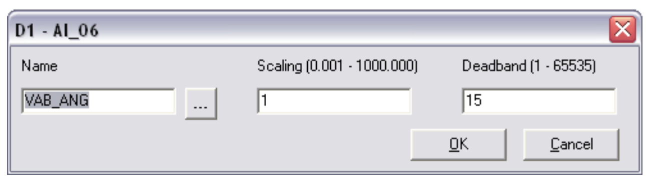

Figure D.7 AI Point Label, Scaling and Deadband in QuickSet Software

The **SET DNP *x* CO_00 <Enter>** command allows you to populate the DNP counter map with per-point deadbands. Entering these settings is similar to defining the analog input map settings.

You can use the command **SET DNP *x* BO_00 TERSE <Enter>** to change the binary output Map *x* as shown in *Figure D.8*. You may populate the custom BO map with any of the 32 remote bits (RB01–RB32). You can define bit pairs in BO maps by including a colon (:) between the bit labels.

```
=>>SET DNP 1 BO_00 TERSE <Enter>
Binary Output Map

DNP Binary Output Label Name (23 characters)
BO_00   := NA
? > RB01 <Enter>

DNP Binary Output Label Name (23 characters)
BO_01   := NA
? > RB02 <Enter>

DNP Binary Output Label Name (23 characters)
BO_02   := NA
? > RB03:RB04 <Enter>

DNP Binary Output Label Name (23 characters)
BO_03   := NA
? > RB05:RB06 <Enter>

DNP Binary Output Label Name (23 characters)
BO_04   := NA
? > end <Enter>

=>>
```

Figure D.8 Sample Custom DNP3 BO Map Settings

You may also use QuickSet to enter the BO map settings as shown in the screen capture in *Figure D.9*.

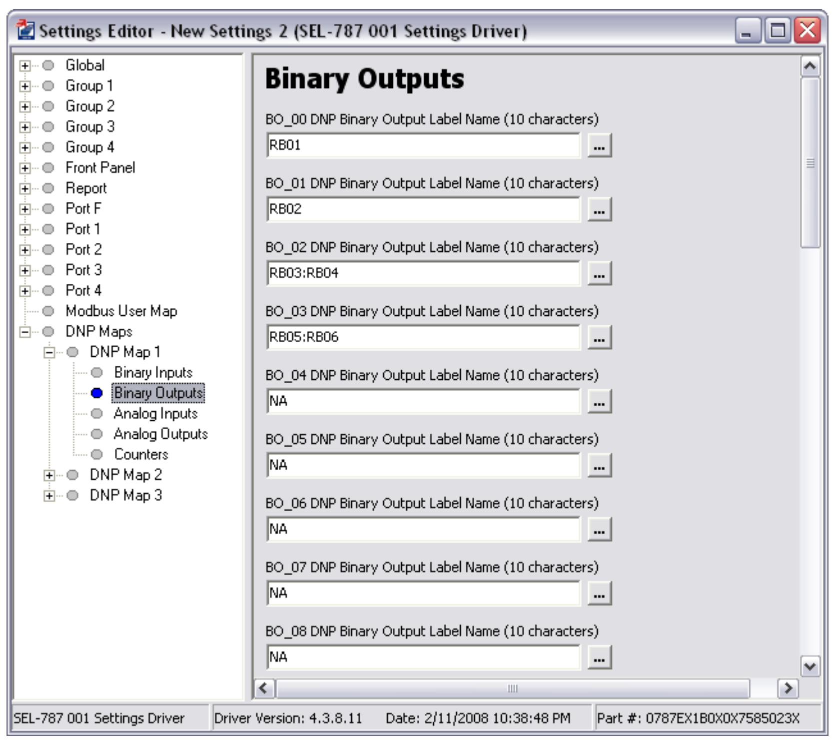

Figure D.9 Binary Output Map Entry in QuickSet Software

The binary input (BI) maps are modified in a similar manner, but pairs are not allowed.

Appendix E
Modbus Communications

Overview

This appendix describes the Modbus RTU communications features supported by the SEL-787 Transformer Protection Relay. Complete specifications for the Modbus protocol are available from the Modbus user's group website at www.modbus.org.

Enable the Modbus TCP protocol with the optional Ethernet port settings. The SEL-787 supports as many as two Modbus TCP sessions. The TCP port number for each session is selected with the Ethernet port settings. The default TCP port number is the Modbus TCP registered port 502. Modbus TCP uses the device IP address as the Modbus identifier and accesses the data in the relay by using the same function codes and data maps as Modbus RTU.

Enable Modbus RTU protocol with the serial port settings. When Modbus RTU protocol is enabled, the relay switches the port to Modbus RTU protocol and deactivates the ASCII protocol.

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

The SEL-787 Modbus communication allows a Modbus master device to do the following:

- ➤ Acquire metering, monitoring, and event data from the relay.
- ➤ Control SEL-787 output contacts.
- ➤ Read the SEL-787 self-test status and learn the present condition of all the relay protection elements.
- ➤ Read most of the relay settings and modify the relay settings.

NOTE: Be aware of the following setting in the relay:
Under Global settings category Access Control, there is a setting called BLOCK MODBUS SET.

The BLOCK MODBUS SET setting is used to block relay settings changes via Modbus or DeviceNet protocols. The factory-default setting, BLKMBSET := NONE, **allows** all setting changes via Modbus or DeviceNet communications. The BLKMBSET := R_S setting **prevents** Modbus or DeviceNet communications from resetting to the factory-default settings. The BLKMBSET := ALL setting **blocks** all changes to the settings via the Modbus or the DeviceNet protocol.

You are strongly advised to change the BLKMBSET (BLOCK MODBUS SET) := ALL if you do not want the PLC (Programmable Logic Controller) or DCS (Distributed Control System) to send the settings to the SEL-787 relay. There is a strong possibility that under special conditions like a reboot, the

PLC/DCS will send default settings to the relay, overwriting the existing settings. To protect the existing settings under these conditions it is highly recommended to set the setting to "ALL."

Communications Protocol

Modbus Queries

Modbus RTU master devices initiate all exchanges by sending a query. The query consists of the fields shown in *Table E.1*.

Table E.1 Modbus Query Fields

Field	Number of Bytes
Slave Device Address	1 byte
Function Code	1 byte
Data Region	0–251 bytes
Cyclical Redundancy Check (CRC)	2 bytes

The SEL-787 SLAVEID setting defines the device address. Set this value to a unique number for each device on the Modbus network. For Modbus communication to operate properly, no two slave devices may have the same address.

The cyclical redundancy check detects errors in the received data. If an error is detected, the relay discards the packet.

Modbus Responses

The slave device sends a response message after it performs the action the query specifies. If the slave cannot execute the query command for any reason, it sends an error response. Otherwise, the slave device response is formatted similarly to the query and includes the slave address, function code, data (if applicable), and a cyclical redundancy check value.

Supported Modbus Function Codes

The SEL-787 supports the Modbus function codes shown in *Table E.2*.

Table E.2 SEL-787 Modbus Function Codes

Codes	Description
01h	Read Discrete Output Coil Status
02h	Read Discrete Input Status
03h	Read Holding Registers
04h	Read Input Registers
05h	Force Single Coil
06h	Preset Single Register
08h	Diagnostic Command
10h	Preset Multiple Registers
60h	Read Parameter Information
61h	Read Parameter Text
62h	Read Enumeration Text
7Dh	Encapsulate Modbus Packet With Control
7Eh	NOP (can only be used with the 7Dh function)

Modbus Exception Responses

The SEL-787 sends an exception code under the conditions described in *Table E.3*.

Table E.3 SEL-787 Modbus Exception Codes

Exception Code	Error Type	Description
1	Illegal Function Code	The received function code is either undefined or unsupported.
2	Illegal Data Address	The received command contains an unsupported address in the data field (i.e., cannot write to a read-only register, cannot write because the settings are locked, etc.).
3	Illegal Data Value	The received command contains a value that is out of range.
4	Device Error	The SEL-787 is in the wrong state for the function a query specifies. This also stands for Service Failure for DeviceNet interface applications. The relay is unable to perform the action specified by a query (i.e., cannot write to a read-only register, cannot write because settings are locked, etc.).
6	Busy	The device is unable to process the command at this time, due to a busy resource.

In the event that any of the errors listed in *Table E.3* occur, the relay assembles a response message that includes the exception code in the data field. The relay sets the most significant bit in the function code field to indicate to the master that the data field contains an error code, instead of the required data.

Cyclical Redundancy Check

The SEL-787 calculates a 2-byte CRC value through use of the device address, function code, and data region. It appends this value to the end of every Modbus response. When the master device receives the response, it recalculates the CRC. If the calculated CRC matches the CRC sent by the SEL-787, the master device uses the data received. If there is no match, the check fails and the message is ignored. The devices use a similar process when the master sends queries.

01h Read Discrete Output Coil Status Command

Use function code 01h to read the On/Off status of the selected bits (coils) (see the Map shown in *Table E.14*). You can read the status of as many as 2000 bits per query, using the fields shown in *Table E.4*. Note that the SEL-787 coil addresses start at 0 (e.g., Coil 1 is located at address zero). The coil status is packed one coil per bit of the data field. The Least Significant Bit (LSB) of the first data byte contains the starting coil address in the query. The other coils follow towards the high order end of this byte and from low order to high order in subsequent bytes.

Table E.4 01h Read Discrete Output Coil Status Command (Sheet 1 of 2)

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (01h)
2 bytes	Address of the first bit
2 bytes	Number of bits to read
2 bytes	CRC-16

Table E.4 01h Read Discrete Output Coil Status Command (Sheet 2 of 2)

Bytes	Field
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (01h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the SEL-787 calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte. *Table E.14* includes the coil number and lists all possible coils (identified as Outputs and Remote bits) available in the device. Note that the command depends on the device hardware configuration; the device responds only to installed cards.

The relay responses to errors in the query are shown in *Table E.5*.

Table E.5 Responses to 01h Read Discrete Output Coil Query Errors

Error	Error Code Returned	Communication Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

02 Read Input Status Command

Use function code 02h to read the On/Off status of the selected bits (inputs), as shown in *Table E.6*. You can read the status of as many as 2000 bits per query. Note that input addresses start at 0 (e.g., Input 1 is located at address zero). The input status is packed one input per bit of the data field. The LSB of the first data byte contains the starting input address in the query. The other inputs follow towards the high order end of this byte, and from low order to high order in subsequent bytes.

Table E.6 02h Read Input Status Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (02h)
2 bytes	Address of the first bit
2 bytes	Number of bits to read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (02h)
1 byte	Bytes of data (*n*)
n bytes	Data
2 bytes	CRC-16

To build the response, the device calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte.

In each row, the input numbers are assigned from the right-most input to the left-most input (i.e., Input 1 is TLED_06 and Input 8 is ENABLED). Input addresses start at 0000 (i.e., Input 1 is located at Input Address 0000). *Table E.7* includes the coil address in decimal and lists all possible inputs (Relay Word bits) available in the device. Note that the command depends on the device hardware configuration; the device responds only to installed cards.

Table E.7 02h SEL-787 Inputs (Sheet 1 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description[a]
0–7	2	Relay Element Status Row 0
8–15	2	Relay Element Status Row 1
16–23	2	Relay Element Status Row 2
24–31	2	Relay Element Status Row 3
32–39	2	Relay Element Status Row 4
40–47	2	Relay Element Status Row 5
48–55	2	Relay Element Status Row 6
56–63	2	Relay Element Status Row 7
64–71	2	Relay Element Status Row 8
72–79	2	Relay Element Status Row 9
80–87	2	Relay Element Status Row 10
88–95	2	Relay Element Status Row 11
96–103	2	Relay Element Status Row 12
104–111	2	Relay Element Status Row 13
112–119	2	Relay Element Status Row 14
120–127	2	Relay Element Status Row 15
128–135	2	Relay Element Status Row 16
136–143	2	Relay Element Status Row 17
144–151	2	Relay Element Status Row 18
152–159	2	Relay Element Status Row 19
160–167	2	Relay Element Status Row 20
168–175	2	Relay Element Status Row 21
176–183	2	Relay Element Status Row 22
184–191	2	Relay Element Status Row 23
192–199	2	Relay Element Status Row 24
200–207	2	Relay Element Status Row 25
208–215	2	Relay Element Status Row 26
216–223	2	Relay Element Status Row 27
224–231	2	Relay Element Status Row 28
232–239	2	Relay Element Status Row 29
240–247	2	Relay Element Status Row 30
248–255	2	Relay Element Status Row 31
256–263	2	Relay Element Status Row 32

Table E.7 02h SEL-787 Inputs (Sheet 2 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description[a]
264–271	2	Relay Element Status Row 33
272–279	2	Relay Element Status Row 34
280–287	2	Relay Element Status Row 35
288–295	2	Relay Element Status Row 36
296–303	2	Relay Element Status Row 37
304–311	2	Relay Element Status Row 38
312–319	2	Relay Element Status Row 39
320–327	2	Relay Element Status Row 40
328–335	2	Relay Element Status Row 41
336–343	2	Relay Element Status Row 42
344–351	2	Relay Element Status Row 43
352–359	2	Relay Element Status Row 44
360–367	2	Relay Element Status Row 45
368–375	2	Relay Element Status Row 46
376–383	2	Relay Element Status Row 47
384–391	2	Relay Element Status Row 48
392–399	2	Relay Element Status Row 49
400–407	2	Relay Element Status Row 50
408–415	2	Relay Element Status Row 51
416–423	2	Relay Element Status Row 52
424–431	2	Relay Element Status Row 53
432–439	2	Relay Element Status Row 54
440–447	2	Relay Element Status Row 55
448–455	2	Relay Element Status Row 56
456–463	2	Relay Element Status Row 57
464–471	2	Relay Element Status Row 58
472–479	2	Relay Element Status Row 59
480–487	2	Relay Element Status Row 60
488–495	2	Relay Element Status Row 61
496–503	2	Relay Element Status Row 62
504–511	2	Relay Element Status Row 63
512–519	2	Relay Element Status Row 64
520–527	2	Relay Element Status Row 65
528–535	2	Relay Element Status Row 66
536–543	2	Relay Element Status Row 67
544–551	2	Relay Element Status Row 68
552–559	2	Relay Element Status Row 69
560–567	2	Relay Element Status Row 70
568–575	2	Relay Element Status Row 71
576–583	2	Relay Element Status Row 72
584–591	2	Relay Element Status Row 73
592–599	2	Relay Element Status Row 74
600–607	2	Relay Element Status Row 75

Table E.7 02h SEL-787 Inputs (Sheet 3 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description[a]
608–615	2	Relay Element Status Row 76
616–623	2	Relay Element Status Row 77
624–631	2	Relay Element Status Row 78
632–639	2	Relay Element Status Row 79
640–647	2	Relay Element Status Row 80
648–655	2	Relay Element Status Row 81
656–663	2	Relay Element Status Row 82
664–671	2	Relay Element Status Row 83
672–679	2	Relay Element Status Row 84
680–687	2	Relay Element Status Row 85
688–695	2	Relay Element Status Row 86
696–703	2	Relay Element Status Row 87
704–711	2	Relay Element Status Row 88
712–719	2	Relay Element Status Row 89
720-727	2	Relay Element Status Row 90
728-735	2	Relay Element Status Row 91
736-743	2	Relay Element Status Row 92
744-751	2	Relay Element Status Row 93
752-759	2	Relay Element Status Row 94
760-767	2	Relay Element Status Row 95
768-775	2	Relay Element Status Row 96
776-783	2	Relay Element Status Row 97
784-791	2	Relay Element Status Row 98
792-799	2	Relay Element Status Row 99
800-807	2	Relay Element Status Row 100
808-815	2	Relay Element Status Row 101
816-823	2	Relay Element Status Row 102
824-831	2	Relay Element Status Row 103
832-839	2	Relay Element Status Row 104
840-847	2	Relay Element Status Row 105
848-855	2	Relay Element Status Row 106

[a] The input numbers are assigned from the right-most input to the left-most input in the Relay row as show in the following example.
Address 7 = ENABLED
Address 6 = TRIP
Address 5 = T01_LED
Address 4 = T02_LED
Address 3 = T03_LED
Address 2 = T04_LED
Address 1 = T05_LED
Address 0 = T06_LED

The relay responses to errors in the query are shown in *Table E.8*.

Table E.8 Responses to 02h Read Input Query Errors

Error	Error Code Returned	Communication Counter Increments
Invalid bit to read	Illegal Data Address (02h)	Invalid Address
Invalid number of bits to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

03h Read Holding Register Command

Use function code 03h to read directly from the Modbus Register Map shown in *Table E.34*. You can read a maximum of 125 registers at once with this function code. Most masters use 4X references with this function code. If you are accustomed to 4X references with this function code, for five-digit addressing, add 40001 to the standard database address.

Table E.9 03h Read Holding Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (03h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (03h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.10*.

Table E.10 Responses to 03h Read Holding Register Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

04h Read Input Register Command

Use function code 04h to read directly from the Modbus Register Map shown in *Table E.34*. You can read a maximum of 125 registers at once with this function code. Most masters use 3X references with this function code. If you are accustomed to 3X references with this function code, for five-digit addressing, add 30001 to the standard database address.

Table E.11 04h Read Input Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (04h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (04h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.12*.

Table E.12 Responses to 04h Read Input Register Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal register to read	Illegal Data Address (02h)	Invalid Address
Illegal number of registers to read	Illegal Data Value (03h)	Illegal Register
Format error	Illegal Data Value (03h)	Bad Packet Format

05h Force Single Coil Command

Use function code 05h to set or clear a coil. In *Table E.13*, the command response is identical to the command request.

Table E.13 05h Force Single Coil Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (05h)
2 bytes	Coil Reference
1 byte	Operation Code (FF for bit set, 00 for bit clear)
1 byte	Placeholder (00)
2 bytes	CRC-16

Table E.14 lists the coil numbers supported by the SEL-787. The physical coils (coils 0–26) are self-resetting. Pulsing a Set remote bit (decimal address 59 through 90) causes the remote bit to be cleared at the end of the pulse.

Table E.14 01h, 05h SEL-787 Output (Sheet 1 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description
0	01, 05	Pulse OUT101 1 second
1	01, 05	Pulse OUT102 1 second
2	01, 05	Pulse OUT103 1 second
3	01, 05	Pulse OUT301 1 second
4	01, 05	Pulse OUT302 1 second

Table E.14 01h, 05h SEL-787 Output (Sheet 2 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description
5	01, 05	Pulse OUT303 1 second
6	01, 05	Pulse OUT304 1 second
7	01, 05	Reserved
8	01, 05	Reserved
9	01, 05	Reserved
10	01, 05	Reserved
11	01, 05	Pulse OUT401 1 second
12	01, 05	Pulse OUT402 1 second
13	01, 05	Pulse OUT403 1 second
14	01, 05	Pulse OUT404 1 second
15	01, 05	Reserved
16	01, 05	Reserved
17	01, 05	Reserved
18	01, 05	Reserved
19	01, 05	Pulse OUT501 1 second
20	01, 05	Pulse OUT502 1 second
21	01, 05	Pulse OUT503 1 second
22	01, 05	Pulse OUT504 1 second
23	01, 05	Reserved
24	01, 05	Reserved
25	01, 05	Reserved
26	01, 05	Reserved
27	01, 05	RB01
28	01, 05	RB02
29	01, 05	RB03
30	01, 05	RB04
31	01, 05	RB05
32	01, 05	RB06
33	01, 05	RB07
34	01, 05	RB08
35	01, 05	RB09
36	01, 05	RB10
37	01, 05	RB11
38	01, 05	RB12
39	01, 05	RB13
40	01, 05	RB14
41	01, 05	RB15
42	01, 05	RB16
43	01, 05	RB17
44	01, 05	RB18
45	01, 05	RB19
46	01, 05	RB20
47	01, 05	RB21
48	01, 05	RB22

Table E.14 01h, 05h SEL-787 Output (Sheet 3 of 3)

Coil Address (Decimal)	Function Code Supported	Coil Description
49	01, 05	RB23
50	01, 05	RB24
51	01, 05	RB25
52	01, 05	RB26
53	01, 05	RB27
54	01, 05	RB28
55	01, 05	RB29
56	01, 05	RB30
57	01, 05	RB31
58	01, 05	RB32
59	01, 05	Pulse RB01[a]
60	01, 05	Pulse RB02[a]
61	01, 05	Pulse RB03[a]
62	01, 05	Pulse RB04[a]
63	01, 05	Pulse RB05[a]
64	01, 05	Pulse RB06[a]
65	01, 05	Pulse RB07[a]
66	01, 05	Pulse RB08[a]
67	01, 05	Pulse RB09[a]
68	01, 05	Pulse RB10[a]
69	01, 05	Pulse RB11[a]
70	01, 05	Pulse RB12[a]
71	01, 05	Pulse RB13[a]
72	01, 05	Pulse RB14[a]
73	01, 05	Pulse RB15[a]
74	01, 05	Pulse RB16[a]
75	01, 05	Pulse RB17[a]
76	01, 05	Pulse RB18[a]
77	01, 05	Pulse RB19[a]
78	01, 05	Pulse RB20[a]
79	01, 05	Pulse RB21[a]
80	01, 05	Pulse RB22[a]
81	01, 05	Pulse RB23[a]
82	01, 05	Pulse RB24[a]
83	01, 05	Pulse RB25[a]
84	01, 05	Pulse RB26[a]
85	01, 05	Pulse RB27[a]
86	01, 05	Pulse RB28[a]
87	01, 05	Pulse RB29[a]
88	01, 05	Pulse RB30[a]
89	01, 05	Pulse RB31[a]
90	01, 05	Pulse RB32[a]

[a] Pulsing a Set remote bit will cause the remote bit to be cleared at the end of the pulse (1 SELOGIC processing interval).

Coil addresses start at 0000 (i.e., Coil 1 is located at Coil address 0000). If the device is disabled it will respond with error code 4 (Device Error). In addition to Error Code 4, the device responses to errors in the query are shown in *Table E.15*.

Table E.15 Responses to 05h Force Single Coil Query Errors

Error	Error Code Returned	Communication Counter Increments
Invalid bit (coil)	Illegal Data Address (02h)	Invalid Address
Invalid bit state requested	Illegal Data Value (03h)	Illegal Register
Format Error	Illegal Data Value (03h)	Bad Packet Format

06h Preset Single Register Command

The SEL-787 uses this function to allow a Modbus master to write directly to a database register. Refer to the Modbus Register Map in *Table E.34* for a list of registers that can be written by using this function code. If you are accustomed to 4X references with this function code, for six-digit addressing, add 400001 to the standard database addresses.

In *Table E.16*, the command response is identical to the command required by the master.

Table E.16 06h Preset Single Register Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (06h)
2 bytes	Register Address
2 bytes	Data
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.17*.

Table E.17 Responses to 06h Preset Single Register Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal register address	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal register value	Illegal Data Value (03h)	Illegal Write
Format error	Illegal Data Value (03h)	Bad Packet Format

08h Loopback Diagnostic Command

The SEL-787 uses this function to allow a Modbus master to perform a diagnostic test on the Modbus communications channel and relay. When the subfunction field is 0000h, the relay returns a replica of the received message.

Table E.18 08h Loopback Diagnostic Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field (identical to data in Master request)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.19*.

Table E.19 Responses to 08h Loopback Diagnostic Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal subfunction code	Illegal Data Value (03h)	Invalid Function Code/Op Code
Format error	Illegal Data Value (03h)	Bad Packet Format

10h Preset Multiple Registers Command

This function code works much like code 06h, except that it allows you to write multiple registers at once, as many as 100 per operation. If you are accustomed to 4X references with the function code, for six-digit addressing, simply add 400001 to the standard database addresses.

Table E.20 10h Preset Multiple Registers Command (Sheet 1 of 2)

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers to Write
1 byte	Number of Bytes of Data (*n*)
n bytes	Data
2 bytes	CRC-16

Table E.20 10h Preset Multiple Registers Command (Sheet 2 of 2)

Bytes	Field
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers
2 bytes	CRC-16

The relay responses to errors in the query are shown below.

Table E.21 10h Preset Multiple Registers Query Error Messages

Error	Error Code Returned	Communication Counter Increments
Illegal register to set	Illegal Data Address (02h)	Invalid Address Illegal Write
Illegal number of registers to set	Illegal Data Value (03h)	Illegal Register Illegal Write
Incorrect number of bytes in query data region	Illegal Data Value (03h)	Bad Packet Format Illegal Write
Invalid register data value	Illegal Data Value (03h)	Illegal Write

60h Read Parameter Information Command

The SEL-787 uses this function to allow a Modbus master to read parameter information from the relay. One parameter (setting) is read in each query.

Table E.22 60h Read Parameter Information Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (60h)
2 bytes	Parameter Number
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (60h)
2 bytes	Parameter Number
1 byte	Parameter Descriptor
1 byte	Parameter Conversion
2 bytes	Parameter Minimum Settable Value
2 bytes	Parameter Maximum Settable Value
2 bytes	Parameter Default Value
2 bytes	CRC-16

The Parameter Descriptor field is defined in *Table E.23*.

Table E.23 60h Read Parameter Descriptor Field Definition

Bit	Name	Description
0	RO: Read-only	1 when the setting is read-only
1	H: Hidden	1 when the setting is hidden
2	DBL: 32-bit	1 when the following setting is a fractional value of this setting
3	RA: RAM-only	1 when the setting is not saved in nonvolatile memory
4	RR: Read-only if running	1 when the setting is read-only if in running/operational state
5‘	P: Power Cycle or Reset	1 when the setting change requires a power cycle or reset
6	0	Reserved
7	Extend	Reserved to extend the descriptor table

The Parameter Conversion field is defined in *Table E.24*.

Table E.24 60h Read Parameter Conversion Field Definition

Conversion Value	Type	Multiplier	Divisor	Offset	Base
0	Boolean	1	1	0	1
1	Unsigned Integer	1	1	0	1
2	Unsigned Integer	1	10	0	1
3	Unsigned Integer	1	100	0	1
4	Unsigned Integer	1	1000	0	1
5	Hexadecimal	1	1	0	1
6	Integer	1	1	0	1
7	Integer	1	10	0	1
8	Integer	1	100	0	1
9	Integer	1	1000	0	1
10	Enumeration	1	1	0	1
11	Bit Enumeration	1	1	0	1

Use *Table E.25* to calculate the actual (not scaled) value of the parameter (setting):

$$\text{value} = \frac{(\text{ParameterValue} + \text{Offset}) \bullet \text{Multiplier} \bullet \text{Base}}{\text{Divisor}} \qquad \textbf{Equation E.1}$$

Use *Table E.25* to calculate the scaled setting value:

$$\text{value} = \frac{\text{value} \bullet \text{Divisor}}{\text{Multiplier} \bullet \text{Base}} - \text{Offset} \qquad \textbf{Equation E.2}$$

The relay response to errors in the query are shown *Table E.25*.

Table E.25 Responses to 60h Read Parameter Information Query Errors

Error	Error Code Returned	Communication Counter Increments
Illegal parameter to read	Illegal Address (02h)	Invalid Address

61h Read Parameter Text Command

The SEL-787 uses this function to allow a Modbus master to read parameter text from the relay. One parameter text (setting name) is read in each query.

Table E.26 61h Read Parameter Text Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (61h)
2 bytes	Parameter Number
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (61h)
2 bytes	Parameter Number
16 bytes	Parameter Text (setting name)
4 bytes	Parameter Units (e.g., Amps)
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.27*.

Table E.27 61h Read Parameter Text Query Error Messages

Error	Error Code Returned	Communication Counter Increments
Illegal parameter to read	Illegal Address (02h)	Invalid Address

62h Read Enumeration Text Command

The SEL-787 uses this function to allow a Modbus master to read parameter enumeration or bit enumeration values (setting lists) from the relay. One parameter enumeration is read in each query.

Table E.28 62h Read Enumeration Text Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (62h)
2 bytes	Parameter Number
1 byte	Enumeration Index
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (62h)
2 bytes	Parameter Number
1 byte	Enumeration Index
16 bytes	Enumeration Text
2 bytes	CRC-16

The relay responses to errors in the query are shown in *Table E.29*.

Table E.29 61h Read Parameter Enumeration Text Query Error Messages

Error	Error Code Returned	Communication Counter Increments
Illegal parameter to read	Illegal Address (02h)	Invalid Address
Illegal enumeration in index	Illegal Data Value (03h)	Illegal Register

7Dh Encapsulated Packet With Control Command

The SEL-787 uses this function to allow a Modbus master to perform control operations and another Modbus function with one query. The Device Net card will transmit this command periodically to achieve high-speed I/O processing and establish a heartbeat between the DeviceNet card and the main board.

Table E.30 7Dh Encapsulated Packet With Control Command

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Control Command (same as write to 2000h)
1 byte	Embedded Modbus Function
n bytes	Optional Data to Support Modbus Function (0–250)
2 bytes	CRC-16
A successful response from the slave will have the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Status Information (Register 2100h or 2101h based on Bit 3 in Control Command Word)
1 byte	Embedded Modbus Function
n bytes	Optional data to support the Modbus function (0–250)
2 bytes	CRC-16

Table E.31 shows the format of the relay responses to errors in the query.

Table E.31 7Dh Encapsulated Packet Query Errors

Bytes	Field
Queries from the master must have the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Status Information (Register 2100h or 2101h based on Bit 3 in Control Command Word)
1 byte	Modbus Function with Error Flag
1 bytes	Function Error Code[a]
2 bytes	CRC-16

[a] If the embedded function code is invalid, then an illegal function code is returned here and the illegal function counter is incremented. This error code is returned by the embedded function for all valid embedded functions.

7Eh NOP Command

This function code has no operation. This allows a Modbus master to perform a control operation without any other Modbus command. This is only used inside of the 7Dh when no regular Modbus query is required.

Table E.32 7Eh NOP Command

Bytes	Field
An example of a 7D message response using 7E will have the following format:	
1 byte	Slave Address
1 byte	Function Code (7Dh)
2 bytes	Status Information
1 byte	Function Code (7Eh)
2 bytes	CRC-16

Reading Parameter Information and Value Using Modbus

Through use of Modbus commands, you can read the present value of a parameter as well as parameter name, units, low limit, high limit, scale, and even the enumeration string (if the parameter is an enumeration type). This means that you can use a general user interface to retrieve and display specific parameter details from the relay. Use the **60h**, **61h**, and **62h** commands to retrieve parameter information, and use the **03** command to retrieve values.

Modifying Relay Settings Using Modbus

The SEL-787 does not provide password protection. It is assumed that because the interface is a binary protocol with CRC-16 protection, the interface is being handled by an intelligent master system. Therefore, the master would provide password protection.

Any of the settings listed in the Modbus Register Map (*Table E.34*) can be changed. The high and low limits provided in the table might cover a wider range than what is acceptable by the particular model or configuration. The settings are not saved as and when they are received. The relay acknowledges the write operation, but it does not change the relay settings. The relay holds these settings until there are no further edits for a time specified by SETTINGS TIMEOUT register (4010h). After this timeout, the relay attempts to save the settings. If there are no errors, the settings are saved. If, however, a setting interdependency rule is violated, the settings are not saved. The relay will set the Config Fault bit in the TRIP STATUS HI register to indicate that the save settings operation has failed. The relay will also set ERROR REGISTER (4016h) flags to indicate the type of error and ERROR ADDRESS Register to indicate the register that caused the issue.

Parameters such as date and time can be changed with the appropriate registers by using Modbus Function Code 06h or 10h.

The ability to change the settings via Modbus protocol can be blocked by the Global Setting BLKMBSET or the BLOCK MODBUS SET register.

Controlling Output Contacts Using Modbus

The SEL-787 includes registers for controlling some of the outputs. See LOGIC COMMAND (2000h), RESET COMMAND (2001h), and registers in the Reset Settings region for the control features supported by the relay. Use Modbus function codes 06h or 10h to write appropriate flags. Remember that when writing to the Logic command register with output contacts, it is not a bit operation. All the bits in that register need to be written together to reflect the state you want for each of the outputs.

User-Defined Modbus Data Region and SET M Command

The SEL-787 Modbus Register Map defines an area of 125 contiguous addresses whose contents are defined by 125 user-settable addresses. This feature allows you to take 125 discrete values from anywhere in the Modbus Register Map and place them in contiguous registers that you can then read in a single command. SEL ASCII command **SET M** provides a convenient method to define the user map addresses. The user map can also be defined by writing to user map registers MOD_001 to MOD_125.

To use the user-defined data region, follow the steps listed below.

Step 1. Define the list of desired quantities (as many as 125). Arrange the quantities in any order that is convenient for you to use.

Step 2. Refer to *Table E.33* for a list of the Modbus label for each quantity.

Step 3. Execute **SET M** command from the command line to map user registers 001 to 125 (MOD_001 to MOD_125) using the labels in *Table E.33*.

Note that this step can also be performed using Modbus protocol. Use Modbus Function Code 06h to write to registers MOD_001 through MOD_125.

Step 4. Use Modbus function code 03h or 04h to read the desired quantities from addresses 126 through 250 (user map values).

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 1 of 3)

Register Address	Label
644	FPGA
645	GPSB
646	HMI
647	RAM
648	ROM
649	CR_RAM
650	NON_VOL
651	CLKSTS
652	CID_FILE
653	RTD
654	P3P3PS
655	P5PS
656	P2P5PS
657	P3P75PS
658	N1P25PS
659	N5PS
660	CLKBAT
661	CTBRD
662	CARDC
663	CARDD
664	CARDE
665	IAW1STS
666	IBW1STS
667	ICW1STS
668	IAW2STS
669	IBW2STS
670	ICW2STS
671	INSTS
672	VASTS
673	VBSTS
674	VCSTS
675	RLYSTS
676–683	Reserved
684	IAW1_MAG
685	IAW1_ANG
686	IBW1_MAG
687	IBW1_ANG
688	ICW1_MAG
689	ICW1_ANG
690	IGW1_MAG
691	IGW1_ANG
692	3I2W1MAG
693	IAVW1MAG
694	IAW2_MAG
695	IAW2_ANG
696	IBW2_MAG
697	IBW2_ANG
698	ICW2_MAG
699	ICW2_ANG
700	IGW2_MAG
701	IGW2_ANG
702	3I2W2MAG
703	IAVW2MAG
704	IN_MAG
705	IN_ANG
706–708	Reserved
709	VAB_MAG
710	VAB_ANG
711	VBC_MAG
712	VBC_ANG
713	VCA_MAG
714	VCA_ANG
715	VAVE_MAG
716	VA_MAG
717	VA_ANG
718	VB_MAG
719	VB_ANG
720	VC_MAG
721	VC_ANG
722	VG_MAG
723	VG_ANG
724	VAVE_MAG
725	3V2_MAG
726	P
727	Q
728	S
729	PF
730	VHZ
731	FREQ
732	MWHPH
733	MWHPL
734	MWHNH
735	MWHNL
736	MVRHPH
737	MVRHPL
738	MVRHNH
739	MVRHNL
740	ENRGY_S
741	ENRGYMN
742	ENRGY_H
743	ENRGY_D
744	ENRGYMO
745	ENRGY_Y
746–753	Reserved
754	IAD
755	IBD
756	ICD
757	IGD
758	3I2D
759	IAPD
760	IBPD
761	ICPD
762	IGPD
763	3I2PD
764	PDEM_R_S
765	PDEM_RMN
766	PDEM_R_H
767	PDEM_R_D
768	PDEM_RMO
769	PDEM_R_Y
770	IAW1_THD
771	IBW1_THD
772	ICW1_THD
773	IAW2_THD
774	IBW2_THD
775	ICW2_THD
776	VA_THD
777	VB_THD
778	VC_THD
779	VAB_THD
780	VBC_THD
781	VCA_THD
782	RTDAMB
783	RTDOTHMX
784	RTD1
785	RTD2
786	RTD3
787	RTD4
788	RTD5
789	RTD6
790	RTD7
791	RTD8
792	RTD9
793	RTD10
794	RTD11
795	RTD12
796–806	Reserved
807	IAW1RMS
808	IBW1RMS
809	ICW1RMS
810	IAW2RMS
811	IBW2RMS
812	ICW2RMS
813	INRMS
814	VARMS
815	VBRMS
816	VCRMS
817	VABRMS
818	VBCRMS
819	VCARMS
820	IAW1MX
821	IAW1MN
822	IBW1MX
823	IBW1MN
824	ICW1MX
825	ICW1MN
826	IGW1MX
827	IGW1MN
828	IAW2MX
829	IAW2MN
830	IBW2MX
831	IBW2MN
832	ICW2MX
833	ICW2MN
834	IGW2MX
835	IGW2MN
836	INMX
837	INMN
838	VABMX
839	VABMN
840	VBCMX
841	VBCMN
842	VCAMX
843	VCAMN
844	KW3PMX
845	KW3PMN
846	KVAR3PMX
847	KVAR3PMN
848	KVA3PMX
849	KVA3PMN
850	FREQMX
851	FREQMN
852	RTD1MX
853	RTD1MN

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 2 of 3)

Register Address	Label	Register Address	Label	Register Address	Label	Register Address	Label
854	RTD2MX	900	AI403MXH	955	AI404L	1006	MV19H
855	RTD2MN	901	AI403MXL	956	AI501H	1007	MV19L
856	RTD3MX	902	AI403MNH	957	AI501L	1008	MV20H
857	RTD3MN	903	AI403MNL	958	AI502H	1009	MV20L
858	RTD4MX	904	AI403MXH	959	AI502L	1010	MV21H
859	RTD4MN	905	AI403MXL	960	AI503H	1011	MV21L
860	RTD5MX	906	AI404MNH	961	AI503L	1012	MV22H
861	RTD5MN	907	AI404MNL	962	AI504H	1013	MV22L
862	RTD6MX	908	AI501MXH	963	AI504L	1014	MV23H
863	RTD6MN	909	AI501MXL	964–969	Reserved	1015	MV23L
864	RTD7MX	910	AI501MNH	970	MV01H	1016	MV24H
865	RTD7MN	911	AI501MNL	971	MV01L	1017	MV24L
866	RTD8MX	912	AI502MXH	972	MV02H	1018	MV25H
867	RTD8MN	913	AI502MXL	973	MV02L	1019	MV25L
868	RTD9MX	914	AI502MNH	974	MV03H	1020	MV26H
869	RTD9MN	915	AI502MNL	975	MV03L	1021	MV26L
870	RTD10MX	916	AI503MXH	976	MV04H	1022	MV27H
871	RTD10MN	917	AI503MXL	977	MV04L	1023	MV27L
872	RTD11MX	918	AI503MNH	978	MV05H	1024	MV28H
873	RTD11MN	919	AI503MNL	979	MV05L	1025	MV28L
874	RTD12MX	920	AI504MXH	980	MV06H	1026	MV29H
875	RTD12MN	921	AI504MXL	981	MV06L	1027	MV29L
876	AI301MXH	922	AI504MNH	982	MV07H	1028	MV30H
877	AI301MXL	923	AI504MNL	983	MV07L	1029	MV30L
878	AI301MNH	924	MXMN_R_S	984	MV08H	1030	MV31H
879	AI301MNL	925	MXMN_RMN	985	MV08L	1031	MV31L
880	AI302MXH	926	MXMN_R_H	986	MV09H	1032	MV32H
881	AI302MXL	927	MXMN_R_D	987	MV09L	1033	MV32L
882	AI302MNH	928	MXMN_RMO	988	MV10H	1034	SC01
883	AI302MNL	929	MXMN_R_Y	989	MV10L	1035	SC02
884	AI303MXH	930–939	Reserved	990	MV11H	1036	SC03
885	AI303MXL	940	AI301H	991	MV11L	1037	SC04
886	AI303MNH	941	AI301L	992	MV12H	1038	SC05
887	AI303MNL	942	AI302H	993	MV12L	1039	SC06
888	AI304MXH	943	AI302L	994	MV13H	1040	SC07
889	AI304MXL	944	AI303H	995	MV13L	1041	SC08
890	AI304MNH	945	AI303L	996	MV14H	1042	SC09
891	AI304MNL	946	AI304H	997	MV14L	1043	SC10
892	AI401MXH	947	AI304L	998	MV15H	1044	SC11
893	AI401MXL	948	AI401H	999	MV15L	1045	SC12
894	AI401MNH	949	AI401L	1000	MV16H	1046	SC13
895	AI401MNL	950	AI402H	1001	MV16L	1047	SC14
896	AI402MXH	951	AI402L	1002	MV17H	1048	SC15
897	AI402MXL	952	AI403H	1003	MV17L	1049	SC16
898	AI402MNH	953	AI403L	1004	MV18H	1050	SC17
899	AI402MNL	954	AI404H	1005	MV18L	1051	SC18

Table E.33 Modbus Register Labels for Use With SET M Command (Sheet 3 of 3)

Register Address	Label
1052	SC19
1053	SC20
1054	SC21
1055	SC22
1056	SC23
1057	SC24
1058	SC25
1059	SC26
1060	SC27
1061	SC28
1062	SC29
1063	SC30
1064	SC31
1065	SC32
1066–1081	Reserved
1082	NUMEVE
1083	EVESEL
1084	EVE_S
1085	EVEMN
1086	EVE_H
1087	EVE_D
1088	EVEMO
1089	EVE_Y
1090	EVE_TYPE
1091	EVE_TRGT
1092	EVE_IAW1
1093	EVE_IBW1
1094	EVE_ICW1
1095	EVE_IGW1
1096	EVE_IAW2
1097	EVE_IBW2
1098	EVE_ICW2
1099	EVE_IGW2
1100	EVE_IN
1101	EVE_VAB
1102	EVE_VBC
1103	EVE_VCA
1104	EVE_VG
1105	EVE_DY
1106	EVE_FREQ
1107	EVE_MAXA
1108	EVE_MAXO
1109	RES_1109
1110–1116	Reserved
1117	TRIP_LO
1118	TRIP_HI
1119	WARN_LO
1120	WARN_HI
1121–1125	Reserved
1126	NUMRCV
1127	NUMOTH
1128	INVADR
1129	BADCRC
1130	UARTERR
1131	ILLFUNC
1132	ILLREG
1133	ILLWR
1134	BADPKTF
1135	BADPKTL
1136–1141	Reserved
1142	ROW_0
1143	ROW_1
1144	ROW_2
1145	ROW_3
1146	ROW_4
1147	ROW_5
1148	ROW_6
1149	ROW_7
1150	ROW_8
1151	ROW_9
1152	ROW_10
1153	ROW_11
1154	ROW_12
1155	ROW_13
1156	ROW_14
1157	ROW_15
1158	ROW_16
1159	ROW_17
1160	ROW_18
1161	ROW_19
1162	ROW_20
1163	ROW_21
1164	ROW_22
1165	ROW_23
1166	ROW_24
1167	ROW_25
1168	ROW_26
1169	ROW_27
1170	ROW_28
1171	ROW_29
1172	ROW_30
1173	ROW_31
1174	ROW_32
1175	ROW_33
1176	ROW_34
1177	ROW_35
1178	ROW_36
1179	ROW_37
1180	ROW_38
1181	ROW_39
1182	ROW_40
1183	ROW_41
1184	ROW_42
1185	ROW_43
1186	ROW_44
1187	ROW_45
1188	ROW_46
1189	ROW_47
1190	ROW_48
1191	ROW_49
1192	ROW_50
1193	ROW_51
1194	ROW_52
1195	ROW_53
1196	ROW_54
1197	ROW_55
1198	ROW_56
1199	ROW_57
1200	ROW_58
1201	ROW_59
1202	ROW_60
1203	ROW_61
1204	ROW_62
1205	ROW_63
1206	ROW_64
1207	ROW_65
1208	ROW_66
1209	ROW_67
1210	ROW_68
1211	ROW_69
1212	ROW_70
1213	ROW_71
1214	ROW_72
1215	ROW_73
1216	ROW_74
1217	ROW_75
1218	ROW_76
1219	ROW_77
1220	ROW_78
1221	ROW_79
1222	ROW_80
1223	ROW_81
1224	ROW_82
1225	ROW_83
1226	ROW_84
1227	ROW_85
1228	ROW_86
1229	ROW_87
1230	ROW_88
1231	ROW_89
1232	ROW_90
1233	ROW_91
1234	ROW_92
1235	ROW_93
1236	ROW_94
1237	ROW_95
1238	ROW_96
1239	ROW_97
1240	ROW_98
1241	ROW_99
1242	ROW_100
1243	ROW_101
1244	ROW_102
1245	ROW_103
1246	ROW_104
1247	ROW_105
1248	ROW_106
1249	NA

Reading History Data Using Modbus

Using the Modbus Register Map (*Table E.34*), you can download a complete history of the last 50 events via Modbus. The history contains the date and time stamp, type of event that triggered the report, currents, and voltages at the time of the event. Please refer to the *Historical Data* section in the map.

To use Modbus to download history data, write the event number (1–50) to the EVENT LOG SEL register at address 1692 (when a zero is written to the register, the relay will return event number one). Then, read the history of the specific event number you requested from the registers shown in the *Historical Data* section of the Modbus Register Map (*Table E.34*). After a power cycle, the history data registers show the history data corresponding to the latest event. This information updates dynamically; whenever there is a new event, the history data registers update automatically with new event data. If specific event number data have been retrieved using a write to the EVENT LOG SEL register, the event data registers stay frozen with that specific event history. These registers return to the free running latest event history data mode when a zero is written to the event selection register from a prior nonzero selection.

Modbus Register Map

NOTE: Certain Modbus quantities are reported as 32-bit numbers; however, Modbus registers are only 16-bit. This results in displaying the Modbus quantities in a LOW and HIGH register. To determine the 32-bit number, concatenate the LOW register to the end of the HIGH register. For example, if the HIGH register value is 0x5ADC and the LOW register value is 0xF43B, the resulting 32-bit value is 0x5ADCF43B.

Table E.34 lists the data available in the Modbus interface and its description, range, and scaling information. The table also shows the parameter number for access using the DeviceNet interface. The DeviceNet parameter number is obtained by adding 100 to the Modbus register address.

Table E.34 Modbus Register Map (Sheet 1 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
0 (R)	Reserved[c]		0	100	1		
User Map Register							
1 (R/W)	USER REG #1		644	1249	684	1	101
	•						
	•						
	•						
125 (R/W)	USER REG #125		644	1249	1249	1	225
User Map Reg Val							
126–250 (R)	USER REG#1 VAL–USER REG#125 VAL		0	65535	0	1	226–350
251–259 (R)	Reserved[c]		0	0	0		351–359
Access Control							
260 (R/W)	BLOCK MODBUS SET 0 = NONE 1 = R_S 2 = ALL		0	2	0		360

Table E.34 Modbus Register Map (Sheet 2 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
General Settings							
261 (R/W)	PHASE ROTATION 0 = ABC 1 = ACB		0	1	0		361
262 (R/W)	RATED FREQ. 0 = 50 1 = 60	Hz	0	1	1		362
263 (R/W)	DATE FORMAT 0 = MDY 1 = YMD 2 = DMY		0	2	0		363
264 (R/W)	EVE MSG PTS EN		0	32	0	1	364
Group Selection							
265 (R/W)	GRP CHG DELAY	sec	0	400	3	1	365
Breaker Failure Set							
266 (R/W)	52A INTERLOCK 0 = N 1 = Y		0	1	0		366
267 (R/W)	BRKR1 FAIL DELAY	sec	0	200	50	0.01	367
268 (R/W)	BRKR2 FAIL DELAY	sec	0	200	50	0.01	368
Through-Fault Set							
269 (R/W)	THR FLT WDG 0 = OFF 1 = 1 2 = 2		0	2	0		369
270 (R/W)	THR FLT ALARM PU	%	500	9000	1000	0.1	370
271 (R/W)	XFMR IMPEDANCE	%	20	400	100	0.1	371
272 (R/W)	IRIG TIME SOURCE 0 = IRIG1 1 = IRIG2		0	1	0		372
273–275 (R)	Reserved[c]		0	0	0		373–375
Configuration Settings							
276 (R/W)	WDG1 CT CONN 0 = DELTA 1 = WYE		0	1	1		376
277 (R/W)	WDG2 CT CONN 0 = DELTA 1 = WYE		0	1	1		377
278 (R/W)	WDG1 PHASE CTR		1	50000	100	1	378
279 (R/W)	WDG2 PHASE CTR		1	50000	1000	1	379
280 (R/W)	MVA SET ENABLE		0	1	1		380
281 (R/W)	MAX XFMR CAP	MVA	2	50000	500	0.1	381
282 (R/W)	DEFINE CT COMP 0 = N 1 = Y		0	1	0		382
283 (R/W)	WDG1 CT COMP		0	12	12	1	383
284 (R/W)	WDG2 CT COMP		0	12	12	1	384
285 (R/W)	WDG1 L-L INT KV	kV	0	1000	138	1	385
286 (R/W)	WDG1 L-L FRAC KV	kV	0	99	0	0.01	386
287 (R/W)	WDG2 L-L INT KV	kV	0	1000	13	1	387
288 (R/W)	WDG2 L-L FRAC KV	kV	0	99	80	0.01	388

Table E.34 Modbus Register Map (Sheet 3 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
289 (R/W)	NEUT1 CT RATIO		1	50000	120	1	389
290 (R/W)	PHASE PT RATIO		1	10000	120	1	390
291 (R/W)	PHASE PTR FRAC		0	99	0	0.01	391
292 (R/W)	VNOM INT KV	kV	0	1000	13	1	392
293 (R/W)	VNOM FRAC ICV	kV	0	99	80	0.01	393
294 (R/W)	PT CONNECTION 0 = DELTA 1 = WYE		0	1	0		394
295 (R/W)	VOLT-CURR WDG		1	2	2	1	395
296 (R/W)	COMP ANGLE	Deg	0	360	0	1	396
297 (R/W)	SINGLE V INPUT 0 = N 1 = Y		0	1	0		397
Transformer Differential (Xfmr Differential)							
298 (R/W)	XFMR DIFF ENABLE 0 = N 1 = Y		0	1	1		398
299 (R/W)	WDG1 CURR TAP	A	10	3100	100	0.01	399
300 (R/W)	WDG2 CURR TAP	A	10	3100	100	0.01	400
301 (R/W)	OPERATE CURR LVL	pu	10	100	30	0.01	401
302 (R/W)	87A ENABLE 0 = N 1 = Y		0	1	1		402
303 (R/W)	DIFF CURR AL LVL	pu	5	100	15	0.01	403
304 (R/W)	DIFF CURR AL DLY	sec	10	1200	50	0.1	404
305 (R/W)	RESTRAINT SLOPE1	%	5	90	25	1	405
306 (R)	Reserved[c]		0	0	0		406
307 (R/W)	RESTRAINT SLOPE2	%	5	90	70	1	407
308 (R/W)	RES SLOPE1 LIMIT	pu	10	200	30	0.1	408
309 (R/W)	UNRES CURR LVL	pu	10	200	100	0.1	409
310 (R/W)	PCT2 ENABLE 0 = N 1 = Y		0	1	1		410
311 (R/W)	2ND HARM BLOCK	%	5	100	15	1	411
312 (R/W)	PCT4 ENABLE 0 = N 1 = Y		0	1	1		412
313 (R/W)	4TH HARM BLOCK	%	5	100	15	1	413
314 (R/W)	PCT5 ENABLE 0 = N 1 = Y		0	1	1		414
315 (R/W)	5TH HARM BLOCK	%	5	100	35	1	415
316 (R/W)	TH5 ENABLE 0 = N 1 = Y		0	1	0		416
317 (R/W)	5TH HARM AL LVL	pu	2	320	10	0.01	417
318 (R/W)	5TH HARM AL DLY	sec	0	1200	10	0.1	418
319 (R/W)	HARMONIC RESTRNT 0 = N 1 = Y		0	1	1		419

Table E.34 Modbus Register Map (Sheet 4 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
320 (R/W)	HARM BLOCK 0 = N 1 = Y		0	1	0		420
321 (R)	Reserved[c]		0	0	0		421
Restricted Earth Fault							
322 (R/W)	POL QTY FROM WDG 0 = OFF 1 = 1 2 = 2 3 = 12		0	3	0		422
323 (R/W)	REF1 CURR LEVEL	pu	5	300	25	0.01	423
Winding 1 Maximum Phase Instantaneous Overcurrent (WDG1 Max Ph IOC)							
324 (R/W)	WDG1 IOC L1 EN 0 = N 1 = Y		0	1	0		424
325 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	425
326 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	426
327 (R/W)	WDG1 IOC L2 EN 0 = N 1 = Y		0	1	0		427
328 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	428
329 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	429
330 (R/W)	WDG1 IOC L3 EN 0 = N 1 = Y		0	1	0		430
331 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	431
332 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	432
333 (R/W)	WDG1 IOC L4 EN 0 = N 1 = Y		0	1	0		433
334 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	434
335 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	435
Winding 1 Residual Instantaneous Overcurrent (WDG1 Res IOC)							
336 (R/W)	WDG1 RESIOC L1EN 0 = N 1 = Y		0	1	0		436
337 (R/W)	RES IOC LEVEL	A	10	9600	200	0.01	437
338 (R/W)	RES IOC DELAY	sec	0	500	50	0.01	438
339 (R/W)	WDG1 RESIOC L2EN 0 = N 1 = Y		0	1	0		439
340 (R/W)	RES IOC LEVEL	A	10	9600	200	0.01	440
341 (R/W)	RES IOC DELAY	sec	0	500	50	0.01	441
Winding 1 Negative-Sequence Instantaneous Overcurrent (WDG1 Neg Seq IOC)							
342 (R/W)	W1 NSEQ IOC L1EN 0 = N 1 = Y		0	1	0		442
343 (R/W)	NSEQ IOC LEVEL	A	10	9600	200	0.01	443
344 (R/W)	NSEQ IOC DELAY	sec	1	1200	2	0.1	444

Table E.34 Modbus Register Map (Sheet 5 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
345 (R/W)	W1 NSEQ IOC L2EN 0 = N 1 = Y		0	1	0		445
346 (R/W)	NSEQ IOC LEVEL	A	10	9600	200	0.01	446
347 (R/W)	NSEQ IOC DELAY	sec	1	1200	2	0.1	447
Winding 1 Maximum Phase Time-Overcurrent (WDG1 Max Ph TOC)							
348 (R/W)	WDG1 TOC ENABLE 0 = N 1 = Y		0	1	0		448
349 (R/W)	PHASE TOC LEVEL	A	10	1600	120	0.01	449
350 (R/W)	PHASE TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2		450
351 (R/W)	PHASE TOC TDIAL		5	1500	300	0.01	451
352 (R/W)	EM RESET DELAY 0 = N 1 = Y		0	1	0		452
353 (R/W)	CONST TIME ADDER	sec	0	100	0	0.01	453
354 (R/W)	MIN RESPONSE TIM	sec	0	100	0	0.01	454
Winding 1 Residual Time Overcurrent (WDG1 Res TOC)							
355 (R/W)	WDG1 RES TOC EN 0 = N 1 = Y		0	1	0		455
356 (R/W)	RES TOC LEVEL	A	10	1600	10	0.01	456
357 (R/W)	RES TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2		457
358 (R/W)	RES TOC TDIAL		5	1500	150	0.01	458
359 (R/W)	EM RESET DELAY 0 = N 1 = Y		0	1	0		459
360 (R/W)	CONST TIME ADDER	sec	0	100	0	0.01	460
361 (R/W)	MIN RESPONSE TIM	sec	0	100	0	0.01	461
Winding 1 Negative-Sequence Time-Overcurrent (WDG1 Neq Seq TOC)							
362 (R/W)	WDG1 NSEQ TOC EN 0 = N 1 = Y		0	1	0		462
363 (R/W)	NSEQ TOC LEVEL	A	10	1600	120	0.01	463
364 (R/W)	NSEQ TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2		464
365 (R/W)	NSEQ TOC TDIAL		5	1500	300	0.01	465
366 (R/W)	EM RESET DELAY 0 = N 1 = Y		0	1	0		466

Table E.34 Modbus Register Map (Sheet 6 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
367 (R/W)	CONST TIME ADDER	sec	0	100	0	0.01	467
368 (R/W)	MIN RESPONSE TIM	sec	0	100	0	0.01	468
Winding 2 Maximum Phase Instantaneous Overcurrent (WDG2 Max Ph IOC)							
369 (R/W)	WDG2 IOC L1 EN 0 = N 1 = Y		0	1	0		469
370 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	470
371 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	471
372 (R/W)	WDG2 IOC L2 EN 0 = N 1 = Y		0	1	0		472
373 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	473
374 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	474
375 (R/W)	WDG2 IOC L3 EN 0 = N 1 = Y		0	1	0		475
376 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	476
377 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	477
378 (R/W)	WDG2 IOC L4 EN 0 = N 1 = Y		0	1	0		478
379 (R/W)	PHASE IOC LEVEL	A	10	9600	200	0.01	479
380 (R/W)	PHASE IOC DELAY	sec	0	500	0	0.01	480
Winding 2 Residual Instantaneous Overcurrent (WDG2 Res IOC)							
381 (R/W)	WDG2 RESIOC L1EN 0 = N 1 = Y		0	1	0		481
382 (R/W)	RES IOC LEVEL	A	10	9600	200	0.01	482
383 (R/W)	RES IOC DELAY	sec	0	500	50	0.01	483
384 (R/W)	WDG2 RESIOC L2EN 0 = N 1 = Y		0	1	0		484
385 (R/W)	RES IOC LEVEL	A	10	9600	200	0.01	485
386 (R/W)	RES IOC DELAY	sec	0	500	50	0.01	486
Winding 2 Negative-Sequence Instantaneous Overcurrent (WDG2 Neg Seq IOC)							
387 (R/W)	W2 NSEQ IOC L1EN 0 = N 1 = Y		0	1	0		487
388 (R/W)	NSEQ IOC LEVEL	A	10	9600	200	0.01	488
389 (R/W)	NSEQ IOC DELAY	sec	1	1200	2	0.1	489
390 (R/W)	W2 NSEQ IOC L2EN 0 = N 1 = Y		0	1	0		490
391 (R/W)	NSEQ IOC LEVEL	A	10	9600	200	0.01	491
392 (R/W)	NSEQ IOC DELAY	sec	1	1200	2	0.1	492
Winding 2 Maximum Phase Time-Overcurrent (WDG2 Max Ph TOC)							
393 (R/W)	WDG2 TOC ENABLE 0 = N 1 = Y		0	1	0		493
394 (R/W)	PHASE TOC LEVEL	A	10	1600	120	0.01	494

Table E.34 Modbus Register Map (Sheet 7 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
395 (R/W)	PHASE TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2		495
396 (R/W)	PHASE TOC TDIAL		5	1500	300	0.01	496
397 (R/W)	EM RESET DELAY 0 = N 1 = Y		0	1	0		497
398 (R/W)	CONST TIME ADDER	sec	0	100	0	0.01	498
399 (R/W)	MIN RESPONSE TIM	sec	0	100	0	0.01	499
Winding 2 Residual Time-Overcurrent (WDG2 Res TOC)							
400 (R/W)	WDG2 RES TOC EN 0 = N 1 = Y		0	1	0		500
401 (R/W)	RES TOC LEVEL	A	10	1600	10	0.01	501
402 (R/W)	RES TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2		502
403 (R/W)	RES TOC TDIAL		5	1500	150	0.01	503
404 (R/W)	EM RESET DELAY 0 = N 1 = Y		0	1	0		504
405 (R/W)	CONST TIME ADDER	sec	0	100	0	0.01	505
406 (R/W)	MIN RESPONSE TIM	sec	0	100	0	0.01	506
Winding 2 Negative-Sequence Time-Overcurrent (WDG2 Neq Seq TOC)							
407 (R/W)	WDG2 NSEQ TOC EN 0 = N 1 = Y		0	1	0		507
408 (R/W)	NSEQ TOC LEVEL	A	10	1600	120	0.01	508
409 (R/W)	NSEQ TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2		509
410 (R/W)	NSEQ TOC TDIAL		5	1500	300	0.01	510
411 (R/W)	EM RESET DELAY 0 = N 1 = Y		0	1	0		511
412 (R/W)	CONST TIME ADDER	sec	0	100	0	0.01	512
413 (R/W)	MIN RESPONSE TIM	sec	0	100	0	0.01	513
Neutral Instantaneous Overcurrent							
414 (R/W)	NEUT IOC L1 EN 0 = N 1 = Y		0	1	0		514
415 (R/W)	NEUT IOC LEVEL	A	10	9600	200	0.01	515
416 (R/W)	NEUT IOC DELAY	sec	0	500	50	0.01	516

Table E.34 Modbus Register Map (Sheet 8 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
417 (R/W)	NEUT IOC L2 EN 0 = N 1 = Y		0	1	0		517
418 (R/W)	NEUT IOC LEVEL	A	10	9600	200	0.01	518
419 (R/W)	NEUT IOC DELAY	sec	0	500	50	0.01	519
Neutral Time-Overcurrent							
420 (R/W)	NEUT TOC LVL EN 0 = N 1 = Y		0	1	0		520
421 (R/W)	NEUT TOC LEVEL	A	10	1600	10	0.01	521
422 (R/W)	NEUT TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2		522
423 (R/W)	NEUT TOC TDIAL		5	1500	150	0.01	523
424 (R/W)	EM RESET DELAY 0 = N 1 = Y		0	1	0		524
425 (R/W)	CONST TIME ADDER	sec	0	100	0	0.01	525
426 (R/W)	MIN RESPONSE TIM	sec	0	100	0	0.01	526
427–431 (R)	Reserved[c]		0	0	0		527–531
RTD Settings							
432 (R/W)	RTD ENABLE 0 = NONE 1 = INT 2 = EXT		0	2	0		532
433 (R/W)	RTD1 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		533
434 (R/W)	RTD1 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		534
435 (R/W)	RTD1 TRIP LEVEL 0 = Off	degC	0	250	0	1	535
436 (R/W)	RTD1 WARN LEVEL 0 = Off	degC	0	250	0	1	536
437 (R/W)	RTD2 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		537
438 (R/W)	RTD2 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		538
439 (R/W)	RTD2 TRIP LEVEL 0 = Off	degC	0	250	0	1	539
440 (R/W)	RTD2 WARN LEVEL 0 = Off	degC	0	250	0	1	540

Table E.34 Modbus Register Map (Sheet 9 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
441 (R/W)	RTD3 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		541
442 (R/W)	RTD3 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		542
443 (R/W)	RTD3 TRIP LEVEL 0 = Off	degC	0	250	0	1	543
444 (R/W)	RTD3 WARN LEVEL 0 = Off	degC	0	250	0	1	544
445 (R/W)	RTD4 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		545
446 (R/W)	RTD4 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		546
447 (R/W)	RTD4 TRIP LEVEL 0 = Off	degC	0	250	0	1	547
448 (R/W)	RTD4 WARN LEVEL 0 = Off	degC	0	250	0	1	548
449 (R/W)	RTD5 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		549
450 (R/W)	RTD5 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		550
451 (R/W)	RTD5 TRIP LEVEL 0 = Off	degC	0	250	0	1	551
452 (R/W)	RTD5 WARN LEVEL 0 = Off	degC	0	250	0	1	552
453 (R/W)	RTD6 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		553
454 (R/W)	RTD6 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		554
455 (R/W)	RTD6 TRIP LEVEL 0 = Off	degC	0	250	0	1	555
456 (R/W)	RTD6 WARN LEVEL 0 = Off	degC	0	250	0	1	556
457 (R/W)	RTD7 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		557

Table E.34 Modbus Register Map (Sheet 10 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
458 (R/W)	RTD7 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		558
459 (R/W)	RTD7 TRIP LEVEL 0 = Off	degC	0	250	0	1	559
460 (R/W)	RTD7 WARN LEVEL 0 = Off	degC	0	250	0	1	560
461 (R/W)	RTD8 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		561
462 (R/W)	RTD8 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		562
463 (R/W)	RTD8 TRIP LEVEL 0 = Off	degC	0	250	0	1	563
464 (R/W)	RTD8 WARN LEVEL 0 = Off	degC	0	250	0	1	564
465 (R/W)	RTD9 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		565
466 (R/W)	RTD9 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		566
467 (R/W)	RTD9 TRIP LEVEL 0 = Off	degC	0	250	0	1	567
468 (R/W)	RTD9 WARN LEVEL 0 = Off	degC	0	250	0	1	568
469 (R/W)	RTD10 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		569
470 (R/W)	RTD10 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		570
471 (R/W)	RTD10 TRIP LEVEL 0 = Off	degC	0	250	0	1	571
472 (R/W)	RTD10 WARN LEVEL 0 = Off	degC	0	250	0	1	572
473 (R/W)	RTD11 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		573
474 (R/W)	RTD11 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		574
475 (R/W)	RTD11 TRIP LEVEL 0 = Off	degC	0	250	0	1	575
476 (R/W)	RTD11 WARN LEVEL 0 = Off	degC	0	250	0	1	576

Table E.34 Modbus Register Map (Sheet 11 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
477 (R/W)	RTD12 LOCATION 0 = OFF 1 = AMB 2 = OTH		0	2	0		577
478 (R/W)	RTD12 TYPE 0 = PT100 1 = NI100 2 = NI120 3 = CU10		0	3	0		578
479 (R/W)	RTD12 TRIP LEVEL 0 = Off	degC	0	250	0	1	579
480 (R/W)	RTD12 WARN LEVEL 0 = Off	degC	0	250	0	1	580
481–486 (R)	Reserved[c]		0	0	0		581–586
Phase Undervoltage							
487 (R/W)	PHASE UV LVL1 EN 0 = N 1 = Y		0	1	0		587
488 (R/W)	PHASE UV LEVEL	V	125	3000	600	0.1	588
489 (R/W)	PHASE UV DELAY	sec	0	1200	5	0.1	589
490 (R/W)	PHASE UV LVL2 EN 0 = N 1 = Y		0	1	0		590
491 (R/W)	PHASE UV LEVEL	V	125	3000	600	0.1	591
492 (R/W)	PHASE UV DELAY	sec	0	1200	50	0.1	592
Phase Overvoltage							
493 (R/W)	PHASE OV LVL1 EN 0 = N 1 = Y		0	1	0		593
494 (R/W)	PHASE OV LEVEL	V	125	3000	2400	0.1	594
495 (R/W)	PHASE OV DELAY	sec	0	1200	5	0.1	595
496 (R/W)	PHASE OV LVL2 EN 0 = N 1 = Y		0	1	0		596
497 (R/W)	PHASE OV LEVEL	V	125	3000	2400	0.1	597
498 (R/W)	PHASE OV DELAY	sec	0	1200	50	0.1	598
Negative-Sequence Overvoltage							
499 (R/W)	NSEQ OV LVL1 EN 0 = N 1 = Y		0	1	0		599
500 (R/W)	NSEQ OV LEVEL	V	125	3000	2400	0.1	600
501 (R/W)	NSEQ OV DELAY	sec	0	1200	5	0.1	601
502 (R/W)	NSEQ OV LVL2 EN 0 = N 1 = Y		0	1	0		602
503 (R/W)	NSEQ OV LEVEL	V	125	3000	2400	0.1	603
504 (R/W)	NSEQ OV DELAY	sec	0	1200	50	0.1	604
505–514 (R)	Reserved[c]		0	0	0		605–614

Table E.34 Modbus Register Map (Sheet 12 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
Volts/Hertz							
515 (R/W)	ENABLE V/HZ PROT 0 = N 1 = Y		0	1	1		615
516 (R/W)	XFMR WDG CONN 0 = DELTA 1 = WYE		0	1	1		616
517 (R/W)	LVL1 V/HZ PICKUP	%	100	200	105	1	617
518 (R/W)	LVL1 TIME DLY	sec	4	40000	100	0.01	618
519 (R/W)	LVL2 CURVE SHAPE 0 = OFF 1 = DD 2 = ID 3 = I 4 = U		0	4	2		619
520 (R/W)	LVL2 INV-TM PU	%	100	200	105	1	620
521 (R/W)	LVL2 INV-TM CURV 0 = 0.5 1 = 1.0 2 = 2.0		0	2	2		621
522 (R/W)	LVL2 INV-TM FCTR	sec	1	100	1	0.1	622
523 (R/W)	LVL2 PICKUP 1	%	100	200	175	1	623
524 (R/W)	LVL2 TIME DLY 1	sec	4	40000	300	0.01	624
525 (R/W)	LVL2 PICKUP 2	%	101	200	176	1	625
526 (R/W)	LVL2 TIME DLY 2	sec	4	40000	300	0.01	626
527 (R/W)	LVL2 RESET TIME	sec	0	40000	24000	0.01	627
Power Elements							
528 (R/W)	ENABLE PWR ELEM 0 = N 1 = 3P1 2 = 3P2		0	2	0		628
529 (R/W)	ENABLE 3PWR1P 0 = N 1 = Y		0	1	0		629
530 (R/W)	3PH PWR ELEM PU	VA	2	65000	20000	0.1	630
531 (R/W)	PWR ELEM TYPE 0 = +WATTS 1 = –WATTS 2 = +VARS 3 = –VARS		0	3	2		631
532 (R/W)	PWR ELEM DELAY	sec	0	2400	0	0.1	632
533 (R/W)	ENABLE 3PWR2P 0 = N 1 = Y		0	1	0		633
534 (R/W)	3PH PWR ELEM PU	VA	2	65000	20000	0.1	634
535 (R/W)	PWR ELEM TYPE 0 = +WATTS 1 = –WATTS 2 = +VARS 3 = –VARS		0	3	2		635
536 (R/W)	PWR ELEM DELAY	sec	0	2400	0	0.1	636

Table E.34 Modbus Register Map (Sheet 13 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
Frequency Settings							
537 (R/W)	FREQ1 TRIP ENABL 0 = N 1 = Y		0	1	0		637
538 (R/W)	FREQ1 TRIP LEVEL	Hz	200	700	600	0.1	638
539 (R/W)	FREQ1 TRIP DELAY	sec	0	2400	10	0.1	639
540 (R/W)	FREQ2 TRIP ENABL 0 = N 1 = Y		0	1	0		640
541 (R/W)	FREQ2 TRIP LEVEL	Hz	200	700	600	0.1	641
542 (R/W)	FREQ2 TRIP DELAY	sec	0	2400	10	0.1	642
543 (R/W)	FREQ3 TRIP ENABL 0 = N 1 = Y		0	1	0		643
544 (R/W)	FREQ3 TRIP LEVEL	Hz	200	700	600	0.1	644
545 (R/W)	FREQ3 TRIP DELAY	sec	0	2400	10	0.1	645
546 (R/W)	FREQ4 TRIP ENABL 0 = N 1 = Y		0	1	0		646
547 (R/W)	FREQ4 TRIP LEVEL	Hz	200	700	600	0.1	647
548 (R/W)	FREQ4 TRIP DELAY	sec	0	2400	10	0.1	648
Demand Metering							
549 (R/W)	ENABLE DEM MTR 0 = OFF 1 = W1 2 = W2		0	2	0		649
550 (R/W)	DEMAND MTR TYPE 0 = THM 1 = ROL		0	1	0		650
551 (R/W)	DEM TIME CONSTNT 0 = 5 1 = 10 2 = 15 3 = 30 4 = 60	min	0	4	0		651
552 (R/W)	PH CURR DEM LVL	A	1	160	50	0.1	652
553 (R/W)	RES CURR DEM LVL	A	1	160	10	0.1	653
554 (R/W)	3I2 CURR DEM LVL	A	1	160	10	0.1	654
555–564 (R)	Reserved[c]		0	0	0		655–664
Trip/Close Logic							
565 (R/W)	MIN TRIP TIME	sec	0	4000	5	0.1	665
566 (R/W)	CLOSE1 FAIL DLY	sec	0	4000	5	0.1	666
567 (R/W)	CLOSE2 FAIL DLY	sec	0	4000	5	0.1	667
568–575 (R)	Reserved[c]		0	0	0		668–675
SELOGIC Enables							
576 (R/W)	SELOGIC LATCHES		0	32	4	1	676
577 (R/W)	SV/TIMERS		0	32	5	1	677
578 (R/W)	SELOGIC COUNTERS		0	32	0	1	678

Table E.34 Modbus Register Map (Sheet 14 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
579 (R/W)	MATH VARIABLES		0	32	0	1	679
580–584 (R)	Reserved[c]		0	0	0		680–684
Output Contacts 0 = N 1 = Y							
585 (R/W)	OUT101 FAIL-SAFE		0	1	1		685
586 (R/W)	OUT102 FAIL-SAFE		0	1	0		686
587 (R/W)	OUT103 FAIL-SAFE		0	1	0		687
588 (R/W)	OUT301 FAIL-SAFE		0	1	0		688
589 (R/W)	OUT302 FAIL-SAFE		0	1	0		689
590 (R/W)	OUT303 FAIL-SAFE		0	1	0		690
591 (R/W)	OUT304 FAIL-SAFE		0	1	0		691
592 (R/W)	OUT401 FAIL-SAFE		0	1	0		692
593 (R/W)	OUT402 FAIL-SAFE		0	1	0		693
594 (R/W)	OUT403 FAIL-SAFE		0	1	0		694
595 (R/W)	OUT404 FAIL-SAFE		0	1	0		695
596 (R/W)	OUT501 FAIL-SAFE		0	1	0		696
597 (R/W)	OUT502 FAIL-SAFE		0	1	0		697
598 (R/W)	OUT503 FAIL-SAFE		0	1	0		698
599 (R/W)	OUT504 FAIL-SAFE		0	1	0		699
600–604 (R)	Reserved[c]		0	0	0		700–704
Event Report Set							
605 (R/W)	EVENT LENGTH 0 = 15 1 = 64	cyc	0	1	0		705
606 (R/W)	PREFAULT LENGTH	cyc	1	59	5	1	706
607 (R)	Reserved[c]		0	0	0		707
608 (R/W)	ENABLE ALIASES		0	20	4	1	708
609 (R/W)	LDP ACQ RATE 0 = 5 1 = 10 2 = 15 3 = 30 4 = 60	min	0	4	2		709
610 (R/W)	AUTO-REMOVAL EN 0 = N 1 = Y		0	1	0		710
611 (R)	NUM OF COUNTS		2	20	5	1	711
612 (R)	REMOVAL TIME	sec	1	900	10	0.1	712
613–614 (R)	Reserved[c]		0	0	0		713–714
Front Panel Set							
615 (R/W)	DISPLY PTS ENABL		0	32	4	1	715
616 (R/W)	LOCAL BITS ENABL		0	32	0	1	716
617 (R/W)	LCD TIMEOUT 0 = Off	min	0	30	15	1	717
618 (R/W)	LCD CONTRAST		1	8	5	1	718
619 (R/W)	CLOSE RESET LEDS 0 = N 1 = Y		0	1	1		719
620–624 (R)	Reserved[c]		0	0	0		720–724

Table E.34 Modbus Register Map (Sheet 15 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
Reset Settings							
625 (R/W)	RESET DATA Bit 0 = TRIP RESET Bit 1 = SET TO DEFAULTS Bit 2 = RESET STAT DATA Bit 3 = RESET HIST DATA Bit 4 = RESET COMM CNTR Bit 5 = Reserved[c] Bit 6 = RST ENRGY DATA Bit 7 = RST MX/MN DATA Bit 8 = RST DEMAND Bit 9 = RST PEAK DEMAND Bits 10–Bit 15 = Reserved		0	1023	0		725
626–635 (R)	Reserved[c]		0	0	0		726–735
Date/Time Set							
636 (R/W)	SET SEC		0	5999	0	0.01	736
637 (R/W)	SET MIN		0	59	0	1	737
638 (R/W)	SET HOUR		0	23	0	1	738
639 (R/W)	SET DAY		1	31	1	1	739
640 (R/W)	SET MONTH		1	12	1	1	740
641 (R/W)	SET YEAR		2000	9999	2000	1	741
642–643 (R)	Reserved[c]		0	0	0		742–743
Device Status	0 = OK 1 = WARN 2 = FAIL						
644 (R)	FPGA STATUS		0	2	0		744
645 (R)	GPSB STATUS		0	2	0		745
646 (R)	HMI STATUS		0	2	0		746
647 (R)	RAM STATUS		0	2	0		747
648 (R)	ROM STATUS		0	2	0		748
649 (R)	CR_RAM STATUS		0	2	0		749
650 (R)	NON_VOL STATUS		0	2	0		750
651 (R)	CLOCK STATUS		0	2	0		751
652 (R)	CID FILE STATUS		0	2	0		752
653 (R)	RTD STATUS		0	2	0		753
654 (R)	+3.3V STATUS		0	2	0		754
655 (R)	+5.0V STATUS		0	2	0		755
656 (R)	+2.5V STATUS		0	2	0		756
657 (R)	+3.75V STATUS		0	2	0		757
658 (R)	–1.25V STATUS		0	2	0		758
659 (R)	–5.0V STATUS		0	2	0		759
660 (R)	CLK_BAT STATUS		0	2	0		760
661 (R)	CT BOARD STATUS		0	2	0		761
662 (R)	CARD C STATUS		0	2	0		762
663 (R)	CARD D STATUS		0	2	0		763
664 (R)	CARD E STATUS		0	2	0		764
665 (R)	IAW1 STATUS		0	2	0		765
666 (R)	IBW1 STATUS		0	2	0		766
667 (R)	ICW1 STATUS		0	2	0		767

Table E.34 Modbus Register Map (Sheet 16 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
668 (R)	IAW2 STATUS		0	2	0		768
669 (R)	IBW2 STATUS		0	2	0		769
670 (R)	ICW2 STATUS		0	2	0		770
671 (R)	IN STATUS		0	2	0		771
672 (R)	VA STATUS		0	2	0		772
673 (R)	VB STATUS		0	2	0		773
674 (R)	VC STATUS		0	2	0		774
675 (R)	RELAY STATUS 0 = ENABLED 1 = DISABLED		0	1	0		775
676–683 (R)	Reserved[c]		0	0	0		776–783
Current Data							
684 (R)	IAW1 CURRENT	A	0	65535	0	1	784
685 (R)	IAW1 ANGLE	deg	–1800	1800	0	0.1	785
686 (R)	IBW1 CURRENT	A	0	65535	0	1	786
687 (R)	IBW1 ANGLE	deg	–1800	1800	0	0.1	787
688 (R)	ICW1 CURRENT	A	0	65535	0	1	788
689 (R)	ICW1 ANGLE	deg	–1800	1800	0	0.1	789
690 (R)	IGW1 CURRENT	A	0	65535	0	1	790
691 (R)	IGW1 ANGLE	deg	–1800	1800	0	0.1	791
692 (R)	3I2W1 NSEQ CURR	A	0	65535	0	1	792
693 (R)	W1 AVERAGE CURR	A	0	65535	0	1	793
694 (R)	IAW2 CURRENT	A	0	65535	0	1	794
695 (R)	IAW2 ANGLE	deg	–1800	1800	0	0.1	795
696 (R)	IBW2 CURRENT	A	0	65535	0	1	796
697 (R)	IBW2 ANGLE	deg	–1800	1800	0	0.1	797
698 (R)	ICW2 CURRENT	A	0	65535	0	1	798
699 (R)	ICW2 ANGLE	deg	–1800	1800	0	0.1	799
700 (R)	IGW2 CURRENT	A	0	65535	0	1	800
701 (R)	IGW2 ANGLE	deg	–1800	1800	0	0.1	801
702 (R)	3I2W2 NSEQ CURR	A	0	65535	0	1	802
703 (R)	W2 AVERAGE CURR	A	0	65535	0	1	803
704 (R)	IN CURRENT	A	0	65535	0	1	804
705 (R)	IN ANGLE	deg	–1800	1800	0	0.1	805
706–708 (R)	Reserved[c]		0	0	0		806–808
Voltage Data							
709 (R)	VAB	V	0	65535	0	1	809
710 (R)	VAB ANGLE	deg	–1800	1800	0	0.1	810
711 (R)	VBC	V	0	65535	0	1	811
712 (R)	VBC ANGLE	deg	–1800	1800	0	0.1	812
713 (R)	VCA	V	0	65535	0	1	813
714 (R)	VCA ANGLE	deg	–1800	1800	0	0.1	814
715 (R)	AVERAGE LINE V[d]	V	0	65535	0	1	815

Table E.34 Modbus Register Map (Sheet 17 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
716 (R)	VAN	V	0	65535	0	1	816
717 (R)	VAN ANGLE	deg	–1800	1800	0	0.1	817
718 (R)	VBN	V	0	65535	0	1	818
719 (R)	VBN ANGLE	deg	–1800	1800	0	0.1	819
720 (R)	VCN	V	0	65535	0	1	820
721 (R)	VCN ANGLE	deg	–1800	1800	0	0.1	821
722 (R)	VG	V	0	65535	0	1	822
723 (R)	VG ANGLE	deg	–1800	1800	0	0.1	823
724 (R)	AVERAGE L-N VOLT[e]	V	0	65535	0	1	824
725 (R)	NEG-SEQ VOLT 3V2	V	0	65535	0	1	825
Power Data							
726 (R)	REAL POWER	kW	–32768	32767	0	1	826
727 (R)	REACTIVE POWER	kVAR	–32768	32767	0	1	827
728 (R)	APPARENT POWER	kVA	–32768	32767	0	1	828
729 (R)	POWER FACTOR		–100	100	0	0.01	829
730 (R)	VOLTS PER HERTZ	%	0	1000	0	0.1	830
731 (R)	FREQUENCY	Hz	200	700	600	0.1	831
Energy Data[f]							
732 (R)	MWHP HI	MWhr	0	65535	0	0.001	832
733 (R)	MWHP LO	MWhr	0	65535	0	0.001	833
734 (R)	MWHN HI	MWhr	0	65535	0	0.001	834
735 (R)	MWHN LO	MWhr	0	65535	0	0.001	835
736 (R)	MVRHP HI	MVRh	0	65535	0	0.001	836
737 (R)	MVRHP LO	MVRh	0	65535	0	0.001	837
738 (R)	MVRHN HI	MVRh	0	65535	0	0.001	838
739 (R)	MVRHN LO	MVRh	0	65535	0	0.001	839
740 (R)	LAST RST TIME-ss		0	5999	0	0.01	840
741 (R)	LAST RST TIME-mm		0	59	0	1	841
742 (R)	LAST RST TIME-hh		0	23	0	1	842
743 (R)	LAST RST DATE-dd		1	31	1	1	843
744 (R)	LAST RST DATE-mm		1	12	1	1	844
745 (R)	LAST RST DATE-yy		2000	9999	2000	1	845
746–753 (R)	Reserved[c]		0	0	0		846–853
Demand Data							
754 (R)	IA DEMAND	A	0	65535	0	1	854
755 (R)	IB DEMAND	A	0	65535	0	1	855
756 (R)	IC DEMAND	A	0	65535	0	1	856
757 (R)	IG DEMAND	A	0	65535	0	1	857
758 (R)	3I2 DEMAND	A	0	65535	0	1	858
Peak Demand Data							
759 (R)	IA PEAK DEMAND	A	0	65535	0	1	859
760 (R)	IB PEAK DEMAND	A	0	65535	0	1	860

Table E.34 Modbus Register Map (Sheet 18 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
761 (R)	IC PEAK DEMAND	A	0	65535	0	1	861
762 (R)	IG PEAK DEMAND	A	0	65535	0	1	862
763 (R)	3I2 PEAK DEMAND	A	0	65535	0	1	863
764 (R)	PEAKD RST TIM-ss		0	5999	0	0.01	864
765 (R)	PEAKD RST TIM-mm		0	59	0	1	865
766 (R)	PEAKD RST TIM-hh		0	23	0	1	866
767 (R)	PEAKD RST DAT-dd		1	31	1	1	867
768 (R)	PEAKD RST DAT-mm		1	12	1	1	868
769 (R)	PEAKD RST DAT-yy		2000	9999	2000	1	869
Harmonic Data							
770 (R)	IAW1 THD	%	0	65535	0	0.1	870
771 (R)	IBW1 THD	%	0	65535	0	0.1	871
772 (R)	ICW1 THD	%	0	65535	0	0.1	872
773 (R)	IAW2 THD	%	0	65535	0	0.1	873
774 (R)	IBW2 THD	%	0	65535	0	0.1	874
775 (R)	ICW2 THD	%	0	65535	0	0.1	875
776 (R)	VA THD	%	0	65535	0	0.1	876
777 (R)	VB THD	%	0	65535	0	0.1	877
778 (R)	VC THD	%	0	65535	0	0.1	878
779 (R)	VAB THD	%	0	65535	0	0.1	879
780 (R)	VBC THD	%	0	65535	0	0.1	880
781 (R)	VCA THD	%	0	65535	0	0.1	881
RTD Data							
782 (R)	MAX AMBIENT RTD 7FFFh = Open 8000h = Short 7FFCh = Comm Fail 7FF8h = Stat Fail 7FFEh = Fail 7FF0h = NA	degC	–32768	32767	0	1	882
783 (R)	MAX OTHER RTD	degC	–32768	32767	0	1	883
784 (R)	RTD1	degC	–32768	32767	0	1	884
785 (R)	RTD2	degC	–32768	32767	0	1	885
786 (R)	RTD3	degC	–32768	32767	0	1	886
787 (R)	RTD4	degC	–32768	32767	0	1	887
788 (R)	RTD5	degC	–32768	32767	0	1	888
789 (R)	RTD6	degC	–32768	32767	0	1	889
790 (R)	RTD7	degC	–32768	32767	0	1	890
791 (R)	RTD8	degC	–32768	32767	0	1	891
792 (R)	RTD9	degC	–32768	32767	0	1	892
793 (R)	RTD10	degC	–32768	32767	0	1	893
794 (R)	RTD11	degC	–32768	32767	0	1	894
795 (R)	RTD12	degC	–32768	32767	0	1	895
796–806 (R)	Reserved[c]		0	0	0		896–906

Table E.34 Modbus Register Map (Sheet 19 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
RMS Data							
807 (R)	IAW1 RMS	A	0	65535	0	1	907
808 (R)	IBW1 RMS	A	0	65535	0	1	908
809 (R)	ICW1 RMS	A	0	65535	0	1	909
810 (R)	IAW2 RMS	A	0	65535	0	1	910
811 (R)	IBW2 RMS	A	0	65535	0	1	911
812 (R)	ICW2 RMS	A	0	65535	0	1	912
813 (R)	IN RMS	A	0	65535	0	1	913
814 (R)	VA RMS	V	0	65535	0	1	914
815 (R)	VB RMS	V	0	65535	0	1	915
816 (R)	VC RMS	V	0	65535	0	1	916
817 (R)	VAB RMS	V	0	65535	0	1	917
818 (R)	VBC RMS	V	0	65535	0	1	918
819 (R)	VCA RMS	V	0	65535	0	1	919
MAX/MIN MTR Data							
820 (R)	IAW1 MAX	A	0	65535	0	1	920
821 (R)	IAW1 MIN	A	0	65535	0	1	921
822 (R)	IBW1 MAX	A	0	65535	0	1	922
823 (R)	IBW1 MIN	A	0	65535	0	1	923
824 (R)	ICW1 MAX	A	0	65535	0	1	924
825 (R)	ICW1 MIN	A	0	65535	0	1	925
826 (R)	IGW1 MAX	A	0	65535	0	1	926
827 (R)	IGW1 MIN	A	0	65535	0	1	927
828 (R)	IAW2 MAX	A	0	65535	0	1	928
829 (R)	IAW2 MIN	A	0	65535	0	1	929
830 (R)	IBW2 MAX	A	0	65535	0	1	930
831 (R)	IBW2 MIN	A	0	65535	0	1	931
832 (R)	ICW2 MAX	A	0	65535	0	1	932
833 (R)	ICW2 MIN	A	0	65535	0	1	933
834 (R)	IGW2 MAX	A	0	65535	0	1	934
835 (R)	IGW2 MIN	A	0	65535	0	1	935
836 (R)	IN MAX	A	0	65535	0	1	936
837 (R)	IN MIN	A	0	65535	0	1	937
838 (R)	VAB/VA MAX	V	0	65535	0	1	938
839 (R)	VAB/VA MIN	V	0	65535	0	1	939
840 (R)	VBC/VB MAX	V	0	65535	0	1	940
841 (R)	VBC/VB MIN	V	0	65535	0	1	941
842 (R)	VCA/VC MAX	V	0	65535	0	1	942
843 (R)	VCA/VC MIN	V	0	65535	0	1	943
844 (R)	KW3P MAX	kW	–32768	32767	0	1	944
845 (R)	KW3P MIN	kW	–32768	32767	0	1	945
846 (R)	KVAR3P MAX	kVAR	–32768	32767	0	1	946

Table E.34 Modbus Register Map (Sheet 20 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
847 (R)	KVAR3P MIN	kVAR	–32768	32767	0	1	947
848 (R)	KVA3P MAX	kVA	–32768	32767	0	1	948
849 (R)	KVA3P MIN	kVA	–32768	32767	0	1	949
850 (R)	FREQ MAX	Hz	0	65535	0	0.1	950
851 (R)	FREQ MIN	Hz	0	65535	0	0.1	951
MAX/MIN RTD Data							
852 (R)	RTD1 MAX	degC	–32768	32767	0	1	952
853 (R)	RTD1 MIN	degC	–32768	32767	0	1	953
854 (R)	RTD2 MAX	degC	–32768	32767	0	1	954
855 (R)	RTD2 MIN	degC	–32768	32767	0	1	955
856 (R)	RTD3 MAX	degC	–32768	32767	0	1	956
857 (R)	RTD3 MIN	degC	–32768	32767	0	1	957
858 (R)	RTD4 MAX	degC	–32768	32767	0	1	958
859 (R)	RTD4 MIN	degC	–32768	32767	0	1	959
860 (R)	RTD5 MAX	degC	–32768	32767	0	1	960
861 (R)	RTD5 MIN	degC	–32768	32767	0	1	961
862 (R)	RTD6 MAX	degC	–32768	32767	0	1	962
863 (R)	RTD6 MIN	degC	–32768	32767	0	1	963
864 (R)	RTD7 MAX	degC	–32768	32767	0	1	964
865 (R)	RTD7 MIN	degC	–32768	32767	0	1	965
866 (R)	RTD8 MAX	degC	–32768	32767	0	1	966
867 (R)	RTD8 MIN	degC	–32768	32767	0	1	967
868 (R)	RTD9 MAX	degC	–32768	32767	0	1	968
869 (R)	RTD9 MIN	degC	–32768	32767	0	1	969
870 (R)	RTD10 MAX	degC	–32768	32767	0	1	970
871 (R)	RTD10 MIN	degC	–32768	32767	0	1	971
872 (R)	RTD11 MAX	degC	–32768	32767	0	1	972
873 (R)	RTD11 MIN	degC	–32768	32767	0	1	973
874 (R)	RTD12 MAX	degC	–32768	32767	0	1	974
875 (R)	RTD12 MIN	degC	–32768	32767	0	1	975
MAX/MIN AI3 Data[f]							
876 (R)	AI301 MX–HI	EU	–32768	32767	0	0.001	976
877 (R)	AI301 MX–LO	EU	–32768	32767	0	0.001	977
878 (R)	AI301 MN–HI	EU	–32768	32767	0	0.001	978
879 (R)	AI301 MN–LO	EU	–32768	32767	0	0.001	979
880 (R)	AI302 MX–HI	EU	–32768	32767	0	0.001	980
881 (R)	AI302 MX–LO	EU	–32768	32767	0	0.001	981
882 (R)	AI302 MN–HI	EU	–32768	32767	0	0.001	982
883 (R)	AI302 MN–LO	EU	–32768	32767	0	0.001	983
884 (R)	AI303 MX–HI	EU	–32768	32767	0	0.001	984
885 (R)	AI303 MX–LO	EU	–32768	32767	0	0.001	985
886 (R)	AI303 MN–HI	EU	–32768	32767	0	0.001	986

Table E.34 Modbus Register Map (Sheet 21 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
887 (R)	AI303 MN–LO	EU	–32768	32767	0	0.001	987
888 (R)	AI304 MX–HI	EU	–32768	32767	0	0.001	988
889 (R)	AI304 MX–LO	EU	–32768	32767	0	0.001	989
890 (R)	AI304 MN–HI	EU	–32768	32767	0	0.001	990
891 (R)	AI304 MN–LO	EU	–32768	32767	0	0.001	991
MAX/MIN AI4 Data[f]							
892 (R)	AI401 MX–HI	EU	–32768	32767	0	0.001	992
893 (R)	AI401 MX–LO	EU	–32768	32767	0	0.001	993
894 (R)	AI401 MN–HI	EU	–32768	32767	0	0.001	994
895 (R)	AI401 MN–LO	EU	–32768	32767	0	0.001	995
896 (R)	AI402 MX–HI	EU	–32768	32767	0	0.001	996
897 (R)	AI402 MX–LO	EU	–32768	32767	0	0.001	997
898 (R)	AI402 MN–HI	EU	–32768	32767	0	0.001	998
899 (R)	AI402 MN–LO	EU	–32768	32767	0	0.001	999
900 (R)	AI403 MX–HI	EU	–32768	32767	0	0.001	1000
901 (R)	AI403 MX–LO	EU	–32768	32767	0	0.001	1001
902 (R)	AI403 MN–HI	EU	–32768	32767	0	0.001	1002
903 (R)	AI403 MN–LO	EU	–32768	32767	0	0.001	1003
904 (R)	AI404 MX–HI	EU	–32768	32767	0	0.001	1004
905 (R)	AI404 MX–LO	EU	–32768	32767	0	0.001	1005
906 (R)	AI404 MN–HI	EU	–32768	32767	0	0.001	1006
907 (R)	AI404 MN–LO	EU	–32768	32767	0	0.001	1007
MAX/MIN AI5 Data[f]							
908 (R)	AI501 MX–HI	EU	–32768	32767	0	0.001	1008
909 (R)	AI501 MX–LO	EU	–32768	32767	0	0.001	1009
910 (R)	AI501 MN–HI	EU	–32768	32767	0	0.001	1010
911 (R)	AI501 MN–LO	EU	–32768	32767	0	0.001	1011
912 (R)	AI502 MX–HI	EU	–32768	32767	0	0.001	1012
913 (R)	AI502 MX–LO	EU	–32768	32767	0	0.001	1013
914 (R)	AI502 MN–HI	EU	–32768	32767	0	0.001	1014
915 (R)	AI502 MN–LO	EU	–32768	32767	0	0.001	1015
916 (R)	AI503 MX–HI	EU	–32768	32767	0	0.001	1016
917 (R)	AI503 MX–LO	EU	–32768	32767	0	0.001	1017
918 (R)	AI503 MN–HI	EU	–32768	32767	0	0.001	1018
919 (R)	AI503 MN–LO	EU	–32768	32767	0	0.001	1019
920 (R)	AI504 MX–HI	EU	–32768	32767	0	0.001	1020
921 (R)	AI504 MX–LO	EU	–32768	32767	0	0.001	1021
922 (R)	AI504 MN–HI	EU	–32768	32767	0	0.001	1022
923 (R)	AI504 MN–LO	EU	–32768	32767	0	0.001	1023
MAX/MIN RST Data							
924 (R)	MX/MN RST TIM-ss		0	5999	0	0.01	1024
925 (R)	MX/MN RST TIM-mm		0	59	0	1	1025

Table E.34 Modbus Register Map (Sheet 22 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
926 (R)	MX/MN RST TIM-hh		0	23	0	1	1026
927 (R)	MX/MN RST DAT-dd		1	31	1	1	1027
928 (R)	MX/MN RST DAT-mm		1	12	1	1	1028
929 (R)	MX/MN RST DAT-yy		2000	9999	2000	1	1029
930–939 (R)	Reserved[c]		0	0	0		1030–1039
Analog Input Data[f]							
940 (R)	AI301–HI	EU	–32768	32767	0	0.001	1040
941 (R)	AI301–LO	EU	–32768	32767	0	0.001	1041
942 (R)	AI302–HI	EU	–32768	32767	0	0.001	1042
943 (R)	AI302–LO	EU	–32768	32767	0	0.001	1043
944 (R)	AI303–HI	EU	–32768	32767	0	0.001	1044
945 (R)	AI303–LO	EU	–32768	32767	0	0.001	1045
946 (R)	AI304–HI	EU	–32768	32767	0	0.001	1046
947 (R)	AI304–LO	EU	–32768	32767	0	0.001	1047
948 (R)	AI401–HI	EU	–32768	32767	0	0.001	1048
949 (R)	AI401–LO	EU	–32768	32767	0	0.001	1049
950 (R)	AI402–HI	EU	–32768	32767	0	0.001	1050
951 (R)	AI402–LO	EU	–32768	32767	0	0.001	1051
952 (R)	AI403–HI	EU	–32768	32767	0	0.001	1052
953 (R)	AI403–LO	EU	–32768	32767	0	0.001	1053
954 (R)	AI404–HI	EU	–32768	32767	0	0.001	1054
955 (R)	AI404–LO	EU	–32768	32767	0	0.001	1055
956 (R)	AI501–HI	EU	–32768	32767	0	0.001	1056
957 (R)	AI501–LO	EU	–32768	32767	0	0.001	1057
958 (R)	AI502–HI	EU	–32768	32767	0	0.001	1058
959 (R)	AI502–LO	EU	–32768	32767	0	0.001	1059
960 (R)	AI503–HI	EU	–32768	32767	0	0.001	1060
961 (R)	AI503–LO	EU	–32768	32767	0	0.001	1061
962 (R)	AI504–HI	EU	–32768	32767	0	0.001	1062
963 (R)	AI504–LO	EU	–32768	32767	0	0.001	1063
964–969 (R)	Reserved[c]		0	0	0		1064–1069
Math Variables[f]							
970 (R)	MV01–HI		–32768	32767	0	0.01	1070
971 (R)	MV01–LO		–32768	32767	0	0.01	1071
972 (R)	MV02–HI		–32768	32767	0	0.01	1072
973 (R)	MV02–LO		–32768	32767	0	0.01	1073
974 (R)	MV03–HI		–32768	32767	0	0.01	1074
975 (R)	MV03–LO		–32768	32767	0	0.01	1075
976 (R)	MV04–HI		–32768	32767	0	0.01	1076
977 (R)	MV04–LO		–32768	32767	0	0.01	1077
978 (R)	MV05–HI		–32768	32767	0	0.01	1078
979 (R)	MV05–LO		–32768	32767	0	0.01	1079
980 (R)	MV06–HI		–32768	32767	0	0.01	1080

Table E.34 Modbus Register Map (Sheet 23 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
981 (R)	MV06–LO		–32768	32767	0	0.01	1081
982 (R)	MV07–HI		–32768	32767	0	0.01	1082
983 (R)	MV07–LO		–32768	32767	0	0.01	1083
984 (R)	MV08–HI		–32768	32767	0	0.01	1084
985 (R)	MV08–LO		–32768	32767	0	0.01	1085
986 (R)	MV09–HI		–32768	32767	0	0.01	1086
987 (R)	MV09–LO		–32768	32767	0	0.01	1087
988 (R)	MV10–HI		–32768	32767	0	0.01	1088
989 (R)	MV10–LO		–32768	32767	0	0.01	1089
990 (R)	MV11–HI		–32768	32767	0	0.01	1090
991 (R)	MV11–LO		–32768	32767	0	0.01	1091
992 (R)	MV12–HI		–32768	32767	0	0.01	1092
993 (R)	MV12–LO		–32768	32767	0	0.01	1093
994 (R)	MV13–HI		–32768	32767	0	0.01	1094
995 (R)	MV13–LO		–32768	32767	0	0.01	1095
996 (R)	MV14–HI		–32768	32767	0	0.01	1096
997 (R)	MV14–LO		–32768	32767	0	0.01	1097
998 (R)	MV15–HI		–32768	32767	0	0.01	1098
999 (R)	MV15–LO		–32768	32767	0	0.01	1099
1000 (R)	MV16–HI		–32768	32767	0	0.01	1100
1001 (R)	MV16–LO		–32768	32767	0	0.01	1101
1002 (R)	MV17–HI		–32768	32767	0	0.01	1102
1003 (R)	MV17–LO		–32768	32767	0	0.01	1103
1004 (R)	MV18–HI		–32768	32767	0	0.01	1104
1005 (R)	MV18–LO		–32768	32767	0	0.01	1105
1006 (R)	MV19–HI		–32768	32767	0	0.01	1106
1007 (R)	MV19–LO		–32768	32767	0	0.01	1107
1008 (R)	MV20–HI		–32768	32767	0	0.01	1108
1009 (R)	MV20–LO		–32768	32767	0	0.01	1109
1010 (R)	MV21–HI		–32768	32767	0	0.01	1110
1011 (R)	MV21–LO		–32768	32767	0	0.01	1111
1012 (R)	MV22–HI		–32768	32767	0	0.01	1112
1013 (R)	MV22–LO		–32768	32767	0	0.01	1113
1014 (R)	MV23–HI		–32768	32767	0	0.01	1114
1015 (R)	MV23–LO		–32768	32767	0	0.01	1115
1016 (R)	MV24–HI		–32768	32767	0	0.01	1116
1017 (R)	MV24–LO		–32768	32767	0	0.01	1117
1018 (R)	MV25–HI		–32768	32767	0	0.01	1118
1019 (R)	MV25–LO		–32768	32767	0	0.01	1119
1020 (R)	MV26–HI		–32768	32767	0	0.01	1120
1021 (R)	MV26–LO		–32768	32767	0	0.01	1121
1022 (R)	MV27–HI		–32768	32767	0	0.01	1122
1023 (R)	MV27–LO		–32768	32767	0	0.01	1123
1024 (R)	MV28–HI		–32768	32767	0	0.01	1124
1025 (R)	MV28–LO		–32768	32767	0	0.01	1125
1026 (R)	MV29–HI		–32768	32767	0	0.01	1126
1027 (R)	MV29–LO		–32768	32767	0	0.01	1127

Table E.34 Modbus Register Map (Sheet 24 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1028 (R)	MV30–HI		–32768	32767	0	0.01	1128
1029 (R)	MV30–LO		–32768	32767	0	0.01	1129
1030 (R)	MV31–HI		–32768	32767	0	0.01	1130
1031 (R)	MV31–LO		–32768	32767	0	0.01	1131
1032 (R)	MV32–HI		–32768	32767	0	0.01	1132
1033 (R)	MV32–LO		–32768	32767	0	0.01	1133
Device Counters							
1034 (R)	COUNTER SC01		0	65000	0	1	1134
	• • •						• • •
1065 (R)	COUNTER SC32		0	65000	0	1	1165
1066–1081 (R)	Reserved[c]		0	0	0		1166–1181
Historical Data							
1082 (R)	NO. EVENT LOGS		0	50	0	1	1182
1083 (R/W)	EVENT LOG SEL		0	50	0	1	1183
1084 (R)	EVENT TIME ss		0	5999	0	0.01	1184
1085 (R)	EVENT TIME mm		0	59	0	1	1185
1086 (R)	EVENT TIME hh		0	23	0	1	1186
1087 (R)	EVENT DAY dd		0	31	1	1	1187
1088 (R)	EVENT DAY mm		0	12	1	1	1188
1089 (R)	EVENT DAY yy		0	9999	2000	1	1189
1090 (R)	EVENT TYPE 0 = NA 1 = DIFF 87 TRIP 2 = REF TRIP 3 = WDG1 PH 50 TRIP 4 = WDG1 GND 50 TRIP 5 = WDG1 50Q TRIP 6 = WDG2 PH 50 TRIP 7 = WDG2 GND 50 TRIP 8 = WDG2 50Q TRIP 9 = NEUTRAL 50 TRIP 10 = WDG1 PH 51 TRIP 11 = WDG1 GND 51 TRIP 12 = WDG1 51Q TRIP 13 = WDG2 PH 51 TRIP 14 = WDG2 GND 51 TRIP 15 = WDG2 51Q TRIP 16 = NEUTRAL 51 TRIP 17 = POWERELEMNT TRIP 18 = UNDERVOLT TRIP 19 = OVERVOLT TRIP 20 = VOLT/HZ 24 TRIP 21 = FREQUENCY81 TRIP 22 = RTD TRIP 23 = RTD FAIL TRIP 24 = BKR FAILURE TRIP 25 = REMOTE TRIP 26 = COMMIDLELOSSTRIP 27 = TRIGGER 28 = ER TRIGGER 29 = TRIP 30 = WDG1 PH A 50TRIP 31 = WDG1 PH B 50TRIP 32 = WDG1 PH C 50TRIP 33 = WDG2 PH A 50TRIP 34 = WDG2 PH B 50TRIP 35 = WDG2 PH C 50TRIP 36 = WDG1 PH A 51TRIP 37 = WDG1 PH B 51TRIP 38 = WDG1 PH C 51TRIP 39 = WDG2 PH A 51TRIP 40 = WDG2 PH B 51TRIP 41 = WDG2 PH C 51TRIP		0	29	0		1190
1091 (R)	EVENT TARGETS Bit 0 = TLED_06 Bit 1 = TLED_05 Bit 2 = TLED_04 Bit 3 = TLED_03 Bit 4 = TLED_02 Bit 5 = TLED_01 Bit 6 = TRIP_LED Bit 7 = ENABLED		0	255	0		1191

Table E.34 Modbus Register Map (Sheet 25 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1092 (R)	EVENT IAW1	A	0	65535	0	1	1192
1093 (R)	EVENT IBW1	A	0	65535	0	1	1193
1094 (R)	EVENT ICW1	A	0	65535	0	1	1194
1095 (R)	EVENT IGW1	A	0	65535	0	1	1195
1096 (R)	EVENT IAW2	A	0	65535	0	1	1196
1097 (R)	EVENT IBW2	A	0	65535	0	1	1197
1098 (R)	EVENT ICW2	A	0	65535	0	1	1198
1099 (R)	EVENT IGW2	A	0	65535	0	1	1199
1100 (R)	EVENT IN	A	0	65535	0	1	1200
1101 (R)	EVENT VAB/VAN	V	0	65535	0	1	1201
1102 (R)	EVENT VBC/VBN	V	0	65535	0	1	1202
1103 (R)	EVENT VCA/VCN	V	0	65535	0	1	1203
1104 (R)	EVENT VG	V	0	65535	0	1	1204
1105 (R)	EVENT DELTA/WYE 0 = DELTA 1 = WYE		0	1	0		1205
1106 (R)	EVENT FREQ	Hz	2000	7000	6000	0.01	1206
1107 (R)	EVNT MAX AMB RTD	degC	–32768	32767	0	1	1207
1108 (R)	EVNT MAX OTH RTD	degC	–32768	32767	0	1	1208
1109–1116 (R)	Reserved[c]		0	0	0		1209–1216
Trip/Warn Data							
1117 (R)	TRIP STATUS LO Bit 0 = WDG1 50 PHASE Bit 1 = WDG1 50 GROUND Bit 2 = WDG1 50 NEGSEQ Bit 3 = WDG1 51 PHASE Bit 4 = WDG1 51 GROUND Bit 5 = WDG1 51 NEGSEQ Bit 6 = WDG2 50 PHASE Bit 7 = WDG2 50 GROUND Bit 8 = WDG2 50 NEGSEQ Bit 9 = WDG2 51 PHASE Bit 10 = WDG2 51 GROUND Bit 11 = WDG2 51 NEGSEQ Bit 12 = NEUTRAL 50 Bit 13 = NEUTRAL 51 Bit 14 = RESTR DIFF 87R Bit 15 = UNRESTR DIFF 87U		0	65535	0		1217
1118 (R)	TRIP STATUS HI Bit 0 = UNDERVOLT 27P Bit 1 = OVERVOLT 59P Bit 2 = NSEQVOLT 59Q Bit 3 = POWER ELEMENTS Bit 4 = FREQUENCY 81 Bit 5 = VOLTS/HERTZ Bit 6 = RESTRCTD EARTH Bit 7 = RTD TRIP Bit 8 = BREAKER FAIL Bit 9 = REMOTE TRIP Bit 10–Bit 14 = RESERVED Bit 15 = TRIP		0	65535	0		1218

NOTE: The Trip/Warn Status register bits are momentarily set as long as the trip/warn condition exists. When a trip event occurs, the elements are latched to the rising edge of the TRIP Relay Word bit and they are not cleared until a target reset is issued from any interface.

Table E.34 Modbus Register Map (Sheet 26 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1119 (R)	WARN STATUS LO Bit 0 = THR FAULT ALARM Bit 1 = DEMAND ALARM Bit 2 = RTD FAULT Bit 3 = CONFIG FAULT Bit 4 = COMM FAULT Bit 5 = COMM IDLE Bit 6 = COMM LOSS Bit 7 = DIFF ALARM 87A Bit 8 = 5TH HARMONIC ALM Bit 9 = RTD ALARM Bit 10 = LOSS OF POTNTIAL Bit 11 = AI HI/LO ALARM Bit 12 = RESERVED Bit 13 = HALARM Bit 14 = SALARM Bit 15 = WARNING		0	65535	0		1219
1120 (R)	WARN STATUS HI Bit 0–Bit 15 = RESERVED		0	65535	0		1220
1121–1125 (R)	Reserved[c]		0	0	0		1221–1225
Commn Counters							
1126 (R)	NUM MSG RCVD		0	65535	0	1	1226
1127 (R)	NUM OTHER MSG		0	65535	0	1	1227
1128 (R)	INVALID ADDR		0	65535	0	1	1228
1129 (R)	BAD CRC		0	65535	0	1	1229
1130 (R)	UART ERROR		0	65535	0	1	1230
1131 (R)	ILLEGAL FUNCTION		0	65535	0	1	1231
1132 (R)	ILLEGAL REGISTER		0	65535	0	1	1232
1133 (R)	ILLEGAL WRITE		0	65535	0	1	1233
1134 (R)	BAD PKT FORMAT		0	65535	0	1	1234
1135 (R)	BAD PKT LENGTH		0	65535	0	1	1235
1136–1141 (R)	Reserved[c]		0	0	0		1236–1241
Relay Elements							
Only a few Relay Element rows report actual bit enumeration strings specific to that row. Other Relay Element rows report generic bit enumeration strings (as shown for *ROW 10*). For exact bit enumerations of these elements see *Appendix J: Relay Word Bits*.							
1142 (R)	ROW 0 Bit 0 = TLED_06 Bit 1 = TLED_05 Bit 2 = TLED_04 Bit 3 = TLED_03 Bit 4 = TLED_02 Bit 5 = TLED_01 Bit 6 = TRIP_LED Bit 7 = ENABLED		0	255	0		1242
1143 (R)	ROW 1 Bit 0 = 50P24T Bit 1 = 50P23T Bit 2 = 50P22T Bit 3 = 50P21T Bit 4 = 50P14T Bit 5 = 50P13T Bit 6 = 50P12T Bit 7 = 50P11T		0	255	0		1243

Table E.34 Modbus Register Map (Sheet 27 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1144 (R)	ROW 2 Bit 0 = 50Q22T Bit 1 = 50Q21T Bit 2 = 50G22T Bit 3 = 50G21T Bit 4 = 50Q12T Bit 5 = 50Q11T Bit 6 = 50G12T Bit 7 = 50G11T		0	255	0		1244
1145 (R)	ROW 3 Bit 0 = REF1P Bit 1 = REF1R Bit 2 = REF1F Bit 3 = 50GREF1 Bit 4 = REF1E Bit 5 = 50NREF1 Bit 6 = 50N12T Bit 7 = 50N11T		0	255	0		1245
1146 (R)	ROW 4 Bit 0 = * Bit 1 = 51N1T Bit 2 = 51Q2T Bit 3 = 51Q1T Bit 4 = 51G2T Bit 5 = 51G1T Bit 6 = 51P2T Bit 7 = 51P1T		0	255	0		1246
1147 (R)	ROW 5 Bit 0 = 87R Bit 1 = 87R3 Bit 2 = 87R2 Bit 3 = 87R1 Bit 4 = 87U Bit 5 = 87U3 Bit 6 = 87U2 Bit 7 = 87U1		0	255	0		1247
1148 (R)	ROW 6 Bit 0 = 3PWR2T Bit 1 = 3PWR1T Bit 2 = 59P2T Bit 3 = 59P1T Bit 4 = 27P2T Bit 5 = 27P1T Bit 6 = 87AT Bit 7 = TH5T		0	255	0		1248
1149 (R)	ROW 7 Bit 0 = 59Q2T Bit 1 = 59Q1T Bit 2 = BFT2 Bit 3 = BFT1 Bit 4 = 81D4T Bit 5 = 81D3T Bit 6 = 81D2T Bit 7 = 81D1T		0	255	0		1249
1150 (R)	ROW 8 Bit 0 = RTDT Bit 1 = * Bit 2 = * Bit 3 = 24CR Bit 4 = 24C2T Bit 5 = 24C2 Bit 6 = 24D1T Bit 7 = 24D1		0	255	0		1250

Table E.34 Modbus Register Map (Sheet 28 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1151 (R)	ROW 9 Bit 0 = ORED51T Bit 1 = ORED50T Bit 2 = * Bit 3 = * Bit 4 = * Bit 5 = * Bit 6 = * Bit 7 = REMTRIP		0	255	0		1251
1152 (R)	ROW 10 Bit 0 = 50P24P Bit 1 = 50P23P Bit 2 = 50P22P Bit 3 = 50P21P Bit 4 = 50P14P Bit 5 = 50P13P Bit 6 = 50P12P Bit 7 = 50P11P		0	255	0		1252
1153 (R)	ROW 11 Bit 0 = 50Q22P Bit 1 = 50Q21P Bit 2 = 50G22P Bit 3 = 50G21P Bit 4 = 50Q12P Bit 5 = 50Q11P Bit 6 = 50G12P Bit 7 = 50G11P		0	255	0		1253
1154 (R)	ROW 12 Bit 0 = 52A2 Bit 1 = 52A1 Bit 2 = 51P2AR Bit 3 = 51P1CR Bit 4 = 51P1BR Bit 5 = 51P1AR Bit 6 = 50N12P Bit 7 = 50N11P		0	255	0		1254
1155 (R)	ROW 13 Bit 0 = 51P2BR Bit 1 = 51N1P Bit 2 = 51Q2P Bit 3 = 51Q1P Bit 4 = 51G2P Bit 5 = 51G1P Bit 6 = 51P2P Bit 7 = 51P1P		0	255	0		1255
1156 (R)	ROW 14 Bit 0 = 51P2CR Bit 1 = 51N1R Bit 2 = 51Q2R Bit 3 = 51Q1R Bit 4 = 51G2R Bit 5 = 51G1R Bit 6 = 51P2R Bit 7 = 51P1R		0	255	0		1256
1157 (R)	ROW 15 Bit 0 = 5HBL Bit 1 = 5HB3 Bit 2 = 5HB2 Bit 3 = 5HB1 Bit 4 = 2_4HBL Bit 5 = 2_4HB3 Bit 6 = 2_4HB2 Bit 7 = 2_4HB1		0	255	0		1257

Table E.34 Modbus Register Map (Sheet 29 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1158 (R)	ROW 16 Bit 0 = 87HR Bit 1 = 87HR3 Bit 2 = 87HR2 Bit 3 = 87HR1 Bit 4 = 87HB Bit 5 = 87BL3 Bit 6 = 87BL2 Bit 7 = 87BL1		0	255	0		1258
1159 (R)	ROW 17 Bit 0 = 3PWR2P Bit 1 = 3PWR1P Bit 2 = 59P2 Bit 3 = 59P1 Bit 4 = 27P2 Bit 5 = 27P1 Bit 6 = 87AP Bit 7 = TH5		0	255	0		1259
1160 (R)	ROW 18 Bit 0 = 59Q2 Bit 1 = 59Q1 Bit 2 = BFI2 Bit 3 = BFI1 Bit 4 = OTHTRIP Bit 5 = OTHALRM Bit 6 = AMBTRIP Bit 7 = AMBALRM		0	255	0		1260
1161 (R)	ROW 19 Bit 0 = OUT304 Bit 1 = OUT303 Bit 2 = OUT302 Bit 3 = OUT301 Bit 4 = OUT103 Bit 5 = OUT102 Bit 6 = OUT101 Bit 7 = TRIP		0	255	0		1261
1162 (R)	ROW 20 Bit 0 = OUT504 Bit 1 = OUT503 Bit 2 = OUT502 Bit 3 = OUT501 Bit 4 = OUT404 Bit 5 = OUT403 Bit 6 = OUT402 Bit 7 = OUT401		0	255	0		1262
1163 (R)	ROW 21 Bit 0 = IN108 Bit 1 = * Bit 2 = * Bit 3 = * Bit 4 = * Bit 5 = * Bit 6 = IN102 Bit 7 = IN101		0	255	0		1263
1164 (R)	ROW 22 Bit 0 = IN308 Bit 1 = IN307 Bit 2 = IN306 Bit 3 = IN305 Bit 4 = IN304 Bit 5 = IN303 Bit 6 = IN302 Bit 7 = IN301		0	255	0		1264

Table E.34 Modbus Register Map (Sheet 30 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1165 (R)	ROW 23 Bit 0 = IN408 Bit 1 = IN407 Bit 2 = IN406 Bit 3 = IN405 Bit 4 = IN404 Bit 5 = IN403 Bit 6 = IN402 Bit 7 = IN401		0	255	0		1265
1166 (R)	ROW 24 Bit 0 = IN508 Bit 1 = IN507 Bit 2 = IN506 Bit 3 = IN505 Bit 4 = IN504 Bit 5 = IN503 Bit 6 = IN502 Bit 7 = IN501		0	255	0		1266
1167 (R)	ROW 25 Bit 0 = FAULT Bit 1 = IRIGOK Bit 2 = TSOK Bit 3 = WARNING Bit 4 = SALARM Bit 5 = PMDOK Bit 6 = LINKBOK Bit 7 =LINKAOK		0	255	0		1267
1168 (R)	ROW 26 Bit 0 = LOP Bit 1 = * Bit 2 = * Bit 3 = * Bit 4 = CFGFLT Bit 5 = COMMFLT Bit 6 = COMMLOSS Bit 7 = COMMIDLE		0	255	0		1268
1169 (R)	ROW 27 Bit 0 = RSTPKDEM Bit 1 = RSTDEM Bit 2 = RSTMXMN Bit 3 = RSTENRGY Bit 4 = * Bit 5 = * Bit 6 = ER Bit 7 = FREQTRK		0	255	0		1269
1170 (R)	ROW 28 Bit 0 = HALARM Bit 1 = RSTTRGT Bit 2 = DSABLSET Bit 3 = * Bit 4 = RTDA Bit 5 = TRGTR Bit 6 = RTDIN Bit 7 = RTDFLT		0	255	0		1270
1171 (R)	ROW 29 • • •		0	255	0		1271 • • •
1248 (R)	ROW 106		0	255	0		1348
1249–1270 (R)	Reserved[c]		0	0	0		1349—1370

Table E.34 Modbus Register Map (Sheet 31 of 37)

Modbus Register Address[a]		Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
Extra Settings								
WDG1 Per Ph TOC								
1271	(RW)	W1 PH-A TOC EN 0 = N 1 = Y		0	1	0		1371
1272	(RW)	W1 PH-A TOC LVL	A	10	1600	120	0.01	1372
1273	(RW)	W1 PHA TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2	1	1373
1274	(RW)	W1 PHA TOC TDIAL		5	1500	300	0.01	1374
1275	(RW)	W1 PHA EMRST DLY 0 = N 1 = Y		0	1	0		1375
1276	(RW)	W1 PHA CONST TIM	sec	0	100	0	0.01	1376
1277	(RW)	W1 PHA MIN TIM	sec	0	100	0	0.01	1377
1278	(RW)	W1 PH-B TOC EN 0 = N 1 = Y		0	1	0		1378
1279	(RW)	W1 PH-B TOC LVL	A	10	1600	120	0.01	1379
1280	(RW)	W1 PHB TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2	1	1380
1281	(RW)	W1 PHB TOC TDIAL		5	1500	300	0.01	1381
1282	(RW)	W1 PHB EMRST DLY 0 = N 1 = Y		0	1	0		1382
1283	(RW)	W1 PHB CONST TIM	sec	0	100	0	0.01	1383
1284	(RW)	W1 PHB MIN TIM	sec	0	100	0	0.01	1384
1285	(RW)	W1 PH-C TOC EN 0 = N 1 = Y		0	1	0		1385
1286	(RW)	W1 PH-C TOC LVL	A	10	1600	120	0.01	1386
1287	(RW)	W1 PHC TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2	1	1387
1288	(RW)	W1 PHC TOC TDIAL		5	1500	300	0.01	1388
1289	(RW)	W1 PHC EMRST DLY 0 = N 1 = Y		0	1	0		1389
1290	(RW)	W1 PHC CONST TIM	sec	0	100	0	0.01	1390
1291	(RW)	W1 PHC MIN TIM	sec	0	100	0	0.01	1391
WDG2 Per Ph TOC								
1292	(RW)	W2 PH-A TOC EN 0 = N 1 = Y			0	1	0	1392

Table E.34 Modbus Register Map (Sheet 32 of 37)

Modbus Register Address[a]		Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
1293	(RW)	W2 PH-A TOC LVL	A	10	1600	120	0.01	1393
1294	(RW)	W2 PHA TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5	0		9	2	1	1394
1295	(RW)	W2 PHA TOC TDIAL		5	1500	300	0.01	1395
1296	(RW)	W2 PHA EMRST DLY 0 = N 1 = Y			0	1	0	1396
1297	(RW)	W2 PHA CONST TIM	sec	0	100	0	0.01	1397
1298	(RW)	W2 PHA MIN TIM	sec	0	100	0	0.01	1398
1299	(RW)	W2 PH-B TOC EN 0 = N 1 = Y	0	1	0	1399		
1300	(RW)	W2 PH-B TOC LVL	A	10	1600	120	0.01	1400
1301	(RW)	W2 PHB TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2	1	1401
1302		W2 PHB TOC TDIAL		5	1500	300	0.01	1402
1303	(RW)	W2 PHB EMRST DLY 0 = N 1 = Y			0	1	0	1403
1304	(RW)	W2 PHB CONST TIM	sec	0	100	0	0.01	1404
1305	(RW)	W2 PHB MIN TIM	sec	0	100	0	0.01	1405
1306	(RW)	W2 PH-C TOC EN 0 = N 1 = Y			0	1	0	1406
1307	(RW)	W2 PH-C TOC LVL	A	10	1600	120	0.01	1407
1308	(RW)	W2 PHC TOC CURVE 0 = U1 5 = C1 1 = U2 6 = C2 2 = U3 7 = C3 3 = U4 8 = C4 4 = U5 9 = C5		0	9	2	1	1408
1309	(RW)	W2 PHC TOC TDIAL		5	1500	300	0.01	1409
1310	(RW)	W2 PHC EMRST DLY 0 = N 1 = Y			0	1	0	1410
1311	(RW)	W2 PHC CONST TIM	sec	0	100	0	0.01	1411
1312	(RW)	W2 PHC MIN TIM	sec	0	100	0	0.01	1412
Control I/O Commands								
2000H	(W)	LOGIC COMMAND Bit 0 = Breaker1 Close Bit 1 = Breaker1 Open Bit 2 = Breaker2 Close Bit 3 = Return Status 0/1 Bit 4 = DN Aux 1 Cmd Bit 5 = DN Aux 2 Cmd Bit 6 = DN Aux 3 Cmd Bit 7 = DN Aux 4 Cmd Bit 8 = DN Aux 5 Cmd Bit 9 = DN Aux 6 Cmd		0	65535	0	na	

Table E.34 Modbus Register Map (Sheet 33 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
	Bit 10 = DN Aux 7 Cmd Bit 11 = DN Aux 8 Cmd Bit 12 = DN Aux 9 Cmd Bit 13 = DN Aux 10 Cmd Bit 14 = DN Aux 11 Cmd Bit 15 = Breaker2 Open						
2001H (W)	RESET COMMAND Bit 0 = Trip Reset Bit 1 = Set to Defaults Bit 2 = Reset Stat Data Bit 3 = Reset Hist Data Bit 4 = Reset Comm Cntr Bit 5 = Reserved Bit 6 = Rst Enrgy Data Bit 7 = Rst Mx/Mn Data Bit 8 = Rst Demand Bit 9 = Rst Peak Demand Bit 10–Bit 15 = Reserved		0	255	0	na	
Relay Elements							
2100H (R)	FAST STATUS 0 Bit 0 = Faulted Bit 1 = Warning Bit 2 = IN1/IN101 Status Bit 3 = IN2/IN102 Status Bit 4 = IN3/IN401 Status Bit 5 = IN4/IN402 Status Bit6 = IN5/IN403 Status Bit 7 = Reserved Bit 8 = AUX1/OUT101 Status Bit 9 = AUX2/OUT102 Status Bit 10 = AUX3/OUT401 Status Bit 11 = AUX4/OUT402 Status Bit 12 = AUX5/OUT403 Status Bit 13 = AUX6/OUT404 Status Bit 14–Bit 15 = Reserved		0	65535	0	na	
2101H (R)	FAST STATUS 1 Bit 0 = Enabled Bit 1 = Reserved Bit 2 = IN6/IN404 Status Bit 3 = IN7/IN501 Status Bit 4 = IN8/IN502 Status Bit 5 = IN9/IN503 Status Bit 6 = IN10/IN504 Status Bit 7 = Reserved Bit 8 = AUX7/OUT501 Status Bit 9 = AUX8/OUT502 Status Bit 10 = AUX9/OUT503 Status Bit 11 = AUX10/OUT504 Status Bit 12–Bit 15 = Reserved		0	65535	0	na	
2102H (R)	TRIP STATUS LO					na	
2103H (R)	TRIP STATUS HI					na	
2104H (R)	WARN STATUS LO					na	
2105H (R)	WARN STATUS HI					na	
2106H (R)	AVERAGE CURRENT					na	
2107H (R)	IAW1 CURRENT					na	
2108H (R)	IBW1 CURRENT					na	
2109H (R)	ICW1 CURRENT					na	
210AH–210CH (R)	Reserved[c]					na	
210DH (R)	IGW1 CURRENT					na	
210EH (R)	IN1 CURRENT					na	
210FH (R)	Reserved[c]					na	

Table E.34 Modbus Register Map (Sheet 34 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
2110H (R)	FAST STATUS 2 Bit 0 = IN11/IN301 Status Bit 1 = IN12/IN302 Status Bit 2 = IN13/IN303 Status Bit 3 = IN14/IN304 Status Bit 4 = OUT11/OUT301 Status Bit 5 = OUT12/OUT302 Status Bit 6 = OUT13/OUT303 Status Bit 7 = OUT14/OUT304 Status Bit 8 = IN15/IN305 Status Bit 9 = IN16/IN306 Status Bit 10 = IN17/IN307 Status Bit 11 = IN18/IN308 Status Bit 12–Bit 15 = Reserved		0	65535	0	na	
2111H (R)	FAST STATUS 3 Bit 0 = IN19/IN405 Status Bit 1 = IN20/IN406 Status Bit 2 = IN21/IN407 Status Bit 3 = IN22/IN408 Status Bit 4 = IN23/IN505 Status Bit 5 = IN24/IN506 Status Bit 6 = IN25/IN507 Status Bit 7 = IN26/IN508 Status Bit 8–Bit 15 = Reserved		0	65535	0	na	
PAR GROUP INDICES							
3000H (R)	Reserved[c]		0	0	0	na	
3001H (R)	USER MAP REG		1	125	1	1	
3002H (R)	USER MAP REG VAL		126	250	126	1	
3003H (R)	RESERVED AREA1		251	259	259	1	
3004H (R)	ACCESS CONTROL		260	260	260	1	
3005H (R)	GENERAL SETTINGS		261	264	261	1	
3006H (R)	GROUP SELECTION		265	265	265	1	
3007H (R)	BRKR FAILURE SET		266	268	266	1	
3008H (R)	THR FAULT SET		269	275	269	1	
3009H (R)	CONFIG SETTINGS		276	297	276	1	
300AH (R)	XFMR DIFFERNTIAL		298	321	298	1	
300BH (R)	RESTR EARTH FLT		322	323	322	1	
300CH (R)	WDG1 MAX PH IOC		324	335	324	1	
300DH (R)	WDG1 RES IOC		336	341	336	1	
300EH (R)	WDG1 NEG SEQ IOC		342	347	342	1	
300FH (R)	WDG1 MAX PH TOC		348	354	348	1	
3010H (R)	WDG1 RES TOC		355	361	355	1	
3011H (R)	WDG1 NEG SEQ TOC		362	368	362	1	
3012H (R)	WDG2 MAX PH IOC		369	380	369	1	
3013H (R)	WDG2 RES IOC		381	386	381	1	
3014H (R)	WDG2 NEG SEQ IOC		387	392	387	1	
3015H (R)	WDG2 MAX PH TOC		393	399	393	1	
3016H (R)	WDG2 RES TOC		400	406	400	1	
3017H (R)	WDG2 NEG SEQ TOC		407	413	407	1	
3018H (R)	NEUTRAL IOC		414	419	414	1	
3019H (R)	NEUTRAL TOC		420	431	420	1	

Table E.34 Modbus Register Map (Sheet 35 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
301AH (R)	RTD SETTINGS		432	486	432	1	
301BH (R)	PH UNDERVOLTAGE		487	492	487	1	
301CH (R)	PH OVERVOLTAGE		493	498	493	1	
301DH (R)	NSEQ OVERVOLTAGE		499	504	499	1	
301EH (R)	RESERVED AREA2		505	514	505	1	
301FH (R)	VOLTS PER HERTZ		515	527	515	1	
3020H (R)	POWER ELEMENTS		528	536	528	1	
3021H (R)	FREQ SETTINGS		537	548	537	1	
3022H (R)	DEMAND MTR SET		549	554	549	1	
3023H (R)	RESERVED AREA3		555	564	555	1	
3024H (R)	TRIP/CLOSE LOGIC		565	575	565	1	
3025H (R)	SELOGIC ENABLES		576	584	576	1	
3026H (R)	OUTPUT CONTACTS		585	604	585	1	
3027H (R)	EVENT REPORT SET		605	614	605	1	
3028H (R)	FRONT PANEL SET		615	624	615	1	
3029H (R)	RESET SETTINGS		625	635	625	1	
302AH (R)	DATE/TIME SET		636	643	636	1	
302BH (R)	DEVICE STATUS		644	683	644	1	
302CH (R)	CURRENT DATA		684	708	684	1	
302DH (R)	VOLTAGE DATA		709	725	709	1	
302EH (R)	POWER DATA		726	731	726	1	
302FH (R)	ENERGY DATA		732	753	732	1	
3030H (R)	DEMAND DATA		754	758	754	1	
3031H (R)	PEAK DEMAND DATA		759	769	759	1	
3032H (R)	HARMONIC DATA		770	781	770	1	
3033H (R)	RTD DATA		782	796	782	1	
3034H (R)	RESERVED AREA4		797	806	797	1	
3035H (R)	RMS DATA		807	819	807	1	
3036H (R)	MAX/MIN MTR DATA		820	851	820	1	
3037H (R)	MAX/MIN RTD DATA		852	875	852	1	
3038H (R)	MAX/MIN AI3 DATA		876	891	876	1	
3039H (R)	MAX/MIN AI4 DATA		892	907	892	1	
303AH (R)	MAX/MIN AI5 DATA		908	923	908	1	
303BH (R)	MAX/MIN RST DATA		924	939	924	1	
303CH (R)	ANA INP DATA		940	969	940	1	
303DH (R)	MATH VARIABLES		970	1033	970	1	
303EH (R)	DEVICE COUNTERS		1034	1065	1034	1	
303FH (R)	RESERVED AREA5		1066	1081	1066	1	
3040H (R)	HISTORICAL DATA		1082	1116	1082	1	
3041H (R)	TRIP/WARN DATA		1117	1125	1117	1	
3042H (R)	COMMN COUNTERS		1126	1141	1126	1	
3043H (R)	RELAY ELEMENTS		1142	1249	1142	1	

Table E.34 Modbus Register Map (Sheet 36 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
3044H (R)	RESERVED AREA6		1250	1270	1250	1	
3045H (R)	WDG1 PER PH TOC		1271	1291	1271	1	
3046H (R)	WDG2 PER PH TOC		1292	1312	1292	1	
PRODUCT INFORMATION							
4000H (R)	VENDOR CODE 865 = SEL		0	65535	865	na	
4001H (R)	PRODDUCT CODE		0	65535	105	na	
4002H (R/W)	ASA NUMBER LOW		0	65535		na	
4003H (R/W)	ASA NUMBER HIGH		0	65535		na	
4004H (R)	FIRMWARE REVISION		1	32639		na	
4005H (R)	NUM OF PAR		1	2000	1312	na	
4006H (R)	NUM OF PAR GROUP		1	100	70	na	
4007H (R/W)	MAC ID 64-99 = Swr Configurable		1	99	0	na	
4008H (R/W)	DN BAUD RATE 0 = 125 kbps 1 = 250 kbps 2 = 500 kbps 3 = AUTO 4-9 = Swr Configurable		0	9	0	na	
4009H (R/W)	DN STATUS Bit 0 = Explicit Cnxn Bit 1 = I/O Cnxn Bit 2 = Explicit Fault Bit 3 = I/O Fault Bit 4 = I/O Idle Bit 5–Bit 15 = Reserved		0	31	0	na	
400AH	not used						
400BH (R)	CONFIG PAR CKSUM				0	na	
400CH (R)	LANGUAGE CODE 0 = English 1 = French 2 = Spanish (Mexican) 3 = Italian 4 = German 5 = Japanese 6 = Portuguese 7 = Mandarin Chinese 8 = Russian 9 = Dutch				0	na	
400DH (R)	FIRMWARE BUILD NUM		16400	16400	0	na	
400EH	not used						
400FH (R)	PRODUCT SUPPORT BITS Bit 0 = 2nd IO Card installed Bits 1-15 = Reserved					na	
4010H (R/W)	SETTINGS TIMEOUT	ms	500	65535	750	na	
4011H–4013H	Reserved[c]						
4014H (R)	CONFIGURED BIT Bit 0 = Unit Configured Bits 1-15 = Reserved				0	na	
4015H (R)	Reserved[c]		0	0	0	na	

Table E.34 Modbus Register Map (Sheet 37 of 37)

Modbus Register Address[a]	Name/Enums	Units	Min	Max	Def	Multiplier[b]	DeviceNet Parameter Numbers
4016H (R)	ERROR REGISTER Bit 0 = Settings Read Error, Bit 1 = Setting Write Error, Bit 2 = Settings Update Error, Bit 3 = Settings Resource Error, Bit 4 = Settings Locked, Bit 5 = Group Settings Error, Bit 6 = Global Settings Error, Bit 7 = Logic Settings Error Bit 8 = Report Settings Error Bit 9 = Front Panel Settings Error Bit 10 = Memory Not Available, Bit 11 = Settings Prep Error, Bit 12 = Setting Changes Disabled, Bit 13 = Memory Diag Error Bit 14–Bit 15 = Reserved		0	65535	0	na	
4017H (R)	Error Address		0	65535	0	na	
4018H–401FH (R)	Reserved[c]		0	0	0	na	

[a] Registers labeled (R/(W) are read-write registers. Registers labeled (W) are write-only registers. Registers Labeled (R) are read-only registers.
[b] Register value * multiplier = system value as seen by the relay. For example, if the register 685 (IAW1 angle) read 300 in decimal, then the system value is 30 degrees (multiplier = 0.1).
[c] Reserved addresses return 0.
[d] Read this register only when the PT connection is DELTA.
[e] Read this register only when the PT connection is WYE.
[f] The HI and LO registers are high and low 16-bits, respectively. They provide 32-bit information by combining to form a 32-bit register and then applying sign and scaling attributes.

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Appendix F
IEC 61850 Communications

Features

The SEL-787 relay supports the following features using Ethernet and IEC 61850:

- **SCADA—**Connect as many as six simultaneous IEC 61850 MMS client sessions. The SEL-787 also supports as many as six buffered and six unbuffered report control blocks. See *Table F.14*, the CON Logical Device table for Logical Node mapping that enables SCADA control via a Manufacturing Messaging Specification (MMS) browser. Controls support the direct control, Select Before Operate (SBO), and SBO with enhanced security control models.
- **Peer-to-Peer Real-Time Status and Control—**Use GOOSE with as many as 16 incoming (receive) and 8 outgoing (transmit) messages. Virtual bits (VB001–VB128), Breaker Open (OC1, OC2), and Breaker Close (CC1, CC2) bits can be mapped from incoming GOOSE messages.
- **Configuration—**Use FTP client software or ACSELERATOR Architect SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay.

NOTE: The SEL-787 supports one CID file, which should be transferred only if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will no longer have a valid IEC 61850 configuration, and the protocol will stop operating. To restart protocol operation, a valid CID must be transferred to the relay.

- **Commissioning and Troubleshooting—**Use software, such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc., to browse the relay logical nodes and verify functionality.

This appendix presents the information you need to use the IEC 61850 features of the SEL-787:

- Introduction to IEC 61850
- IEC 61850 Operation
- IEC 61850 Configuration
- Logical Node Extensions
- Protocol Implementation Conformance Statement
- ACSI Conformance Statement

Introduction to IEC 61850

In the early 1990s, the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) began to define a Utility Communications Architecture (UCA). They initially focused on inter-control center and substation-to-control center communications and produced the Inter-Control Center Communications Protocol (ICCP) specification. This specification, later adopted by the IEC as 60870-6 TASE.2, became the standard protocol for real-time exchange of data between databases.

In 1994, EPRI and IEEE began work on UCA 2.0 for Field Devices (simply referred to as UCA2). In 1997, they combined efforts with Technical Committee 57 of the IEC to create a common international standard. Their joint efforts created the current IEC 61850 standard.

The IEC 61850 standard, a superset of UCA2, contains most of the UCA2 specification, plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards. The IEC 61850 standard consists of the parts listed in *Table F.1*.

Table F.1 IEC 61850 Document Set

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communication requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communication structure for substations and feeder equipment-Principles and models
IEC 61850-7-2	Basic communication structure for substations and feeder equipment—Abstract Communication Service Interface (ACSI)
IEC 61850-7-3	Basic communication structure for substations and feeder equipment-Common data classes
IEC 61850-7-4	Basic communication structure for substations and feeder equipment—Compatible logical node (LN) classes and data classes
IEC 61850-8-1	SCSM-Mapping to Manufacturing Messaging Specification (MMS) (ISO/IEC 9506-1 and ISO/IEC 9506-2 over ISO/IEC 8802-3)
IEC 61850-9-1	SCSM-Sampled values over serial multidrop point-to-point link
IEC 61850-9-2	SCSM-Sampled values over ISO/IEC 8802-3
IEC 61850-10	Conformance testing

The IEC 61850 document set, available directly from the IEC at http://www.iec.ch, contains information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 61850 systems be familiar with the appropriate sections of these documents.

IEC 61850 Operation

Ethernet Networking

IEC 61850 and Ethernet networking are available as options in the SEL-787. In addition to IEC 61850, the Ethernet port provides support protocols and data exchange, including FTP and Telnet. Access the SEL-787 Port 1 settings to configure all of the Ethernet settings, including IEC 61850 enable settings.

The SEL Ethernet port supports IEC 61850 services, including transport of Logical Node objects, over TCP/IP. The Ethernet port can coordinate a maximum of six concurrent IEC 61850 sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) model to define a set of service and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. These abstract models are used to create objects (data items) and services that exist independently of any underlying protocols. These objects are in conformance with the common data class (CDC) specification IEC 61850-7-3, which describes the type and structure of each element within a logical node. CDCs for status, measurements, controllable analogs and statuses, and settings all have unique CDC attributes. Each CDC attribute belongs to a set of functional constraints that groups the attributes into specific categories such as status (ST), description (DC), and substituted value (SV). Functional constraints, CDCs and CDC attributes are used as building blocks for defining Local Nodes.

UCA2 uses GOMSFE (Generic Object Models for Substation and Feeder Equipment) to present data from station IEDs as a series of objects called models or bricks. The IEC working group has incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

Logical nodes can be organized into logical devices that are similar to directories on a computer disk. As represented in the IEC 61850 network, each physical device can contain many logical devices, and each logical device can contain many logical nodes. Many relays, meters, and other IEC 61850 devices contain one primary logical device where all models are organized.

IEC 61850 devices are capable of self-description. You do not need to refer to the specifications for the logical nodes, measurements, and other components to request data from another IEC 61850 device. IEC 61850 clients can request and display a list and description of the data available in an IEC 61850 server device. This process is similar to the autoconfiguration process used within SEL communications processors (SEL-2032 and SEL-2030). Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also permits extensions to both standard and custom data models. Instead of having to look up data in a profile stored in its database, an IEC 61850 client can simply query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other Supervisory Control and Data Acquisition (SCADA) protocols that present data as a list of addresses or indices, IEC 61850 presents data with descriptors in a composite notation made up of components. *Table F.2* shows how the Winding 1A-phase current expressed as MMXU$A1$phsA$cVal is broken down into its component parts.

Table F.2 Example IEC 61850 Descriptor Components

Components		Description
MMXU	Logical Node	Polyphase measurement unit
A1	Data Object	Phase-to-ground amperes, Winding 1
PhsA	Sub-Data Object	Phase A
cVal	Data Attribute	Complex value

Data Mapping

Device data are mapped to IEC 61850 Logical Nodes (LN) according to rules defined by SEL. Refer to IEC 61850-5:2003(E) and IEC 61850-7-4:2003(E) for the mandatory content and usage of these LNs. The SEL-787 Logical Nodes are grouped under Logical Devices for organization based on function. See *Table F.3* for descriptions of the Logical Devices in an SEL-787. See *Logical Nodes* for a description of the LNs that make up these Logical Devices.

Table F.3 SEL-787 Logical Devices

Logical Device	Description
ANN	Annunciator elements—alarms, status values
CFG	Configuration elements—datasets and report control blocks
CON	Control elements—Remote bits
MET	Metering or Measurement elements—currents, voltages, power, etc.
PRO	Protection elements—protection functions and breaker control

MMS

Manufacturing Messaging Specification (MMS) provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506.

In theory, you can map IEC 61850 to any protocol. However, it can be unwieldy and quite complicated to map objects and services to a protocol that only provides access to simple data points via registers or index numbers. MMS supports complex named objects and flexible services that enable mapping to IEC 61850 in a straightforward manner. This was why the UCA users group used MMS for UCA from that start, and why the IEC chose to keep it for IEC 61850.

GOOSE

The Generic Object Oriented Substation Event (GOOSE) object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE automatically broadcasts messages containing status, controls, and measured values onto the network for use by other devices. IEC 61850 GOOSE sends the messages several times, increasing the likelihood that other devices receive the messages.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other network with Architect. Also, configure outgoing GOOSE messages for SEL devices in Architect. See the Architect online help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference) in each outgoing message and an Ethernet multicast group address. Devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages.

NOTE: Virtual bits mapped to GOOSE subscriptions retain their state until they are overwritten, a new CID file is loaded, or the device is restarted. To reset the virtual bits and remote analogs by restarting the device, issue an **STA C** command or remove and then restore power to the device.

Virtual bits (VB001–VB128) are control inputs that you can map to GOOSE receive messages using Architect. See the VB*nnn* bits in *Table F.15* for details on which logical nodes and names are used for these bits. This information can be useful when searching through device data with MMS browsers. If you intend to use any SEL-787 virtual bits for controls, you must create Architect equations to define these operations. The Virtual Bit Logical Nodes only contain Virtual Bit status, and only those Virtual Bits that are assigned to an SER report will be able to track bit transitions (via reporting) between LN data update scans.

In addition to the Virtual Bits, the breaker control bits CC*n* and OC*n* can also be mapped to GOOSE receive messages.

File Services

The Ethernet File System allows reading or writing data as files. The File System supports FTP. The File System provides:

- A means for the devices to transfer data as files
- A hierarchical file structure for the device data (root level only for SEL-700 series devices)

SCL Files

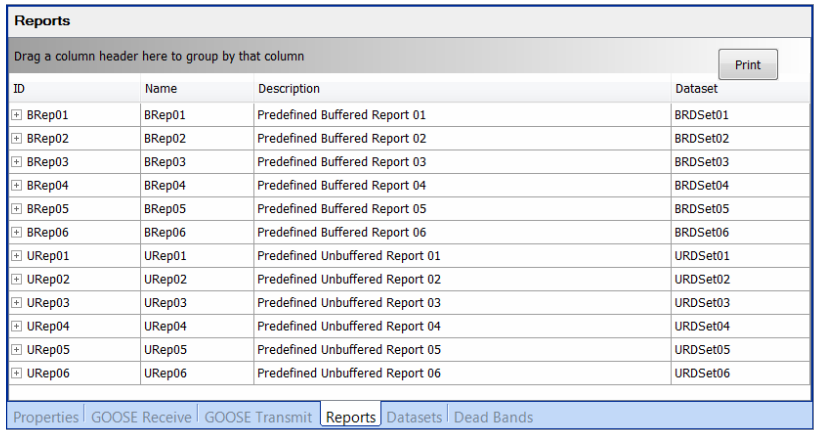
Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- IED Capability Description file (.ICD)
- System Specification Description (.SSD) file
- Substation Configuration Description file (.SCD)
- Configured IED Description file (.CID)

The ICD file described the capabilities of an IED, including information on LN and GOOSE support. The SSD file describes the single-line diagram of the substation and the required LNs. The SCD file contains information on all IEDs, communications configuration data, and a substation description. The CID file, of which there may be several, describes a single instantiated IED within the project, and includes address information.

Reports

The SEL-787 supports buffered and unbuffered report control blocks in the report model as defined in IEC 61850-8-1:2004(E). The predefined reports shown in *Figure F.1* are available by default via IEC 61850.



Reports

Drag a column header here to group by that column

ID	Name	Description	Dataset
BRep01	BRep01	Predefined Buffered Report 01	BRDSet01
BRep02	BRep02	Predefined Buffered Report 02	BRDSet02
BRep03	BRep03	Predefined Buffered Report 03	BRDSet03
BRep04	BRep04	Predefined Buffered Report 04	BRDSet04
BRep05	BRep05	Predefined Buffered Report 05	BRDSet05
BRep06	BRep06	Predefined Buffered Report 06	BRDSet06
URep01	URep01	Predefined Unbuffered Report 01	URDSet01
URep02	URep02	Predefined Unbuffered Report 02	URDSet02
URep03	URep03	Predefined Unbuffered Report 03	URDSet03
URep04	URep04	Predefined Unbuffered Report 04	URDSet04
URep05	URep05	Predefined Unbuffered Report 05	URDSet05
URep06	URep06	Predefined Unbuffered Report 06	URDSet06

Figure F.1 SEL-787 Predefined Reports

There are 12 report control blocks, six buffered reports and six unbuffered. For each report control block, there can be just one client association, i.e., only one client can be associated to a report control block (BRCB or URCB) at any given time. The number of reports (12) and the type of reports (buffered or unbuffered) cannot be changed. However, by using Architect, you can reallocate data within each report dataset to present different data attributes for each report beyond the predefined datasets. For buffered reports, connected clients may edit the report parameters shown in *Table F.4*.

Table F.4 Buffered Report Control Block Client Access

RCB Attribute	User changeable (Report Disabled)	User changeable (Report Enabled)	Default Values
RptId	YES		BRep01–BRep06
RptEna	YES	YES	FALSE
OptFlds	YES		seqNum timeStamp dataSet configRef reasonCode dataRef
BufTm	YES		500
TrgOp	YES		dchg qchg
IntgPd	YES		0
GI	YES[a b]	YES[a]	FALSE
PurgeBuf	YES[a]		FALSE
EntryId	YES		0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once the command is accepted, it will return to zero. Always read as zero.

[b] When disabled, a GI will be processed and the report buffered if a buffer has been previously established. A buffer is established when the report is enabled for the first time.

Similarly, for unbuffered reports, connected clients may edit the report parameters shown in *Table F.5*.

Table F.5 Unbuffered Report Control Block Client Access

RCB Attribute	User changeable (Report Disabled)	User changeable (Report Enabled)	Default Values
RptId	YES		URep01–URep06
RptEna	YES	YES	FALSE
Resv	YES		FALSE
OptFlds	YES		seqNum timeStamp dataSet configRef reasonCode dataRef
BufTm	YES		250
TrgOps	YES		dchg qchg
IntgPd	YES		0
GI		YES[a]	0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once the command is accepted, it will return to zero. Always read as zero.

For Buffered Reports, only one client can enable the RptEna attribute of the BRCB at a time resulting in a client association for that BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB.

For Unbuffered Reports, as many as six (6) clients can enable the RptEna attribute of the URCB at a time, resulting in multiple client associations for that URCB. Once enabled, each client has independent access to a copy of that URCB. The Resv attribute is writable, however, the SEL-787 does not support reservations. Writing any field of the URCB causes the client to obtain their own copy of the URCB-in essence, acquiring a reservation.

Reports are serviced at a 2 Hz rate. The client can set the IntgPd to any value with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The report service rate of 2 Hz results in a report being sent within 500 ms of expiration of the IntgPd. The new IntgPd will begin at the time that the current report is serviced.

Datasets

Datasets are configured using Architect and contain data attributes that represent real data values within the SEL-787 device. See *Logical Nodes* for the logical node tables that list the available data attributes for each logical node and the Relay Word bit mapping for these data attributes. The datasets listed in *Figure F.2* are the defaults for an SEL-787 device. Datasets BRDSet01–BRDSet06 and URDSet01–URDSet06 are preconfigured with common FCDAs to be used for reporting. These datasets can be configured to represent the data you want to monitor. Dataset GPDSet01, which contains breaker status and control data attributes, is used in the default Goose Control Publication.

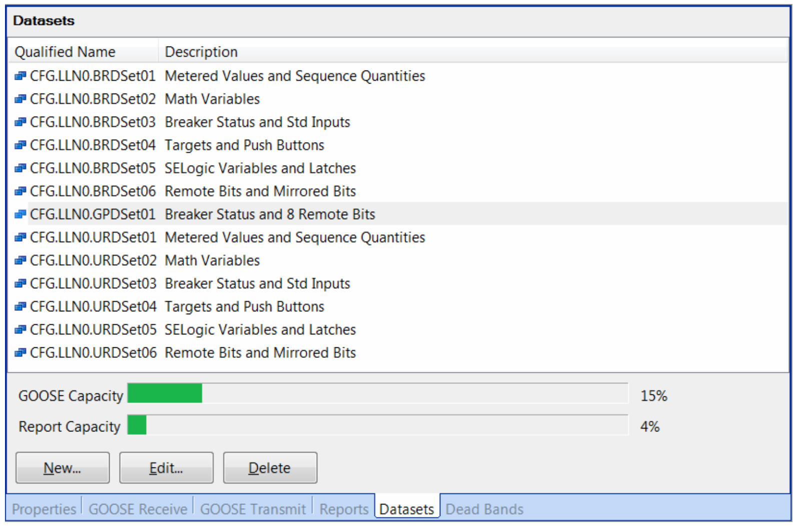


Figure F.2 SEL-787 Datasets

Within Architect, IEC 61850 datasets have two main purposes:

- ➤ GOOSE: You can use predefined or edited datasets, or create new datasets for outgoing GOOSE transmission.
- ➤ Reports: Twelve predefined datasets (BRDSet01 to BRDSet06 and URDSet01 to URDSet06) correspond to the default six buffered and six unbuffered reports. Note that you cannot change the number (12) or type of reports (buffered or unbuffered) within Architect. However, you can alter the data attributes that a dataset contains and so define what data an IEC 61850 client receives with a report.

NOTE: Do not edit the dataset names used in reports. Changing or deleting any of those dataset names will cause a failure in generating the corresponding report.

Supplemental Software

Examine the data structure and value of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc. The settings needed to browse an SEL-787 with an MMS browser are shown below:

OSI-PSEL (Presentation Selector)	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality and t (time stamp) are available at any time. The time stamp is determined when data or quality change is detected.

The time stamp is applied to all data and quality attributes (Boolean, Bstrings, Analogs, etc.) in the same fashion when a data or quality change is detected. However, there is a difference in how the change is detected between the different attribute types. For points that are assigned as SER points, i.e., programmed in the SER report, the change is detected as the receipt of an SER record (which contains the SER time stamp) within the relay.

For all other Booleans or Bstrings, the change is detected via the scanner, which compares the last state against the previous state to detect the change. For analogs, the scanner looks at the amount of change relative to the deadband configured for the point to indicate a change and apply the time stamp. In all cases, these time stamps are used for the reporting model.

Functionally Constrained Data Attributes mapped to points assigned to the SER report have 4 ms SER-accurate time stamps for data change events. In order to ensure that you will get SER-quality time stamps for changes to certain points, you must include those points in the SER report. All other FCDAs are scanned for data changes on a 1/2-second interval and have 1/2-second time-stamp accuracy. See the **SET R** command for information on programming the SER report.

The SEL-787 uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. *Figure F.3* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from SEL-787 datasets that contain them. Internal status indicators provide the information necessary for the device to set these attributes. For example, if the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the SEL-787 will set the Validity attribute to invalid and the Failure attribute to TRUE. Note that the SEL-787 does not set any of the other quality attributes. These attributes will always indicate FALSE (0). See the Architect online help for additional information on GOOSE quality attributes.

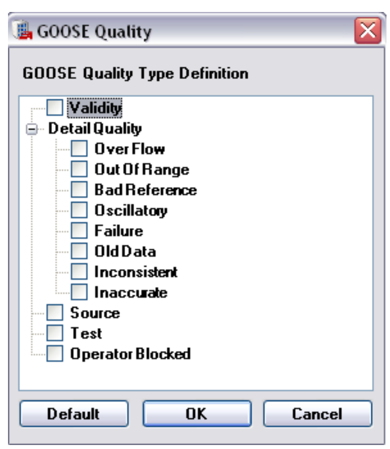


Figure F.3 Goose Quality

GOOSE Processing

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2003(E), IEC 61850-7-2:2003(E), and IEC 61850-8-1:2004(E) via the installed Ethernet port. Outgoing GOOSE messages are processed in accordance with the following constraints:

- You can define as many as eight outgoing GOOSE messages consisting of any Data Attribute (DA) from any Logical Node. A single DA can be mapped to one or more outgoing GOOSE, or one or more times within the same outgoing GOOSE. A user can also map a single GOOSE dataset to multiple GOOSE control blocks.
- The SEL-787 will transmit all configured GOOSE immediately upon successful initialization. If a GOOSE is not retriggered, then, following initial transmission, the SEL-787 will retransmit that GOOSE on a curve. The curve begins at 10 ms and doubles for each retransmission until leveling at the maximum specified in the CID file for that GOOSE. For example, a message with a maximum retransmit interval of 100 ms is retransmitted at intervals of 10 ms, 20 ms, 40 ms, 80 ms, and 100 ms, then repeated every 100 ms until a trigger causes the transmission sequence to be repeated. The time-to-live reported in each transmitted message, is three times the current interval, or two times the interval, if the maximum time-to-live has been reached (30 ms, 60 ms, 120 ms, 240 ms, and 200 ms for the example above; see IEC 61850-8-1, sec. 18.1).
- GOOSE transmission is squelched (silenced) after a permanent (latching) self-test failure.
- Each outgoing GOOSE includes communication parameters (VLAN, Priority, and Multicast Address) and is transmitted entirely in a single network frame.
- The SEL-787 will maintain the configuration of outgoing GOOSE through a power cycle and device reset.

Incoming GOOSE messages are processed in accordance with the following constraints:

- You can configure the SEL-787 to subscribe to as many as 16 incoming GOOSE messages.
- Controls bits in the relay get data from incoming GOOSE messages which are mapped to virtual bits (VB*nnn*). Virtual bits are volatile and are reset to zero when a new CID file is loaded, the device is restarted, or they are overwritten by data from a subscribed GOOSE message.
- The SEL-787 will recognize incoming GOOSE messages as valid based on the following content. Any GOOSE message that fails these checks shall be rejected.
  - Source broadcast MAC address
  - Dataset Reference
  - Application ID
  - GOOSE Control Reference
- Rejection of all DA contained in an incoming GOOSE, based on the accumulation of the following error indications created by inspection of the received GOOSE:
  - **Configuration Mismatch**: the configuration number of the incoming GOOSE changes.

- ➢ **Needs Commissioning**: this Boolean parameter of the incoming GOOSE is true.
- ➢ **Test Mode**: this Boolean parameter of the incoming GOOSE is true.
- ➢ **Decode Error**: the format of the incoming GOOSE is not as configured.

➤ The SEL-787 will discard incoming GOOSE under the following conditions:

- ➢ after a permanent (latching) self-test failure
- ➢ when the relay is disabled
- ➢ when EGSE is set to No

Link-layered priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2004(E).

IEC 61850 Configuration

Settings

Table F.6 lists IEC 61850 settings. IEC 61850 settings are available only if your device includes the optional IEC 61850 protocol.

Table F.6 IEC 61850 Settings

Label	Description	Range	Default
E61850	IEC 61850 interface enable	Y, N	N
EGSE	Outgoing IEC 61850 GSE message enable	Y[a], N	N

[a] Requires E61850 set to Y to send IEC 61850 GSE messages.

Configure all other IEC 61850 settings, including subscriptions to incoming GOOSE messages, with Architect.

Architect Software

The Architect software enables users to design and commission IEC 61850 substations containing SEL IEDs. Users can use Architect to do the following:

- ➤ Organize and configure all SEL IEDs in a substation project.
- ➤ Configure incoming and outgoing GOOSE messages.
- ➤ Edit and create GOOSE datasets.
- ➤ Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- ➤ Use or edit preconfigured datasets for reports.
- ➤ Load IEC 61850 CID files into SEL IEDs.
- ➤ Generate ICD and CID files that will provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.
- ➤ Edit deadband settings for measured values.

Architect provides a GUI for users to select, edit, and create IEC 61850 GOOSE messages important for substation protection, coordination, and control schemes. Typically, the user first places icons representing IEDs in a substation container, then edits the outgoing GOOSE messages or creates new ones for each IED. The user can also select incoming GOOSE messages for each IED to receive from any other IEDs in the domain.

Some measured values are reported to IEC 61850 only when the value changes beyond a defined deadband value. Architect allows a deadband to be changed during the CID file configuration. Check and set the deadband values for your particular application when configuring the CID file for a device.

Architect has the capability to read other manufacturers' ICD and CID files, enabling the user to map the data seamlessly into SEL IED logic. See the Architect online help for more information.

SEL ICD File Versions

Architect generates CID files from ICD files so the ICD file version Architect uses also determines the CID file version generated. Details about the different SEL-787 ICD files can be found in *Table A.5*.

Logical Node Extensions

The following Logical Nodes and Data Classes were created in this device as extensions to the IEC 61850 standard, in accordance with IEC 61850 guidelines.

Table F.7 New Logical Node Extensions

Logical Node	IEC 61850	Description or Comments
Thermal Measurements (for equipment or ambient temperature readings)	MTHR	This LN shall be used to represent values from RTDs and to calculate thermal quantities for Thermal Monitoring.
Demand Metering Statistics	MDST	This LN shall be used for calculation of demand currents in a three-phase system. This shall not be used for billing purposes.

Table F.8 defines the data class, Thermal Metering Data. This class is a collection of simultaneous measurements (or evaluations) that represent the RTD thermal metering values. Valid data depend on the presence and configuration of the RTD module(s).

Table F.8 Thermal Metering Data Logical Node Class Definition

MTHR Class				
Attribute Name	**Attr. Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix, and the LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
EEHealth	INS	External equipment health (RTD Communications Status)		E
Data Objects				
Measured values				
MaxAmbTmp	MV	Maximum Ambient Temperature		E
MaxWdgTmp	MV	Maximum Winding Temperature		E
Tmp	MV	Temperature		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension

Table F.9 defines the data class Demand Metering Statistics. This class is a collection of demand currents and energy.

Table F.9 Demand Metering Statistics Logical Node Class Definition

MDST Class				
Attribute Name	**Attr. Type**	**Explanation**	**T[a]**	**M/O/ C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix, and the LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured values				
DmdA	WYE	Demand Currents		E
PkDmdA	WYE	Peak Demand Currents		E
SupWh	MV	Real energy supply (default supply direction: energy flow towards busbar)		E
SupVArh	MV	Reactive energy supply (default supply direction: energy flow towards busbar)		E
DmdWh	MV	Real energy demand (default demand direction: energy flow from busbar away)		E
DmdVArh	MV	Reactive energy demand (default demand direction: energy flow from busbar away)		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension

Table F.10 Compatible Logical Nodes With Extensions

Logical Node	IEC 61850	Description or Comments
Metering Statistics	MSTA	This LN is used for power system metering statistics.

Table F.11 Metering Statistics Logical Node Class Definition (Sheet 1 of 2)

MSTA Class				
Attribute Name	**Attr. Type**	**Explanation**	**T[a]**	**M/O/ C/E[b]**
LNName		The name shall be composed of the class name, the LN-Prefix, and the LN-Instance-ID according to IEC 61850-7-2.		
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class.		M
Data Objects				
Measured and Metered values				
AvAmps	MV	Average Current		O
AvVolts	MV	Average Voltage		O
MaxVA	MV	Maximum apparent power		O
MinVA	MV	Minimum apparent power		O

Table F.11 Metering Statistics Logical Node Class Definition (Sheet 2 of 2)

MSTA Class				
Attribute Name	**Attr. Type**	**Explanation**	**T[a]**	**M/O/C/E[b]**
MaxW	MV	Maximum real power		O
MinW	MV	Minimum real power		O
MaxVAr	MV	Maximum reactive power		O
MinVAr	MV	Minimum reactive power		O
MaxA	WYE	Maximum Phase Currents		E
MinA	WYE	Minimum Phase Currents		E
MaxPhV	WYE	Maximum Phase to Ground Voltages		E
MinPhV	WYE	Minimum Phase to Ground Voltages		E
MaxP2PV	DEL	Maximum Phase to Phase Voltages		E
MinP2PV	DEL	Minimum Phase to Phase Voltages		E

[a] Transient data objects—the status of data objects with this designation is momentary and must be logged or reported to provide evidence of their momentary state
[b] M: Mandatory; O: Optional; C: Conditional; E: Extension

Logical Nodes

The following tables, *Table F.12* through *Table F.16*, show the Logical Nodes (LNs) supported in the SEL-787 and the associated Relay Word bits or measured quantities. *Table F.12* shows the LN associated with protection elements defined as Logical Device PRO.

Table F.12 Logical Device: PRO (Protection) (Sheet 1 of 7)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
W1CSWI1	Pos.Oper.ctlVal	CC1[a]	Breaker1 close/open command
W2CSWI2	Pos.Oper.ctlVal	CC2[a]	Breaker2 close/open command
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
Functional Constraint = ST			
BFR1RBRF1	OpEx.general	BFT1	Breaker1 failure trip
BFR1RBRF1	Str.general	BFI1	Breaker1 failure initiation
BFR2RBRF2	OpEx.general	BFT2	Breaker2 failure trip
BFR2RBRF2	Str.general	BFI2	Breaker2 failure initiation
C2PVPH2	Op.general	24C2T	Level 2 Volts/Hertz composite element timed out
C2PVPH2	Str.general	24C2	Level 2 Volts/Hertz composite element pickup
C2PVPH2	Str.dirGeneral	unknown	Direction undefined
D1PTOF1	Op.general	81D1T	Level 1 definite-time over-/underfrequency trip
D1PTOF1	Str.general	81D1T	Level 1 definite-time over-/underfrequency trip
D1PTOF1	Str.dirGeneral	unknown	Direction undefined

Table F.12 Logical Device: PRO (Protection) (Sheet 2 of 7)

Logical Node	Attribute	Data Source	Comment
D1PVPH1	Op.general	24D1T	Level 1 Volts/Hertz definite-time element timed out
D1PVPH1	Str.general	24D1	Level 1 Volts/Hertz instantaneous pickup
D1PVPH1	Str.dirGeneral	unknown	Direction undefined
D2PTOF2	Op.general	81D2T	Level 2 definite-time over-/underfrequency trip
D2PTOF2	Str.general	81D2T	Level 2 definite-time over-/underfrequency trip
D2PTOF2	Str.dirGeneral	unknown	Direction undefined
D3PTOF3	Op.general	81D3T	Level 3 definite-time over-/underfrequency trip
D3PTOF3	Str.general	81D3T	Level 3 definite-time over-/underfrequency trip
D3PTOF3	Str.dirGeneral	unknown	Direction undefined
D4PTOF4	Op.general	81D4T	Level 4 definite-time over-/underfrequency trip
D4PTOF4	Str.general	81D4T	Level 4 definite-time over-/underfrequency trip
D4PTOF4	Str.dirGeneral	unknown	Direction undefined
D87APDIF3	Op.general	87AT	Differential current alarm element trip
D87APDIF3	Str.general	87AP	Differential current alarm element pickup
D87APDIF3	Str.dirGeneral	unknown	Direction undefined
D87RPDIF2	Op.general	87R	Restrained differential element trip
D87RPDIF2	Op.phsA	87R1	Restrained Differential Element 1
D87RPDIF2	Op.phsB	87R2	Restrained Differential Element 2
D87RPDIF2	Op.phsC	87R3	Restrained Differential Element 3
D87UPDIF1	Op.general	87U	Unrestrained differential element trip
D87UPDIF1	Op.phsA	87U1	Unrestrained Differential Element 1 trip
D87UPDIF1	Op.phsB	87U2	Unrestrained Differential Element 2 trip
D87UPDIF1	Op.phsC	87U3	Unrestrained Differential Element 3 trip
G11PIOC11	Op.general	50G11T	Level 1 residual ground instantaneous overcurrent element trip–Winding 1
G11PIOC11	Str.general	50G11P	Level 1 residual ground instantaneous overcurrent element pickup–Winding 1
G11PIOC11	Str.dirGeneral	unknown	Direction undefined
G12PIOC12	Op.general	50G12T	Level 2 residual ground instantaneous overcurrent element trip–Winding 1
G12PIOC12	Str.general	50G12P	Level 2 residual ground instantaneous overcurrent element pickup–Winding 1
G12PIOC12	Str.dirGeneral	unknown	Direction undefined
G1PTOC4	Op.general	51G1T	Residual ground time-overcurrent element trip–Winding 1
G1PTOC4	Str.general	51G1P	Residual ground time-overcurrent element pickup–Winding 1
G1PTOC4	Str.dirGeneral	unknown	Direction undefined
G21PIOC13	Op.general	50G21T	Level 1 residual ground instantaneous overcurrent element trip–Winding 2
G21PIOC13	Str.general	50G21P	Level 1 residual ground instantaneous overcurrent element pickup–Winding 2
G21PIOC13	Str.dirGeneral	unknown	Direction undefined
G22PIOC14	Op.general	50G22T	Level 2 residual ground instantaneous overcurrent element trip–Winding 2

Table F.12 Logical Device: PRO (Protection) (Sheet 3 of 7)

Logical Node	Attribute	Data Source	Comment
G22PIOC14	Str.general	50G22P	Level 2 residual ground instantaneous overcurrent element pickup–Winding 2
G22PIOC14	Str.dirGeneral	unknown	Direction undefined
G2PTOC5	Op.general	51G2T	Residual ground time-overcurrent element trip–Winding 2
G2PTOC5	Str.general	51G2P	Residual ground time-overcurrent element pickup–Winding 2
G2PTOC5	Str.dirGeneral	unknown	Direction undefined
HB24PHAR1	Str.phsA	2_4HB1	Second or fourth-harmonic block asserted for Differential Element 1
HB24PHAR1	Str.phsB	2_4HB2	Second or fourth-harmonic block asserted for Differential Element 2
HB24PHAR1	Str.phsC	2_4HB3	Second or fourth-harmonic block asserted for Differential Element 3
HB24PHAR1	Str.general	2_4HBL	Second or fourth-harmonic block asserted (2_4HB1 OR 2_4HB2 OR 2_4HB3)
HB24PHAR1	Str.dirGeneral	unknown	Direction undefined
HB24PHAR1	Str.dirPhsA	unknown	Direction undefined
HB24PHAR1	Str.dirPhsB	unknown	Direction undefined
HB24PHAR1	Str.dirPhsC	unknown	Direction undefined
HB5PHAR2	Str.phsA	5HB1	Fifth-harmonic block asserted for Differential Element 1
HB5PHAR2	Str.phsB	5HB2	Fifth-harmonic block asserted for Differential Element 2
HB5PHAR2	Str.phsC	5HB3	Fifth-harmonic block asserted for Differential Element 3
HB5PHAR2	Str.general	5HBL	Fifth-harmonic block asserted (5HB1 OR 5HB2 OR 5HB3)
HB5PHAR2	Str.dirGeneral	unknown	Direction undefined
HB5PHAR2	Str.dirPhsA	unknown	Direction undefined
HB5PHAR2	Str.dirPhsB	unknown	Direction undefined
HB5PHAR2	Str.dirPhsC	unknown	Direction undefined
LOPPTUV3	Op.general	LOP	Loss of potential
LOPPTUV3	Str.general	LOP	Loss of potential
LOPPTUV3	Str.dirGeneral	unknown	Direction undefined
N11PIOC9	Op.general	50N11T	Level 1 neutral ground instantaneous overcurrent element trip–Input 1
N11PIOC9	Str.general	50N11P	Level 1 neutral ground instantaneous overcurrent element pickup–Input 1
N11PIOC9	Str.dirGeneral	unknown	Direction undefined
N12PIOC10	Op.general	50N12T	Level 2 neutral ground instantaneous overcurrent element trip–Input 1
N12PIOC10	Str.general	50N12P	Level 2 neutral ground instantaneous overcurrent element pickup–Input 1
N12PIOC10	Str.dirGeneral	unknown	Direction undefined
N1PTOC3	Op.general	51N1T	Neutral ground time-overcurrent element trip–Input 1
N1PTOC3	Str.general	51N1P	Neutral ground time-overcurrent element pickup–Input 1
N1PTOC3	Str.dirGeneral	unknown	Direction undefined
P11APIOC19	Op.general	50P11AT	Level 1 A-phase instantaneous overcurrent element trip–Winding 1
P11APIOC19	Str.general	50P11AP	Level 1 A-phase instantaneous overcurrent element pickup–Winding 1
P11APIOC19	Str.dirGeneral	unknown	Direction undefined
P11BPIOC20	Op.general	50P11BT	Level 1 B-phase instantaneous overcurrent element trip–Winding 1

Table F.12 Logical Device: PRO (Protection) (Sheet 4 of 7)

Logical Node	Attribute	Data Source	Comment
P11BPIOC20	Str.general	50P11BP	Level 1 B-phase instantaneous overcurrent element pickup–Winding 1
P11BPIOC20	Str.dirGeneral	unknown	Direction undefined
P11CPIOC21	Op.general	50P11CT	Level 1 C-phase instantaneous overcurrent element trip–Winding 1
P11CPIOC21	Str.general	50P11CP	Level 1 C-phase instantaneous overcurrent element pickup–Winding 1
P11CPIOC21	Str.dirGeneral	unknown	Direction undefined
P11PIOC1	Op.general	50P11T	Level 1 phase instantaneous overcurrent element trip–Winding 1
P11PIOC1	Str.general	50P11P	Level 1 phase instantaneous overcurrent element pickup–Winding 1
P11PIOC1	Str.dirGeneral	unknown	Direction undefined
P12PIOC2	Op.general	50P12T	Level 2 phase instantaneous overcurrent element trip–Winding 1
P12PIOC2	Str.general	50P12P	Level 2 phase instantaneous overcurrent element pickup–Winding 1
P12PIOC2	Str.dirGeneral	unknown	Direction undefined
P13PIOC3	Op.general	50P13T	Level 3 phase instantaneous overcurrent element trip–Winding 1
P13PIOC3	Str.general	50P13P	Level 3 phase instantaneous overcurrent element pickup–Winding 1
P13PIOC3	Str.dirGeneral	unknown	Direction undefined
P14PIOC4	Op.general	50P14T	Level 4 phase instantaneous overcurrent element trip–Winding 1
P14PIOC4	Str.general	50P14P	Level 4 phase instantaneous overcurrent element pickup–Winding 1
P14PIOC4	Str.dirGeneral	unknown	Direction undefined
P1APTOC8	Op.general	51P1AT	Level 1 A-phase time-overcurrent element trip–Winding 1
P1APTOC8	Str.general	51P1AP	Level 1 A-phase time-overcurrent element pickup–Winding 1
P1APTOC8	Str.dirGeneral	unknown	Direction undefined
P1BPTOC9	Op.general	51P1BT	Level 1 B phase time-overcurrent element trip–Winding 1
P1BPTOC9	Str.general	51P1BP	Level 1 B phase time-overcurrent element pickup–Winding 1
P1BPTOC9	Str.dirGeneral	unknown	Direction undefined
P1CPTOC10	Op.general	51P1CT	Level 1 C phase time-overcurrent element trip–Winding 1
P1CPTOC10	Str.general	51P1CP	Level 1 C phase time-overcurrent element pickup–Winding 1
P1CPTOC10	Str.dirGeneral	unknown	Direction undefined
P1PTOC1	Op.general	51P1T	Maximum phase time-overcurrent element trip–Winding 1
P1PTOC1	Str.general	51P1P	Maximum phase time-overcurrent element pickup–Winding 1
P1PTOC1	Str.dirGeneral	unknown	Direction undefined
P1PTOV1	Op.general	59P1T	Level 1 phase overvoltage element trip
P1PTOV1	Str.general	59P1	Level 1 phase overvoltage element pickup
P1PTOV1	Str.dirGeneral	unknown	Direction undefined
P1PTUV1	Op.general	27P1T	Level 1 phase undervoltage element trip
P1PTUV1	Str.general	27P1	Level 1 phase undervoltage element pickup
P1PTUV1	Str.dirGeneral	unknown	Direction undefined
P21APIOC22	Op.general	50P21AT	Level 1 A-phase instantaneous overcurrent element trip–Winding 2
P21APIOC22	Str.general	50P21AP	Level 1 A-phase instantaneous overcurrent element pickup–Winding 2
P21APIOC22	Str.dirGeneral	unknown	Direction undefined

Table F.12 Logical Device: PRO (Protection) (Sheet 5 of 7)

Logical Node	Attribute	Data Source	Comment
P21BPIOC23	Op.general	50P21BT	Level 1 B-phase instantaneous overcurrent element trip–Winding 2
P21BPIOC23	Str.general	50P21BP	Level 1 B-phase instantaneous overcurrent element pickup–Winding 2
P21BPIOC23	Str.dirGeneral	unknown	Direction undefined
P21CPIOC24	Op.general	50P21CT	Level 1 C-phase instantaneous overcurrent element trip–Winding 2
P21CPIOC24	Str.general	50P21CP	Level 1 C-phase instantaneous overcurrent element pickup–Winding 2
P21CPIOC24	Str.dirGeneral	unknown	Direction undefined
P21PIOC5	Op.general	50P21T	Level 1 phase instantaneous overcurrent element trip–Winding 2
P21PIOC5	Str.general	50P21P	Level 1 phase instantaneous overcurrent element pickup–Winding 2
P21PIOC5	Str.dirGeneral	unknown	Direction undefined
P22PIOC6	Op.general	50P22T	Level 2 phase instantaneous overcurrent element trip–Winding 2
P22PIOC6	Str.general	50P22P	Level 2 phase instantaneous overcurrent element pickup–Winding 2
P22PIOC6	Str.dirGeneral	unknown	Direction undefined
P23PIOC7	Op.general	50P23T	Level 3 phase instantaneous overcurrent element trip–Winding 2
P23PIOC7	Str.general	50P23P	Level 3 phase instantaneous overcurrent element pickup–Winding 2
P23PIOC7	Str.dirGeneral	unknown	Direction undefined
P24PIOC8	Op.general	50P24T	Level 3 phase instantaneous overcurrent element trip–Winding 2
P24PIOC8	Str.general	50P24P	Level 3 phase instantaneous overcurrent element pickup–Winding 2
P24PIOC8	Str.dirGeneral	unknown	Direction undefined
P2APTOC11	Op.general	51P2AT	Level 1 A-phase time-overcurrent element trip–Winding 2
P2APTOC11	Str.general	51P2AP	Level 1 A-phase time-overcurrent element pickup–Winding 2
P2APTOC11	Str.dirGeneral	unknown	Direction undefined
P2BPTOC12	Op.general	51P2BT	Level 1 B-phase time-overcurrent element trip–Winding 2
P2BPTOC12	Str.general	51P2BP	Level 1 B-phase time-overcurrent element pickup–Winding 2
P2BPTOC12	Str.dirGeneral	unknown	Direction undefined
P2CPTOC13	Op.general	51P2CT	Level 1 C-phase time-overcurrent element trip–Winding 2
P2CPTOC13	Str.general	51P2CP	Level 1 C-phase time-overcurrent element pickup–Winding 2
P2CPTOC13	Str.dirGeneral	unknown	Direction undefined
P2PTOC2	Op.general	51P2T	Maximum phase time-overcurrent element trip–Winding 2
P2PTOC2	Str.general	51P2P	Maximum phase time-overcurrent element pickup–Winding 2
P2PTOC2	Str.dirGeneral	unknown	Direction undefined
P2PTOV2	Op.general	59P2T	Level 2 phase overvoltage element trip
P2PTOV2	Str.general	59P2	Level 2 phase overvoltage element pickup
P2PTOV2	Str.dirGeneral	unknown	Direction undefined
P2PTUV2	Op.general	27P2T	Level 2 phase undervoltage element trip
P2PTUV2	Str.general	27P2	Level 2 phase undervoltage element pickup
P2PTUV2	Str.dirGeneral	unknown	Direction undefined
PWR1PDOP1	Op.general	3PWR1T	Three-Phase Power Element 1 trip
PWR1PDOP1	Str.general	3PWR1P	Three-Phase Power Element 1 pickup

Table F.12 Logical Device: PRO (Protection) (Sheet 6 of 7)

Logical Node	Attribute	Data Source	Comment
PWR1PDOP1	Str.dirGeneral	unknown	Direction undefined
PWR1PDUP1	Op.general	3PWR1T	Three-Phase Power Element 1 trip
PWR1PDUP1	Str.general	3PWR1P	Three-Phase Power Element 1 pickup
PWR1PDUP1	Str.dirGeneral	unknown	Direction undefined
PWR2PDOP2	Op.general	3PWR2T	Three-Phase Power Element 2 trip
PWR2PDOP2	Str.general	3PWR2P	Three-Phase Power Element 2 pickup
PWR2PDOP2	Str.dirGeneral	unknown	Direction undefined
PWR2PDUP2	Op.general	3PWR2T	Three-Phase Power Element 2 trip
PWR2PDUP2	Str.general	3PWR2P	Three-Phase Power Element 2 pickup
PWR2PDUP2	Str.dirGeneral	unknown	Direction undefined
Q11PIOC15	Op.general	50Q11T	Level 1 negative-sequence instantaneous overcurrent element trip–Winding 1
Q11PIOC15	Str.general	50Q11P	Level 1 negative-sequence instantaneous overcurrent element pickup–Winding 1
Q11PIOC15	Str.dirGeneral	unknown	Direction undefined
Q12PIOC16	Op.general	50Q12T	Level 2 negative-sequence instantaneous overcurrent element trip–Winding 1
Q12PIOC16	Str.general	50Q12P	Level 2 negative-sequence instantaneous overcurrent element pickup–Winding 1
Q12PIOC16	Str.dirGeneral	unknown	Direction undefined
Q1PTOC6	Op.general	51Q1T	Negative-sequence time-overcurrent element trip–Winding 1
Q1PTOC6	Str.general	51Q1P	Negative-sequence time-overcurrent element pickup–Winding 1
Q1PTOC6	Str.dirGeneral	unknown	Direction undefined
Q1TPTOV2	Op.general	59Q1T	Level 1 negative-sequence overvoltage element trip
Q1TPTOV2	Str.general	59Q1	Level 1 negative-sequence overvoltage element pickup
Q1TPTOV2	Str.dirGeneral	unknown	Direction undefined
Q21PIOC17	Op.general	50Q21T	Level 1 negative-sequence instantaneous overcurrent element trip–Winding 2
Q21PIOC17	Str.general	50Q21P	Level 1 negative-sequence instantaneous overcurrent element pickup–Winding 2
Q21PIOC17	Str.dirGeneral	unknown	Direction undefined
Q22PIOC18	Op.general	50Q22T	Level 2 negative-sequence instantaneous overcurrent element trip–Winding 2
Q22PIOC18	Str.general	50Q22P	Level 2 negative-sequence instantaneous overcurrent element pickup–Winding 2
Q22PIOC18	Str.dirGeneral	unknown	Direction undefined
Q2PTOC7	Op.general	51Q2T	Negative-sequence time-overcurrent element trip–Winding 2
Q2PTOC7	Str.general	51Q2P	Negative-sequence time-overcurrent element pickup–Winding 2
Q2PTOC7	Str.dirGeneral	unknown	Direction undefined
Q2TPTOV3	Op.general	59Q2T	Level 2 negative-sequence overvoltage element trip
Q2TPTOV3	Str.general	59Q2	Level 2 negative-sequence overvoltage element pickup

Table F.12 Logical Device: PRO (Protection) (Sheet 7 of 7)

Logical Node	Attribute	Data Source	Comment
Q2TPTOV3	Str.dirGeneral	unknown	Direction undefined
REF1FPDIF4	Op.general	REF1F	REF element forward (internal) fault declaration
REF1PPDIF5	Op.general	REF1P	Restricted earth fault inverse-time O/C element timed-out
REF1RPDIF6	Op.general	REF1R	REF element reverse (external) fault declaration
TRIP1PTRC1	Tr.general	TRIP1	Trip1 logic output
TRIP2PTRC2	Tr.general	TRIP2	Trip2 logic output
TRIP3PTRC3	Tr.general	TRIPXFMR	TripXFMR logic output
W1CSWI1	OpCls.general	CC1	Breaker1 close control
W1CSWI1	OpOpn.general	OC1	Breaker1 open control
W1CSWI1	Pos.stVal	52A1?1:2[b]	Breaker1 position (52A = false, breaker opened; 52A = true, breaker closed)
W1XCBR1	BlkCls.stVal	0	Breaker close blocking not configured by default
W1XCBR1	BlkOpn.stVal	0	Breaker open blocking not configured by default
W1XCBR1	CBOpCap.stVal	None	Breaker physical operation capabilities not known to relay
W1XCBR1	Loc.stVal	0	Breaker local control status not configured by default
W1XCBR1	OpCnt.stVal	0	Breaker operation counts not available
W1XCBR1	Pos.stVal	52A1?1:2[b]	Breaker1 position (52A = false, breaker opened; 52A = true, breaker closed)
W2CSWI2	OpCls.general	CC2	Breaker2 close control
W2CSWI2	OpOpn.general	OC2	Breaker2 open control
W2CSWI2	Pos.stVal	52A2?1:2[b]	Breaker2 position (52A = false, breaker opened; 52A = true, breaker closed)
W2XCBR2	BlkCls.stVal	0	Breaker close blocking not configured by default
W2XCBR2	BlkOpn.stVal	0	Breaker open blocking not configured by default
W2XCBR2	CBOpCap.stVal	None	Breaker physical operation capabilities not known to relay
W2XCBR2	Loc.stVal	0	Breaker local control status not configured by default
W2XCBR2	OpCnt.stVal	0	Breaker operation counts not available
W2XCBR2	Pos.stVal	52A2?1:2[b]	Breaker2 position (52A = false, breaker opened; 52A = true, breaker closed)

[a] Writing a 0 to WnCSWIn.CO.Pos.Oper.ctlVal (n = 1, 2) will cause OCn to assert and writing any other value will cause CCn to assert.
[b] If breaker/contactor is closed, value = 10(2); if breaker/contactor is opened, value = 01(1).

Table F.13 shows the LN associated with measuring elements defined as Logical Device MET.

Table F.13 Logical Device: MET (Metering) (Sheet 1 of 5)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
Functional Constraint = MX[a b]			
METMDST1	DmdA.nseq.instCVal.mag.f	3I2D	Negative-sequence current demand
METMDST1	DmdA.phsA.instCVal.mag.f	IAD	Phase-A current demand

Table F.13 Logical Device: MET (Metering) (Sheet 2 of 5)

Logical Node	Attribute	Data Source	Comment
METMDST1	DmdA.phsB.instCVal.mag.f	IBD	Phase-B current demand
METMDST1	DmdA.phsC.instCVal.mag.f	ICD	Phase-C current demand
METMDST1	DmdA.res.instCVal.mag.f	IGD	Residual current demand
METMDST1	DmdVArh.instMag.f	MVARHP	Reactive energy, three-phase positive
METMDST1	DmdWh.instMag.f	MWHP	Real energy, three-phase positive
METMDST1	PkDmdA.nseq.instCVal.mag.f	3I2PD	Negative-sequence current peak demand
METMDST1	PkDmdA.phsA.instCVal.mag.f	IAPD	Phase-A current peak demand
METMDST1	PkDmdA.phsB.instCVal.mag.f	IBPD	Phase-B current peak demand
METMDST1	PkDmdA.phsC.instCVal.mag.f	ICPD	Phase-C current peak demand
METMDST1	PkDmdA.res.instCVal.mag.f	IGPD	Residual current peak demand
METMDST1	SupVArh.instMag.f	MVARHN	Reactive energy, three-phase negative
METMDST1	SupWh.instMag.f	MWHN	Real energy, three-phase negative
METMHAI1	ThdA1.phsA.instCVal.mag.f	IAW1_THD	Winding 1 A-phase current THD
METMHAI1	ThdA1.phsB.instCVal.mag.f	IBW1_THD	Winding 1 B-phase current THD
METMHAI1	ThdA1.phsC.instCVal.mag.f	ICW1_THD	Winding 1 C-phase current THD
METMHAI1	ThdA1.neut.instCVal.mag.f	IN_THD	Neutral current THD
METMHAI1	ThdA2.phsA.instCVal.mag.f	IAW2_THD	Winding 2 A-phase current THD
METMHAI1	ThdA2.phsB.instCVal.mag.f	IBW2_THD	Winding 2 B-phase current THD
METMHAI1	ThdA2.phsC.instCVal.mag.f	ICW2_THD	Winding 2 C-phase current THD
METMHAI1	ThdPhV.phsA.instCVal.mag.f	VA_THD	A-phase-to-neutral voltage THD
METMHAI1	ThdPhV.phsB.instCVal.mag.f	VB_THD	B-phase-to-neutral voltage THD
METMHAI1	ThdPhV.phsC.instCVal.mag.f	VC_THD	C-phase-to-neutral voltage THD
METMHAI1	ThdPPV.phsAB.instCVal.mag.f	VAB_THD	A-to-B-phase voltage THD
METMHAI1	ThdPPV.phsBC.instCVal.mag.f	VBC_THD	B-to-C-phase voltage THD
METMHAI1	ThdPPV.phsCA.instCVal.mag.f	VCA_THD	C-to-A-phase voltage THD
METMMXU1	A.neut.instCVal.ang.f	IN_ANG	Current, neutral, angle
METMMXU1	A.neut.instCVal.mag.f	IN_MAG	Current, neutral, magnitude
METMMXU1	A1.phsA.instCVal.ang.f	IAW1_ANG	Winding 1 current, A-phase, angle
METMMXU1	A1.phsA.instCVal.mag.f	IAW1_MAG	Winding 1 current, A-phase, magnitude
METMMXU1	A1.phsB.instCVal.ang.f	IBW1_ANG	Winding 1 current, B-phase, angle
METMMXU1	A1.phsB.instCVal.mag.f	IBW1_MAG	Winding 1 current, B-phase, magnitude
METMMXU1	A1.phsC.instCVal.ang.f	ICW1_ANG	Winding 1 current, C-phase, angle
METMMXU1	A1.phsC.instCVal.mag.f	ICW1_MAG	Winding 1 current, C-phase, magnitude
METMMXU1	A1.res.instCVal.ang.f	IGW1_ANG	Winding 1 current, calculated-residual, angle
METMMXU1	A1.res.instCVal.mag.f	IGW1_MAG	Winding 1 current, calculated-residual, magnitude
METMMXU1	A2.phsA.instCVal.ang.f	IAW2_ANG	Winding 2 current, A-phase, angle
METMMXU1	A2.phsA.instCVal.mag.f	IAW2_MAG	Winding 2 current, A-phase, magnitude
METMMXU1	A2.phsB.instCVal.ang.f	IBW2_ANG	Winding 2 current, B-phase, angle

Table F.13 Logical Device: MET (Metering) (Sheet 3 of 5)

Logical Node	Attribute	Data Source	Comment
METMMXU1	A2.phsB.instCVal.mag.f	IBW2_MAG	Winding 2 current, B-phase, magnitude
METMMXU1	A2.phsC.instCVal.ang.f	ICW2_ANG	Winding 2 current, C-phase, angle
METMMXU1	A2.phsC.instCVal.mag.f	ICW2_MAG	Winding 2 current, C-phase, magnitude
METMMXU1	A2.res.instCVal.ang.f	IGW2_ANG	Winding 2 current, calculated-residual, angle
METMMXU1	A2.res.instCVal.mag.f	IGW2_MAG	Winding 2 current, calculated-residual, magnitude
METMMXU1	Hz.instMag.f	FREQ	Frequency
METMMXU1	PhV.phsA.instCVal.ang.f	VA_ANG	Voltage, A-phase-to-neutral, angle
METMMXU1	PhV.phsA.instCVal.mag.f	VA_MAG	Voltage, A-phase-to-neutral, magnitude
METMMXU1	PhV.phsB.instCVal.ang.f	VB_ANG	Voltage, B-phase-to-neutral, angle
METMMXU1	PhV.phsB.instCVal.mag.f	VB_MAG	Voltage, B-phase-to-neutral, magnitude
METMMXU1	PhV.phsC.instCVal.ang.f	VC_ANG	Voltage, C-phase-to-neutral, angle
METMMXU1	PhV.phsC.instCVal.mag.f	VC_MAG	Voltage, C-phase-to-neutral, magnitude
METMMXU1	PhV.res.instCVal.ang.f	VG_ANG	Zero-sequence voltage, angle
METMMXU1	PhV.res.instCVal.mag.f	VG_MAG	Zero-sequence voltage, magnitude
METMMXU1	PPV.phsAB.instCVal.ang.f	VAB_ANG	Voltage, A-to-B-phase, angle
METMMXU1	PPV.phsAB.instCVal.mag.f	VAB_MAG	Voltage, A-to-B-phase, magnitude
METMMXU1	PPV.phsBC.instCVal.ang.f	VBC_ANG	Voltage, B-to-C-phase, angle
METMMXU1	PPV.phsBC.instCVal.mag.f	VBC_MAG	Voltage, B-to-C-phase, magnitude
METMMXU1	PPV.phsCA.instCVal.ang.f	VCA_ANG	Voltage, C-to-A-phase, angle
METMMXU1	PPV.phsCA.instCVal.mag.f	VCA_MAG	Voltage, C-to-A-phase, magnitude
METMMXU1	TotPF.instMag.f	PF	Power factor, three-phase, magnitude
METMMXU1	TotVA.instMag.f	S	Apparent power, three-phase, magnitude
METMMXU1	TotVAr.instMag.f	Q	Reactive power, three-phase, magnitude
METMMXU1	TotW.instMag.f	P	Real power, three-phase, magnitude
METMSQI1	SeqA1.c2.instCVal.ang.f	3I2W1ANG	Winding 1 current, negative-sequence, angle
METMSQI1	SeqA1.c2.instCVal.mag.f	3I2W1MAG	Winding 1 current, negative-sequence, magnitude
METMSQI1	SeqA1.c1.instCVal.ang.f	I1W1_ANG	Winding 1 current, positive-sequence, angle
METMSQI1	SeqA1.c1.instCVal.mag.f	I1W1_MAG	Winding 1 current, positive-sequence, magnitude
METMSQI1	SeqA1.c3.instCVal.ang.f	IGW1_ANG	Winding 1 current, zero-sequence, angle
METMSQI1	SeqA1.c3.instCVal.mag.f	IGW1_MAG	Winding 1 current, zero-sequence, magnitude
METMSQI1	SeqA2.c2.instCVal.ang.f	3I2W2ANG	Winding 2 current, negative-sequence, angle
METMSQI1	SeqA2.c2.instCVal.mag.f	3I2W2MAG	Winding 2 current, negative-sequence, magnitude
METMSQI1	SeqA2.c1.instCVal.ang.f	I1W2_ANG	Winding 2 current, positive-sequence, angle
METMSQI1	SeqA2.c1.instCVal.mag.f	I1W2_MAG	Winding 2 current, positive-sequence, magnitude
METMSQI1	SeqA2.c3.instCVal.ang.f	IGW2_ANG	Winding 2 current, zero-sequence, angle
METMSQI1	SeqA2.c3.instCVal.mag.f	IGW2_MAG	Winding 2 current, zero-sequence, magnitude
METMSQI1	SeqV.c2.instCVal.ang.f	3V2_ANG	Voltage, negative-sequence, angle
METMSQI1	SeqV.c2.instCVal.mag.f	3V2_MAG	Voltage, negative-sequence, magnitude

Table F.13 Logical Device: MET (Metering) (Sheet 4 of 5)

Logical Node	Attribute	Data Source	Comment
METMSQI1	SeqV.c1.instCVal.ang.f	V1_ANG	Voltage, positive-sequence, angle
METMSQI1	SeqV.c1.instCVal.mag.f	V1_MAG	Voltage, positive-sequence, magnitude
METMSQI1	SeqV.c3.instCVal.ang.f	VG_ANG	Voltage, zero-sequence, angle
METMSQI1	SeqV.c3.instCVal.mag.f	VG_MAG	Voltage, zero-sequence, magnitude
METMSTA1	AvAmps01.instMag.f	IAVW1MAG	Winding 1 average current, magnitude
METMSTA1	AvAmps02.instMag.f	IAVW2MAG	Winding 2 average current, magnitude
METMSTA1	AvVolts.instMag.f	VAVE_MAG	Average voltage, magnitude
METMSTA1	MaxA.instCVal.mag.f	INMX	Current, neutral, maximum magnitude
METMSTA1	MaxA1.phsA.instCVal.mag.f	IAW1MX	Winding 1 current, A-phase, maximum magnitude
METMSTA1	MaxA1.phsB.instCVal.mag.f	IBW1MX	Winding 1 current, B-phase, maximum magnitude
METMSTA1	MaxA1.phsC.instCVal.mag.f	ICW1MX	Winding 1 current, C-phase, maximum magnitude
METMSTA1	MaxA1.res.instCVal.mag.f	IGW1MX	Winding 1 current, residual, maximum magnitude
METMSTA1	MaxA2.phsA.instCVal.mag.f	IAW2MX	Winding 2 current, A-phase, maximum magnitude
METMSTA1	MaxA2.phsB.instCVal.mag.f	IBW2MX	Winding 2 current, B-phase, maximum magnitude
METMSTA1	MaxA2.phsC.instCVal.mag.f	ICW2MX	Winding 2 current, C-phase, maximum magnitude
METMSTA1	MaxA2.res.instCVal.mag.f	IGW2MX	Winding 2 current, residual, maximum magnitude
METMSTA1	MaxP2PV.phsAB.instCVal.mag.f	VABMX	Voltage, A-to-B-phase, maximum magnitude
METMSTA1	MaxP2PV.phsBC.instCVal.mag.f	VBCMX	Voltage, B-to-C-phase, maximum magnitude
METMSTA1	MaxP2PV.phsCA.instCVal.mag.f	VCAMX	Voltage, C-to-A-phase, maximum magnitude
METMSTA1	MaxPhV.phsA.instCVal.mag.f	VAMX	Voltage, A-phase-to-neutral, maximum magnitude
METMSTA1	MaxPhV.phsB.instCVal.mag.f	VBMX	Voltage, B-phase-to-neutral, maximum magnitude
METMSTA1	MaxPhV.phsC.instCVal.mag.f	VCMX	Voltage, C-phase-to-neutral, maximum magnitude
METMSTA1	MaxVA.instMag.f	KVA3PMX	Apparent power magnitude, three-phase, maximum
METMSTA1	MaxVAr.instMag.f	KVAR3PMX	Reactive power magnitude, three-phase, maximum
METMSTA1	MaxW.instMag.f	KW3PMX	Real power magnitude, three-phase, maximum
METMSTA1	MinA.instCVal.mag.f	INMN	Current, neutral, minimum magnitude
METMSTA1	MinA1.phsA.instCVal.mag.f	IAW1MN	Winding 1 current, A-phase, minimum magnitude
METMSTA1	MinA1.phsB.instCVal.mag.f	IBW1MN	Winding 1 current, B-phase, minimum magnitude
METMSTA1	MinA1.phsC.instCVal.mag.f	ICW1MN	Winding 1 current, C-phase, minimum magnitude
METMSTA1	MinA1.res.instCVal.mag.f	IGW1MN	Winding 1 current, residual, minimum magnitude
METMSTA1	MinA2.phsA.instCVal.mag.f	IAW2MN	Winding 2 current, A-phase, minimum magnitude
METMSTA1	MinA2.phsB.instCVal.mag.f	IBW2MN	Winding 2 current, B-phase, minimum magnitude
METMSTA1	MinA2.phsC.instCVal.mag.f	ICW2MN	Winding 2 current, C-phase, minimum magnitude
METMSTA1	MinA2.res.instCVal.mag.f	IGW2MN	Winding 2 current, residual, minimum magnitude
METMSTA1	MinP2PV.phsAB.instCVal.mag.f	VABMN	Voltage, A-to-B-phase, minimum magnitude
METMSTA1	MinP2PV.phsBC.instCVal.mag.f	VBCMN	Voltage, B-to-C-phase, minimum magnitude
METMSTA1	MinP2PV.phsCA.instCVal.mag.f	VCAMN	Voltage, C-to-A-phase, minimum magnitude
METMSTA1	MinPhV.phsA.instCVal.mag.f	VAMN	Voltage, A-phase-to-neutral, minimum magnitude

Table F.13 Logical Device: MET (Metering) (Sheet 5 of 5)

Logical Node	Attribute	Data Source	Comment
METMSTA1	MinPhV.phsB.instCVal.mag.f	VBMN	Voltage, B-phase-to-neutral, minimum magnitude
METMSTA1	MinPhV.phsC.instCVal.mag.f	VCMN	Voltage, C-phase-to-neutral, minimum magnitude
METMSTA1	MinVA.instMag.f	KVA3PMN	Apparent power magnitude, three-phase, minimum
METMSTA1	MinVAr.instMag.f	KVAR3PMN	Reactive power magnitude, three-phase, minimum
METMSTA1	MinW.instMag.f	KW3PMN	Real power magnitude, three-phase, minimum
RMS1MMXU2	A1.phsA.instCVal.mag.f	IAW1RMS	Winding1 RMS current, A-phase, magnitude
RMS1MMXU2	A1.phsB.instCVal.mag.f	IBW1RMS	Winding1 RMS current, B-phase, magnitude
RMS1MMXU2	A1.phsC.instCVal.mag.f	ICW1RMS	Winding1 RMS current, C-phase, magnitude
RMS1MMXU2	A2.phsA.instCVal.mag.f	IAW2RMS	Winding 2 RMS current, A-phase, magnitude
RMS1MMXU2	A2.phsB.instCVal.mag.f	IBW2RMS	Winding 2 RMS current, B-phase, magnitude
RMS1MMXU2	A2.phsC.instCVal.mag.f	ICW2RMS	Winding 2 RMS current, C-phase, magnitude
RMS2MMXU3	A.neut.instCVal.mag.f	INRMS	Neutral RMS current, magnitude
RMS2MMXU3	PhV.phsA.instCVal.mag.f	VARMS	RMS voltage, A-phase-to-neutral, magnitude
RMS2MMXU3	PhV.phsB.instCVal.mag.f	VBRMS	RMS voltage, B-phase-to-neutral, magnitude
RMS2MMXU3	PhV.phsC.instCVal.mag.f	VCRMS	RMS voltage, C-phase-to-neutral, magnitude
RMS2MMXU3	PPV.phsAB.instCVal.mag.f	VABRMS	RMS voltage, A-to-B-phase, magnitude
RMS2MMXU3	PPV.phsBC.instCVal.mag.f	VBCRMS	RMS voltage, B-to-C-phase, magnitude
RMS2MMXU3	PPV.phsCA.instCVal.mag.f	VCARMS	RMS voltage, C-to-A-phase, magnitude
THERMMTHR1	MaxAmbTmp.instMag.f	RTDAMB[c]	Ambient RTD temperature
THERMMTHR1	MaxOthTmp.instMag.f	RTDOTHMX[c]	Other maximum RTD temperature
THERMMTHR1	Tmp01.instMag.f–Tmp12.instMag.f	RTD1–RTD12[c]	RTD1–RTD12 temperature
Functional Constraint = ST			
THERMMTHR1	EEHealth.stVal	RTDFLT?1:3[c]	RTD input or communication status

[a] MX values contain instantaneous attributes (instMag and instCVal), which are updated whenever the source updates and other attributes which are only updated when the source goes outside the data sources deadband (mag and cVal). Only the instantaneous values are shown in the table.
[b] Data validity depend on the relay model and installed card options. Refer to Section 1: Introduction and Specifications for different relay models and available card options. Refer to Section 5: Metering and Monitoring for the model dependent metering quantities.
[c] Valid data depend on E49RTD and RTD1LOC–RTD12LOC settings.

Table F.14 shows the LN associated with control elements defined as Logical Device CON.

Table F.14 Logical Device: CON (Remote Control)

Logical Node	Status	Control	Relay Word Bit	Comment
RBGGIO1	SPCSO01.stVal–SPCSO08.stVal	SPCSO01.Oper.ctlVal–SPCSO08.Oper.ctlVal	RB01–RB08	Remote Bits RB01–RB08
RBGGIO2	SPCSO09.stVal–SPCSO16.stVal	SPCSO09.Oper.ctlVal–SPCSO16.Oper.ctlVal	RB09–RB16	Remote Bits RB09–RB16
RBGGIO3	SPCSO17.stVal–SPCSO24.stVal	SPCSO17.Oper.ctlVal–SPCSO24.Oper.ctlVal	RB17–RB24	Remote Bits RB17–RB24
RBGGIO4	SPCSO25.stVal–SPCSO32.stVal	SPCSO25.Oper.ctlVal–SPCSO32.Oper.ctlVal	RB25–RB32	Remote Bits RB25–RB32

Table F.15 shows the LN associated with annunciation elements defined as Logical Device ANN.

Table F.15 Logical Device: ANN (Annunciation) (Sheet 1 of 3)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
Functional Constraint = MX[a]			
AINCGGIO21	AnIn01.instMag.f–AnIn04.instMag.f	AI301–AI304[b]	Analog inputs (AI301 to AI304)—Slot C
AINDGGIO22	AnIn01.instMag.f–AnIn04.instMag.f	AI401–AI404[b]	Analog inputs (AI401 to AI404)—Slot D
AINEGGIO23	AnIn01.instMag.f–AnIn04.instMag.f	AI501–AI504[b]	Analog inputs (AI501 to AI504)—Slot E
MVGGIO12	AnIn01.instMag.f–AnIn32.instMag.f	MV01–MV32[c]	Math variables (MV01 to MV32)
SCGGIO20	AnIn01.instMag.f–AnIn32.instMag.f	SC01–SC32[d]	SELOGIC counters (SC01 to SC32)
Functional Constraint = ST			
INAGGIO1	Ind01.stVal–Ind02.stVal	IN101–IN102	Digital inputs (IN101 to IN102)—Slot A
INCGGIO13	Ind01.stVal–Ind08.stVal	IN301–IN308[b]	Digital inputs (IN301 to IN308)—Slot C
INDGGIO15	Ind01.stVal–Ind08.stVal	IN401–IN408[b]	Digital inputs (IN401 to IN408)—Slot D
INEGGIO17	Ind01.stVal–Ind08.stVal	IN501–IN508[b]	Digital inputs (IN501 to IN508)—Slot E
LBGGIO25	Ind01.stVal–Ind32.stVal	LB01–LB32[e]	Local bits (LB01 to LB32)
LTGGIO5	Ind01.stVal–Ind32.stVal	LT01–LT32[f]	Latch bits (LT01 to LT32)
MBOKGGIO26	Ind01.stVal	ROKA	Channel A, received data OK
MBOKGGIO26	Ind02.stVal	RBADA	Channel A, outage duration over threshold
MBOKGGIO26	Ind03.stVal	CBADA	Channel A, channel unavailability over threshold
MBOKGGIO26	Ind04.stVal	LBOKA	Channel A, looped back OK
MBOKGGIO26	Ind05.stVal	ROKB	Channel B, received data OK
MBOKGGIO26	Ind06.stVal	RBADB	Channel B, outage duration over threshold
MBOKGGIO26	Ind07.stVal	CBADB	Channel B, channel unavailability over threshold
MBOKGGIO26	Ind08.stVal	LBOKB	Channel B, looped back OK
MISCGGIO27	Ind01.stVal–Ind04.stVal	SG1–SG4	Setting Group 1 to 4 selection
MISCGGIO27	Ind05.stVal	HALARM	Indication of a diagnostic failure or warning that warrants an ALARM
MISCGGIO27	Ind06.stVal	SALARM	Indication of software or user activity that warrants an ALARM
MISCGGIO27	Ind07.stVal	WARNING	Relay Word WARNING
MISCGGIO27	Ind08.stVal	IRIGOK	IRIG-B time sync input data are valid
MISCGGIO27	Ind09.stVal	TSOK	Time synchronization OK
MISCGGIO27	Ind10.stVal	DST	Daylight-Saving Time active
MISCGGIO27	Ind11.stVal	LINKA	Asserted when a valid link is detected on Port 1A
MISCGGIO27	Ind12.stVal	LINKB	Asserted when a valid link is detected on Port 1B

Table F.15 Logical Device: ANN (Annunciation) (Sheet 2 of 3)

Logical Node	Attribute	Data Source	Comment
MISCGGIO27	Ind13.stVal	LINKFAIL	Asserted when a valid link is not detected on the active port(s)
MISCGGIO27	Ind14.stVal	PASEL	Asserted when Port 1A is active
MISCGGIO27	Ind15.stVal	PBSEL	Asserted when Port 1B is active
MISCGGIO27	Ind16.stVal	COMMLOSS	DeviceNet communication failure
MISCGGIO27	Ind17.stVal	COMMFLT	DeviceNet internal communication failure
MISCGGIO27	Ind18.stVal	MATHERR	Error in SEL Math computation
MISCGGIO27	Ind19.stVal–Ind32.stVal	0	Reserved for future use
OUTAGGIO2	Ind01.stVal–Ind03.stVal	OUT101–OUT103	Digital outputs (OUT101 to OUT103)—Slot A
OUTCGGIO14	Ind01.stVal–Ind04.stVal	OUT301–OUT304[b]	Digital outputs (OUT301 to OUT304)—Slot C
OUTDGGIO16	Ind01.stVal–Ind04.stVal	OUT401–OUT404[b]	Digital outputs (OUT401 to OUT404)—Slot D
OUTEGGIO18	Ind01.stVal–Ind04.stVal	OUT501–OUT504[b]	Digital outputs (OUT501 to OUT504)—Slot E
PBLEDGGIO7	Ind01.stVal	PB1A_LED	Pushbutton PB1A LED
PBLEDGGIO7	Ind02.stVal	PB1B_LED	Pushbutton PB1B LED
PBLEDGGIO7	Ind03.stVal	PB2A_LED	Pushbutton PB2A LED
PBLEDGGIO7	Ind04.stVal	PB2B_LED	Pushbutton PB2B LED
PBLEDGGIO7	Ind05.stVal	PB3A_LED	Pushbutton PB3A LED
PBLEDGGIO7	Ind06.stVal	PB3B_LED	Pushbutton PB3B LED
PBLEDGGIO7	Ind07.stVal	PB4A_LED	Pushbutton PB4A LED
PBLEDGGIO7	Ind08.stVal	PB4B_LED	Pushbutton PB4B LED
PROGGIO24	Ind01.stVal	REMTRIP	Remote trip
PROGGIO24	Ind02.stVal	ULTRIP1	Unlatch (auto reset) trip from SELOGIC equation
PROGGIO24	Ind03.stVal	ULTRIP2	Unlatch (auto reset) trip from SELOGIC equation
PROGGIO24	Ind04.stVal	ULTRXFMR	Unlatch (auto reset) trip from SELOGIC equation
PROGGIO24	Ind05.stVal	ULCL1	Unlatch close conditions SELOGIC Equation CL1 state
PROGGIO24	Ind06.stVal	ULCL2	Unlatch close conditions SELOGIC Equation CL2 state
PROGGIO24	Ind07.stVal	RTDT	Asserts when any RTD trip is asserted
PROGGIO24	Ind08.stVal	AMBTRIP	Ambient temperature trip
PROGGIO24	Ind09.stVal	OTHTRIP	Other temperature trip
PROGGIO24	Ind10.stVal	TH5T	Fifth-harmonic alarm threshold exceeded for longer than TH5D
PROGGIO24	Ind11.stVal	TH5	Fifth-harmonic alarm threshold exceeded
PROGGIO24	Ind12.stVal	RTDFLT	Asserts when an open or short circuit condition is detected on any enabled RTD input, or communication with the external RTD module has been interrupted
PROGGIO24	Ind13.stVal	PHDEM	Phase current demand pickup
PROGGIO24	Ind14.stVal	3I2DEM	Negative-sequence current demand pickup
PROGGIO24	Ind15.stVal	GNDEM	Zero-sequence current demand pickup
PROGGIO24	Ind16.stVal	50GREF1	Normalized residual current sensitivity threshold exceeded
PROGGIO24	Ind17.stVal	50NREF1	Neutral current sensitivity threshold exceeded

Table F.15 Logical Device: ANN (Annunciation) (Sheet 3 of 3)

Logical Node	Attribute	Data Source	Comment
PROGGIO24	Ind18.stVal	AMBALRM	Ambient temperature alarm
PROGGIO24	Ind19.stVal	OTHALRM	Other temperature alarm
PROGGIO24	Ind20.stVal	FREQTRK	Frequency tracking enable bit
PROGGIO24	Ind21.stVal–Ind32.stVal	0	Reserved for future use
RMBAGGIO8	Ind01.stVal–Ind08.stVal	RMB1A–RMB8A	Receive MIRRORED BITS (RMB1A to RMB8A)
RMBBGGIO10	Ind01.stVal–Ind08.stVal	RMB1B–RMB8B	Receive MIRRORED BITS (RMB1B to RMB8B)
SVGGIO3	Ind01.stVal–Ind32.stVal	SV01–SV32[g]	SELOGIC variables (SV01 to SV32)
SVTGGIO4	Ind01.stVal–Ind32.stVal	SV01T–SV32T[g]	SELOGIC variable timers (SV01T to SV32T)
TLEDGGIO6	Ind01.stVal	ENABLED	ENABLED LED
TLEDGGIO6	Ind02.stVal	TRIP_LED	TRIP LED
TLEDGGIO6	Ind03.stVal–Ind08.stVal	TLED_01–TLED_06	Target LEDs TLED_01 to TLED_06
TMBAGGIO9	Ind01.stVal–Ind08.stVal	TMB1A–TMB8A	Transmit MIRRORED BITS (TMB1A to TMB8A)
TMBBGGIO11	Ind01.stVal–Ind08.stVal	TMB1B–TMB8B	Transmit MIRRORED BITS (TMB1B to TMB8B)
VBGGIO19	Ind001.stVal–Ind128.stVal	VB001–VB128	Virtual bits (VB001 to VB128)

Table F.16 Logical Device: CFG (Configuration)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARTNO	Part number
DevIDLPHD1	PhyNam.serNum	SER_NUM	Serial number
LLN0	NamPlt.swRev	FID	Firmware revision

Protocol Implementation Conformance Statement

Table F.17 and *Table F.18* are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that since the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table F.17 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE Management
A3	GSSE	N	N	
A4	Time Sync	N	N	

Table F.18 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, Not GSSE
T4	GSSE	N	N	
T5	Time Sync	N	N	

Refer to the ACSI Conformance statements for information on the supported services.

MMS Conformance

The Manufacturing Messaging Specification (MMS) stack provides the basis for many IEC 61850 Protocol services. *Table F.19* defines the service support requirement and restrictions of the MMS services in the SEL-700 series products supporting IEC 61850. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table F.19 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
status		Y
getNameList		Y
identify		Y
rename		
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		
deleteVariableAccess		
defineNamedVariableList		
getNamedVariableListAttributes		Y
deleteNamedVariableList		
defineNamedType		
getNamedTypeAttributes		
deleteNamedType		
input		
output		
takeControl		
relinquishControl		
defineSemaphore		
deleteSemaphore		

Table F.19 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
reportPoolSemaphoreStatus		
reportSemaphoreStatus		
initiateDownloadSequence		
downloadSegment		
terminateDownloadSequence		
initiateUploadSequence		
uploadSegment		
terminateUploadSequence		
requestDomainDownload		
requestDomainUpload		
loadDomainContent		
storeDomainContent		
deleteDomain		
getDomainAttributes		Y
createProgramInvocation		
deleteProgramInvocation		
start		
stop		
resume		
reset		
kill		
getProgramInvocationAttributes		
obtainFile		
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		
reportEventConditionStatus		
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		
acknowledgeEventNotification		
getAlarmSummary		
getAlarmEnrollmentSummary		
readJournal		

Table F.19 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		
fileRead		
fileClose		
fileRename		
fileDelete		
fileDirectory		
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
ReconfigureProgramInvocation		

Table F.20 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table F.20 MMS Parameter CBB

MMS Parameter CBB	Client-CR Supported	Server-CR Supported
STR1		Y
STR2		Y
VNAM		Y
VADR		Y
VALT		Y
TPY		Y
VLIS		Y
CEI		

The following Variable Access Conformance Statements (*Table F.21* through *Table F.28*) are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table F.21 Alternate Access Selection Conformance Statement

Alternate Access Selection	Client-CR Supported	Server-CR Supported
accessSelection		Y
component		Y
index		
indexRange		
allElements		
alternateAccess		Y
selectAccess		Y
component		Y
index		
indexRange		
allElements		

Table F.22 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR Supported	Server-CR Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table F.23 VariableSpecification Conformance Statement

VariableSpecification	Client-CR Supported	Server-CR Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table F.24 Read Conformance Statement

Read	Client-CR Supported	Server-CR Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table F.25 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table F.26 DefineNamedVariableList Conformance Statement

DefineVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table F.27 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR Supported	Server-CR Supported
Request		
ObjectName		
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table F.28 DeleteNamedVariableList

DeleteNamedVariableList	Client-CR Supported	Server-CR Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table F.29 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	Y	Y	
SendGOOSEMessage		Y	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		Y	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		Y	

ACSI Conformance Statements

Table F.30 ACSI Basic Conformance Statement

		Client/Subscriber	Server/Publisher	SEL-787 Support
Client-Server Roles				
B11	Server side (of Two-Party Application-Association)	-	c1[a]	YES
B12	Client side (of Two-Party Application-Association)	c1[a]	-	
SCMS Supported				
B21	SCSM: IEC 61850-8-1 used			YES
B22	SCSM: IEC 61850-9-1 used			
B23	SCSM: IEC 61850-9-2 used			
B24	SCSM: other			
Generic Substation Event Model (GSE)				
B31	Publisher side	-	O[b]	YES
B32	Subscriber side	O[b]	-	YES
Transmission of Sampled Value Model (SVC)				
B41	Published side	-	O[b]	
B42	Subscriber side	O[b]	-	

[a] c1 shall be mandatory if support for LOGICAL-DEVICE model has been declared.
[b] O = optional.

Table F.31 ACSI Models Conformance Statement (Sheet 1 of 2)

		Client/Subscriber	Server/Publisher	SEL-787 Support
If Server Side (B11) Supported				
M1	Logical device	c2[a]	c2[a]	YES
M2	Logical node	c3[b]	c3[b]	YES
M3	Data	c4[c]	c4[c]	YES
M4	Data set	c5[d]	c5[d]	YES
M5	Substation	O[e]	O[e]	
M6	Setting group control	O[e]	O[e]	
Reporting				
M7	Buffered report control	O[e]	O[e]	YES
M7-1	sequence-number			YES
M7-2	report-time-stamp			YES
M7-3	reason-for-inclusion			YES
M7-4	data-set-name			YES
M7-5	data-reference			YES
M7-6	buffer-overflow			YES
M7-7	entryID			YES
M7-8	BufTm			YES

Table F.31 ACSI Models Conformance Statement (Sheet 2 of 2)

		Client/Subscriber	Server/Publisher	SEL-787 Support
M7-9	IntgPd			YES
M7-10	G1			YES
M8	Unbuffered report control	O[e]	O[e]	YES
M8-1	sequence-number			YES
M8-2	report-time-stamp			YES
M8-3	reason-for-inclusion			YES
M8-4	data-set-name			YES
M8-5	data-reference			YES
M8-6	BufTm			YES
M8-7	IntgPd			YES
M-8-8	GI			YES
Logging		O[e]	O[e]	
M9	Log control	O[e]	O[e]	
M9-1	IntgPd			
M10	Log	O[e]	O[e]	
M11	Control	M[f]	M[g]	YES
If GSE (B31/32) Is Supported				
M12	GOOSE	O[e]	O[e]	YES
M12-1	entryID			YES
M12-2	DataReflnc			YES
M13	GSSE	O[e]	O[e]	
If GSE (B41/42) Is Supported				
M14	Multicast SVC	O[e]	O[e]	
M15	Unicast SVC	O[e]	O[e]	
M16	Time	M[f]	M[f]	
M17	File Transfer	O[e]	O[e]	

[a] c2 shall be "M" if support for LOGICAL-NODE model has been declared.
[b] c3 shall be "M" if support for DATA model has been declared.
[c] c4 shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time model has been declared.
[d] c5 shall be "M" if support for Report, GSE, or SV models has been declared.
[e] O = Optional.
[f] M = Mandatory.
[g] M = Mandatory.

Table F.32 ACSI Services Conformance Statement (Sheet 1 of 3)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-787 Support
Server (Clause 6)					
S1	ServerDirectory	TP		M[a]	YES
Application Association (Clause 7)					
S2	Associate		M[a]	M[a]	YES
S3	Abort		M[a]	M[a]	YES
S4	Release		M[a]	M[a]	YES
Logical Device (Clause 8)					
S5	LogicalDeviceDirectory	TP	M[a]	M[a]	YES
Logical Node (Clause 9)					
S6	LogicalNodeDirectory	TP	M[a]	M[a]	YES
S7	GetAllDataValues	TP	O[b]	M[a]	YES
Data (Clause 10)					
S8	GetDataValues	TP	M[a]	M[a]	YES
S9	SetDataValues	TP	O[b]	O[b]	YES
S10	GetDataDirectory	TP	O[b]	M[a]	YES
S11	GetDataDefinition	TP	O[b]	M[a]	YES
Data Set (Clause 11)					
S12	GetDataSetValues	TP	O[b]	M[a]	YES
S13	SetDataSetValues	TP	O[b]	O[b]	YES
S14	CreateDataSet	TP	O[b]	O[b]	
S15	DeleteDataSet	TP	O[b]	O[b]	
S16	GetDataSetDirectory	TP	O[b]	O[b]	YES
Substitution (Clause 12)					
S17	SetDataValues	TP	M[a]	M[a]	
Setting Group Control (Clause 13)					
S18	SelectActiveSG	TP	O[b]	O[b]	
S19	SelectEditSG	TP	O[b]	O[b]	
S20	SetSGvalues	TP	O[b]	O[b]	
S21	ConfirmEditSGVal	TP	O[b]	O[b]	
S22	GetSGValues	TP	O[b]	O[b]	
S23	GetSGCBValues	TP	O[b]	O[b]	
S24	Report	TP	c6[c]	c6[c]	YES
S24-1	data-change (dchg)				YES
S24-2	qchg-change (qchg)				YES
S24-3	data-update (dupd)				
S25	GetBRCBValues	TP	c6[c]	c6[c]	YES
S26	SetBRCBValues	TP	c6[c]	c6[c]	YES

Table F.32 ACSI Services Conformance Statement (Sheet 2 of 3)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-787 Support
Unbuffered Report Control Block (URCB)					
S27	Report	TP	c6[c]	c6[c]	YES
S27-1	data-change (dchg)				YES
S27-2	qchg-change (qchg)				YES
S27-3	data-update (dupd)				
S28	GetURCBValues	TP	c6[c]	c6[c]	YES
S29	SetURCBValues	TP	c6[c]	c6[c]	YES
Logging (Clause 14)					
Log Control Block					
S30	GetLCBValues	TP	M[a]	M[a]	
S31	SetLCBValues	TP	O[b]	M[a]	
LOG					
S32	QueryLogByTime	TP	c7[d]	M[a]	
S33	QueryLogByEntry	TP	c7[d]	M[a]	
S34	GetLogStatusValues	TP	M[a]	M[a]	
Generic Substation Event Model (GSE) (Clause 14.3.5.3.4)					
GOOSE-Control-Block					
S35	SendGOOSEMessage	MC	c8[e]	c8[e]	YES
S36	GetReference	TP	O[b]	c9[f]	
S37	GetGOOSEElement				
Number	TP	O[b]	c9[f]		
S38	GetGoCBValues	TP	O[b]	O[b]	YES
S39	SetGoCBValues	TP	O[b]	O[b]	Client/Sub
ONLY					
GSSE-Control-Block					
S40	SendGSSEMessage	MC	c8[e]	c8[e]	
S41	GetReference	TP	O[b]	c9[f]	
S42	GetGSSEElement				
Number	TP	Ob	c9[f]		
S43	GetGsCBValues	TP	O[b]	O[b]	
S44	GetGsCBValues	TP	O[b]	O[b]	
Transmission of Sample Value Model (SVC) (Clause 16)					
Multicast SVC					
S45	SendMSVMessage	MC	c10[g]	c10[g]	
S46	GetMSVCBValues	TP	O[b]	O[b]	
S47	SetMSVCBValues	TP	O[b]	O[b]	

Table F.32 ACSI Services Conformance Statement (Sheet 3 of 3)

Services		AA: TP/MC	Client/ Subscriber	Service/ Publisher	SEL-787 Support
Unicast SVC					
S48	SendUSVMessage	MC	c10[g]	c10[g]	
S49	GetUSVCBValues	TP	O[b]	O[b]	
S50	SetUSVCBValues	TP	O[b]	O[b]	
Control (Clause 16.4.8)					
S51	Select		M[a]	O[b]	YES
S52	SelectWithValue	TP	Ma	O[b]	YES
S53	Cancel	TP	O[b]	M[a]	YES
S54	Operate	TP	M[a]	M[a]	YES
S55	Command-Termination	TP	M[a]	M[a]	YES
S56	TimeActivated-Operate	TP	O[b]	O[b]	
File Transfer (Clause 20)					
S57	GetFile	TP	O[b]	M[a]	
S58	SetFile	TP	O[b]	O[b]	
S59	DeleteFile	TP	O[b]	O[b]	
S60	GetFileAttributeValues	TP	O[b]	M[a]	
Time (Clause 5.5)					
T1	Time resolution of internal clock (nearest negative power of 2 in seconds)				20 (1 µs)
T2	Time accuracy of internal clock				7 (10 ms) for SNTP 18 (4 µs) for IRIG-B
	T1				YES (for IRIG-B)
	T2				YES (for IRIG-B)
	T3				YES (for IRIG-B)
	T4				YES (for IRIG-B)
T3	Supported TimeStamp resolution (nearest negative power of 2 in seconds)				7 (10 ms) for SNTP 18 (4 µs) for IRIG-B

[a] M = Mandatory.
[b] O = Optional.
[c] c6 shall declare support for at least one (BRCB or URCB).
[d] c7 shall declare support for at least one (QueryLogByTime or QueryLogAfter).
[e] c8 shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage).
[f] c9 shall declare support if TP association is available.
[g] c10 shall declare support for at least one (SendMSVMessage or SendUSVMessage).

Appendix G

DeviceNet Communications

Overview

This appendix describes DeviceNet communications features supported by the SEL-787 Transformer Protection Relay.

DeviceNet is a low-level communications network that provides direct connectivity among industrial devices, resulting in improved communication and device-level diagnostics that are otherwise either unavailable or inaccessible through expensive hardwired I/O interfaces. Industrial devices for which DeviceNet provides this direct connectivity include limit switches, photoelectric sensors, valve manifolds, motor starters, process sensors, bar code readers, variable frequency drives, panel displays, and operator interfaces.

The *SEL DeviceNet Communications Card User's Guide* contains more information on the installation and use of the DeviceNet card or the DeviceNet protocol.

NOTE: Be aware of the following setting in the relay:
Under Global settings category Access Control, there is a setting called BLOCK MODBUS SET.

The BLOCK MODBUS SET setting is used to block relay settings changes via Modbus or DeviceNet protocols. The factory-default setting, BLKMBSET := NONE, **allows** all setting changes via Modbus or DeviceNet communications. The BLKMBSET := R_S setting **prevents** Modbus or DeviceNet communications from resetting to the factory-default settings. The BLKMBSET := ALL setting **blocks** all changes to the settings via the Modbus or the DeviceNet protocol.

You are strongly advised to change the BLKMBSET (BLOCK MODBUS SET) := ALL if you do not want the PLC (Programmable Logic Controller) or DCS (Distributed Control System) to send the settings to the SEL-787 relay. There is a strong possibility that under special conditions like a reboot, the PLC/DCS will send default settings to the relay, overwriting the existing settings. To protect the existing settings under these conditions it is highly recommended to set the setting to "ALL."

DeviceNet Card

NOTE: The DeviceNet option has been discontinued and is no longer available as of September 25, 2017.

The DeviceNet Card is an optional accessory that enables connection of the SEL-787 to the DeviceNet automation network. The card (see *Figure G.1*) occupies the communications expansion Slot C in the relay.

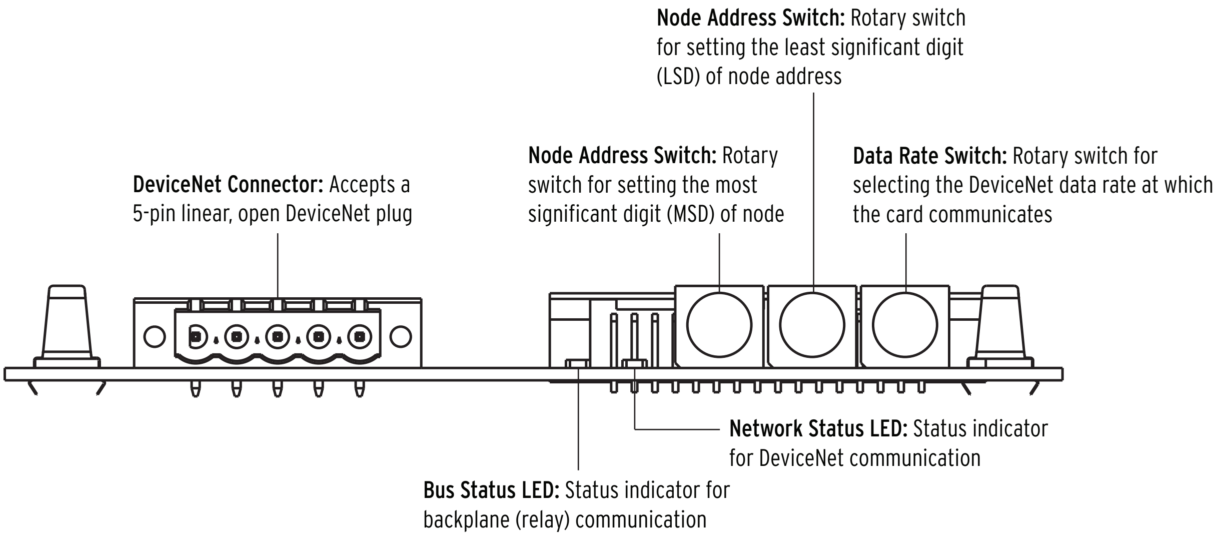


Figure G.1 DeviceNet Card Component Overview

Features

The DeviceNet Card features the following:

- ➤ The card receives the required power from the DeviceNet network.
- ➤ Rotary switches let you set the node address and network data rate prior to mounting in the SEL-787 and applying power. Alternatively, the switches can be set to positions that allow for configuration of these settings over the DeviceNet network, utilizing a network configuration tool such as RSNetWorx for DeviceNet.
- ➤ Status indicators report the status of the device bus and network communications. They are visible from the back panel of the SEL-787 as installed.

You can do the following with the DeviceNet interface:

- ➤ Retrieve metering data such as the following:
  - ➢ Currents
  - ➢ Voltages
  - ➢ Power
  - ➢ Energy
  - ➢ Max/Min
  - ➢ Analog Inputs
  - ➢ Counters

- ➤ Retrieve and modify relay settings
- ➤ Read and set time
- ➤ Monitor device status, trip/warning status, and I/O status
- ➤ Perform high-speed control
- ➤ Reset trip, target, and accumulated data
- ➤ Retrieve events history

The DeviceNet interface can be configured through the use of address and data transmission rate switches. Indicators on the card at the back of the relay show network status and network activity.

Electronic Data Sheet

The Electronic Data Sheet (EDS) is a specially formatted file that includes configurable parameters for the device and public interfaces to those parameters. The EDS file contains information such as number of parameters; groupings; parameter name; minimum, maximum, and default values; units; data format; and scaling. This information makes possible user-friendly configuration tools (e.g., RSNetWorx for DeviceNet or DeviceNet Configurator from OMRON) for device parameter monitoring, modification, or both. The interface to the device can also be easily updated without revision of the configuration software tool itself.

All the registers defined in the Modbus Register Map (*Table E.34*) are available as parameters in a DeviceNet configuration. Parameter names, data ranges, and scaling; enumeration values and strings; parameter groups; and product information are the same as specified in the Modbus Register Map defined in *Table E.34*. The parameter numbers are offset by a count of 100 from the register numbers.

The EDS file for the SEL-787, SEL-xxxRxxx.EDS, is located on the SEL-787 Product Literature CD. It can also be downloaded from the SEL website at selinc.com.

Complete specifications for the DeviceNet protocol are available on the Open DeviceNet Vendor's Association (ODVA) website www.odva.org. ODVA is an independent supplier organization that manages the DeviceNet specification and supports the worldwide growth of DeviceNet.

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Appendix H
MIRRORED BITS Communications

Overview

IMPORTANT: Be sure to configure the port before connecting to a MIRRORED BITS device. If you connect an unconfigured port to a MIRRORED BITS device, the device will appear to be locked up.

NOTE: Complete all of the port settings for a port that you use for MIRRORED BITS communications before you connect an external MIRRORED BITS communications device. If you connect a MIRRORED BITS communications device to a port that is not set for MIRRORED BITS communications operation, the port will be continuously busy.

MIRRORED BITS communications is a direct relay-to-relay communications protocol that allows IEDs to exchange information quickly, securely, and with minimal expense. Use MIRRORED BITS for functions such as remote control and remote sensing. The SEL-787 Transformer Protection Relay supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port; PROTO:=MBA for MIRRORED BITS communications Channel A or PROTO:=MBB for MIRRORED BITS communications Channel B. MIRRORED BITS are either Transmit MIRRORED BITS (TMB) or Received MIRRORED BITS (RMB). Transmit MIRRORED BITS include TMB1A–TMB8A (channel A) and TMB1B–TMB8B (channel B). The last letter (A or B) designates with which channel the bits are associated. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. Control the transmit MIRRORED BITS in SELOGIC control equations. Use the received MIRRORED BITS as arguments in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, and LBOKB. You can also use these channel status bits as arguments in SELOGIC control equations. Use the **COM** command (see *Section 7: Communications*) for additional channel status information.

Because of different applications, the SEL product range supports several variations of the MIRRORED BITS communications protocol. Through port settings, you can set the SEL-787 for compatible operation with SEL-300 series devices, SEL-2505 Remote I/O Modules, and SEL-2100 Logic Processors. When communicating with an SEL-400 series relay, be sure to set the transmission mode setting in the SEL-400 series relay to paced transmission (TXMODE: = P).

Operation

Message Transmission

In the SEL-787, the MIRRORED BITS transmission rate is a function of both the data rate and the power system cycle. At data rates below 9600, the SEL-787 transmits MIRRORED BITS as fast as possible for the given rate. At rates at and above 9600 bps the SEL-787 self-paces, using a technique similar to the SEL-400 series pacing mode. There are no settings to enable or disable the self-pacing mode; the SEL-787 automatically enters the self-pacing mode at data rates of 9600, 19200, and 38400. *Table H.1* shows the transmission rates of the MIRRORED BITS messages at different rates.

NOTE: Exercise caution when applying a MIRRORED BITS channel to relays that protect systems that may not be synchronized because the automatic pacing modes operate under the assumption that both relays are protecting systems of similar frequency. To maintain MIRRORED BITS channel dependability for this application, it is recommended that you use data rates of 2400 or 4800.

Table H.1 Number of MIRRORED BITS Messages for Different Data Rates

Data Rate (bps)	Transmission Rate of MIRRORED BITS Packets
2400	15 ms
4800	7.5 ms
9600	4 times a power system cycle (automatic pacing mode)
19200	4 times a power system cycle (automatic pacing mode)
38400	4 times a power system cycle (automatic pacing mode)

Transmitting at longer intervals for data rates above 9600 avoids overflowing relays that receive MIRRORED BITS at a slower rate.

Message Reception Overview

During synchronized MIRRORED BITS communications with the communications channel in normal state, the relay decodes and checks each received message. If the message is valid, the relay sends each received logic bit (RMB*n*, where *n* = 1 through 8) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*n*A and RMB*n*B relay element bits.

Message Decoding and Integrity Checks

Set the RX_ID of the local SEL-787 to match the TX_ID of the remote SEL-787. The SEL-787 provides indication of the status of each MIRRORED BITS communications channel with Relay Word bits ROKA (receive OK) and ROKB. During normal operation, the relay sets the ROK*c* (*c* = A or B). Upon detecting any of the following conditions, the relay clears the ROK*c* bit when:

- The relay is disabled.
- MIRRORED BITS are not enabled.
- Parity, framing, or overrun errors.
- Receive message identification error.
- No message received in the time three messages have been sent when PROTO = MB*c*, or seven messages have been sent when PROTO = MB8*c*.
- Loopback is enabled.

The relay asserts ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below.

While ROK*c* is deasserted, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, use the RXDFLT setting to determine the default state the MIRRORED BITS should use in place of received data if an error condition is detected. The setting is a mask of 1s, 0s, and/or Xs (for RMB1A–RMB8A), where X represents the most recently received valid value. The positions of the 1s and 0s correspond to the respective positions of the MIRRORED BITS in the Relay Word bits (see *Appendix J: Relay Word Bits*). *Table H.2* is an extract of *Table J.1 on page J.1*, showing the positions of the MIRRORED BITS.

Table H.2 Positions of the MIRRORED BITS

Bit/ Row	7	6	5	4	3	2	1	0
70	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
72	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B

Table H.3 shows an example of the values of the MIRRORED BITS for a RXDFLT setting of 10100111.

Table H.3 MIRRORED BITS Values for a RXDFLT Setting of 10100111

Bit/ Row	7	6	5	4	3	2	1	0
70	1	0	1	0	0	1	1	1

Individual pickup and dropout security counters supervise the movement of each received data bit into the corresponding RMB*n* element. You can set each pickup/dropout security counter from 1 to 8. A setting of 1 causes a security counter to pass every occurrence, while a setting of 8 causes a counter to wait for eight consecutive occurrences in the received data before updating the data bits. The pickup and dropout security count settings are separate. Control the security count settings with the settings RMB*n*PU and RMB*n*DO.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of counted received messages instead of time. Select a setting for the security counter in accordance with the transmission rate (see *Table H.1*). For example, when transmitting at 2400 baud, a security counter set to 2 counts delays a bit by about 30 ms. However, when operating at 9600 baud, a setting of 2 counts delays a bit by about 8.5 ms.

You must consider the impact of the security counter settings in the receiving relay to determine the channel timing performance, particularly when two relays of different processing rates are communicating via MIRRORED BITS, such as an SEL-321 and an SEL-787. The SEL-321 processes power system information each 1/8 power system cycle, but, when transmitting at 19200 baud, the SEL-787 processes MIRRORED BITS messages at 4.15 ms at 60 Hz (4 times per power system cycle at 60 Hz). Although the SEL-321 processes power system information each 1/8 power system cycle, the relay processes the MIRRORED BITS pickup/dropout security counters as MIRRORED BITS messages are received. Because the SEL-787 transmits messages at approximately 1/4-cycle processing interval (9600 baud and above, see *Table H.1*), a counter set to two in the SEL-321 delays a received bit by another approximately 1/2 cycle. However, a security counter in the SEL-787 with a setting of two delays a received bit from the SEL-321 by 1/4 cycle, because the SEL-787 is receiving new MIRRORED BITS messages each 1/8 cycle from the SEL-321.

Channel Synchronization

When an SEL-787 detects a communications error, it deasserts ROKA or ROKB. If an SEL-787 detects two consecutive communications errors, it transmits an attention message, which includes the TXID setting. The relay transmits an attention message until it receives an attention message that includes a match to the TXID setting value. If the attention message is successful, the relay has properly synchronized and data transmission resumes. If the attention message is not successful, the relay repeats the attention message until it is successful.

In summary, when a relay detects an error, it transmits an attention message until it receives an attention message with its own TX_ID included. If three or four relays are connected in a ring topology, the attention message will go all the way around the loop until the originating relay receives it. The message then dies and data transmission resumes. This method of synchronization allows the relays to reliably determine which byte is the first byte of the message. It also forces unsynchronized UARTs to become resynchronized. On the down side, this method takes down the entire loop for a receive error at any relay in the loop. This decreases availability. It also makes one-way communications impossible.

Loopback Testing

Use the **LOOP** command to enable loopback testing. In the loopback mode, you loop the transmit port to the receive port of the same relay to verify transmission messages. While in loopback mode, ROK*c* is deasserted, and another user accessible Relay Word bit, LBOK*c* (Loop Back OK) asserts and deasserts based on the received data checks (see the *Section 7: Communications* for the ACSII commands).

Channel Monitoring

Based on the results of data checks (described above), the relay collects information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- DATE—Date when the dropout occurred
- TIME—Time when the dropout occurred
- RECOVERY_DATE—Date when the channel returned to service (if the channel is currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested)
- RECOVERY_TIME—Time when the channel returned to service (if the channel is currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested)
- DURATION—Time elapsed during dropout
- CAUSE—Reason for dropout (see *Message Decoding and Integrity Checks on page H.2*)

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is currently failed, it is displayed and included in the calculations, as if its recovery were to occur at the time the report was requested.

NOTE: Combine error conditions including RBADA, RBADB, CBADA, and CBADB with other alarm conditions using SELOGIC control equations. You can use these alarm conditions to program the relay to take appropriate action when it detects a communications channel failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay asserts a user-accessible Relay Word bit, RBADA or RBADB. When channel unavailability exceeds a user-definable threshold for Channel A or B, the relay asserts a user-accessible Relay Word bit, CBADA or CBADB. Use the **COMM** command to generate a long or summary report of the communications errors.

Use the RBADPU setting to determine how long a channel error must last before the meter element RBADA is asserted. RBADA is deasserted when the channel error is corrected. RBADPU is accurate to ±1 second.

Use the CBADPU setting to determine the ratio of channel down time to the total channel time before the meter element CBADA is asserted. The times used in the calculation are those that are available in the COM records. See the *COMMUNICATIONS Command* in *Section 7: Communications* for more information.

MIRRORED BITS Protocol for the Pulsar 9600 Baud Modem

To use a Pulsar MBT modem, set setting PROTO := MBTA or MBTB (Port settings). Setting PROTO := MBTA or MBTB hides setting SPEED (forces the baud to 9600), hides setting PARITY (forces parity to a value of 0), hides setting RTSCTS (forces RTSCTS to a value of N), and forces the transmit time to be faster than double the power system cycle. *Table H.4* shows the difference in message transmission periods when not using the Pulsar modem (PROTO ≠ MBTA or MBTB), and using the Pulsar MBT modem (PROTO = MBTA or MBTB).

NOTE: You must consider the idle time in calculations of data transfer latency through a Pulsar MBT modem system.

Table H.4 MIRRORED BITS Communications Message Transmission Period

Baud	PROTO ≠ MBTA or MBTB	PROTO = MBTA or MBTB
38400	4 times a power system cycle	n/a
19200	4 times a power system cycle	n/a
9600	4 times a power system cycle	2 times a power system cycle
4800	7.5 ms	n/a

The relay sets RTS to a negative voltage at the EIA-232 connector to signify that MIRRORED BITS communications matches this specification.

Settings

Set PROTO = MBA or MB8A to enable the MIRRORED BITS protocol channel A on this port. Set PROTO = MBB or MB8B to enable the MIRRORED BITS protocol channel B on this port. The standard MIRRORED BITS protocols MBA and MBB use a 6-data bit format for data encoding. The MB8 protocols MB8A and MB8B use an 8-data bit format, which allows MIRRORED BITS to operate on communication channels requiring an 8-data bit format. For the remainder of this section, PROTO = MBA is assumed. *Table H.5* shows the MIRRORED BITS protocol port settings, ranges, and default settings for Port F, Port 3, and Port 4.

Table H.5 MIRRORED BITS Protocol Settings (Sheet 1 of 2)

Setting Prompt	Setting Description	Factory-Default Setting
TXID	MIRRORED BITS ID of This Device (1–4)	2
RXID	MIRRORED BITS ID of Device Receiving From (1–4)	1
RBADPU	Outage Duration to Set RBAD (1–10000 seconds)	60
CBADPU	Channel Unavailability to Set CBAD (1–10000 ppm)	1000
RXDFLT	8 char string of 1s, 0s, or Xs	XXXXXXXX
RMB1PU	RMB1 Pickup Debounce Messages (1–8 messages)	1
RMB1DO	RMB1 Dropout Debounce Messages (1–8 messages)	1

Table H.5 MIRRORED BITS Protocol Settings (Sheet 2 of 2)

Setting Prompt	Setting Description	Factory-Default Setting
RMB2PU	RMB2 Pickup Debounce Messages (1–8 messages)	1
RMB2DO	RMB2 Dropout Debounce Messages (1–8 messages)	1
RMB3PU	RMB3 Pickup Debounce Messages (1–8 messages)	1
RMB3DO	RMB3 Dropout Debounce Messages (1–8 messages)	1
RMB4PU	RMB4 Pickup Debounce Messages (1–8 messages)	1
RMB4DO	RMB4 Dropout Debounce Messages (1–8 messages)	1
RMB5PU	RMB5 Pickup Debounce Messages (1–8 messages)	1
RMB5DO	RMB5 Dropout Debounce Messages (1–8 messages)	1
RMB6PU	RMB6 Pickup Debounce Messages (1–8 messages)	1
RMB6DO	RMB6 Dropout Debounce Messages (1–8 messages)	1
RMB7PU	RMB7 Pickup Debounce Messages (1–8 messages)	1
RMB7DO	RMB7 Dropout Debounce Messages (1–8 messages)	1
RMB8PU	RMB8 Pickup Debounce Messages (1–8 messages)	1
RMB8DO	RMB8 Dropout Debounce Messages (1–8 messages)	1

Appendix I
Synchrophasors

Introduction

The SEL-787 Transformer Protection Relay provides Phasor Measurement Control Unit (PMCU) capabilities when connected to an IRIG-B time source with an accuracy of ±10 μs or better. Synchrophasor data are available via the **MET PM** ASCII command and the C37.118 Protocol.

Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule at precise instants in time. A high-accuracy clock, commonly called a Global Positioning System (GPS) receiver such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as SEL-787 relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other off-line analysis functions.

The SEL-787 Global settings class contains the synchrophasor settings, including the choice of transmitted synchrophasor data set. The Port settings class selects which serial port(s) can be used for synchrophasor protocol use. See *Settings for Synchrophasors on page I.4*.

The SEL-787 timekeeping function generates status Relay Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELOGIC control equation variables, and programmable digital trigger information is also added to the Relay Word bits for synchrophasors. See *Synchrophasor Relay Word Bits on page I.9*.

When synchrophasor measurement is enabled, the SEL-787 creates the synchrophasor data set at a user-defined rate. Synchrophasor data are available in ASCII format over a serial port set to PROTO = SEL. See *View Synchrophasors Using the MET PM Command on page I.10*.

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. A synchrophasor protocol is available in the SEL-787 that allows for a centralized device to collect data efficiently from several phasor measurement units (PMUs). Some possible uses of a system-wide synchrophasor system include the following:

- Power-system state measurement
- Wide-area network protection and control schemes
- Small-signal analysis
- Power-system disturbance analysis

The SEL-3306 Synchrophasor Processor is a PC-based communications processor specifically designed to interface with PMUs. The SEL-3306 has two primary functions. The first is to collect and correlate synchrophasor data from multiple PMUs. The second is to then compact and transmit synchrophasor data either to a data historian for post-analysis or to visualization software for real-time viewing of a power system.

The SEL-787 supports the protocol portion of the IEEE C37.118, Standard for Synchrophasors for Power Systems. In the SEL-787, this protocol is referred to simply as C37.118. See *Settings Affect Message Contents on page I.11*.

Synchrophasor Measurement

The phasor measurement unit in the SEL-787 measures three voltages and six currents on a constant-time basis. These samples are time-stamped with the IRIG time source. The phase angle is measured relative to an absolute time reference, which is represented by a cosine function in *Figure I.1*. The time-of-day is shown for the two time marks. The reference is consistent with the phase reference defined in the C37.118 standard. During steady-state conditions, the SEL-787 synchrophasor values can be directly compared to values from other phasor measurement units that conform to C37.118. Synchrophasor values are available for the full frequency range of the SEL-787.

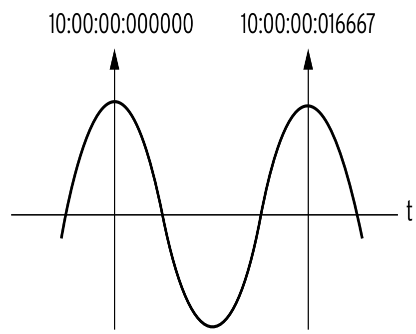

Figure I.1 Phase Reference

The TSOK Relay Word bit asserts when the SEL-787 has determined that the IRIG-B time source has sufficient accuracy and the synchrophasor data meets the specified accuracy. Synchrophasors are still measured if the time source threshold is not met, as indicated by Relay Word bit TSOK = logical 0. The **MET PM** command is not available in this case.

The instrumentation transformers (PTs or CTs) and the interconnecting cables may introduce a time shift in the measured signal. Global settings VCOMP, IW1COMP, and IW2COMP, entered in degrees, are added to the measured phasor angles to create the corrected phasor angles, as shown in *Figure I.2*, *Figure I.3*, and *Equation I.1*. The VCOMP, IW1COMP, and IW2COMP settings may be positive or negative values.

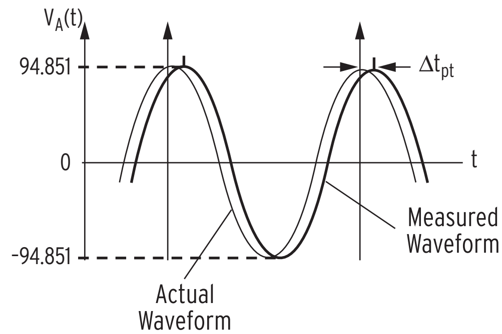

Figure I.2 Waveform at Relay Terminals May Have a Phase Shift

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{freq_{nominal}}\right)} \bullet 360° = \Delta t_{pt} \bullet freq_{nominal} \bullet 360°$$

Equation I.1

If the time shift on the pt measurement path Δt_{pt} = 0.784 ms and the nominal frequency, $freq_{nominal}$ = 60Hz, use *Equation I.2* to obtain the correction angle:

$$0.784 \bullet 10^{-3}s \bullet 60s^{-1} \bullet 360° = 16.934°$$

Equation I.2

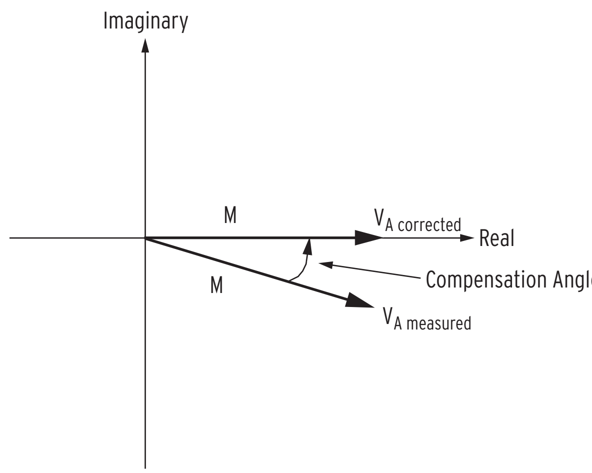

Figure I.3 Correction of Measured Phase Angle

The phasors are rms values scaled in primary units, as determined by Group setting PTR, CTR1, and CTR2 (for the IW1 and IW2 current sources).

Because the sampling reference is based on the GPS clock (IRIG-B signal) and not synchronized to the power system, an examination of successive synchrophasor data sets will almost always show some angular change between samples of the same signal. This is not a malfunction of the relay or the power system, but is merely a result of viewing data from one system with an instrument with an independent time base. In other words, a power system has a nominal frequency of either 50 or 60 Hz, but on closer examination, it is usually running a little faster or slower than nominal.

Settings for Synchrophasors

The phasor measurement unit (PMU) settings are listed in *Table I.1*. Modify these settings when you want to use the C37.118 synchrophasor protocol.

The Global enable setting EPMU must be set to Y before the remaining SEL-787 synchrophasor settings are available. No synchrophasor data collection can take place when EPMU := N.

You must make the serial port settings in *Table I.2* to transmit data with a synchrophasor protocol. It is possible to set EPMU := Y without using any serial ports for synchrophasor protocols. For example, the serial port **MET PM** ASCII command can still be used.

Table I.1 PMU Settings in the SEL-787 for C37.118 Protocol in Global Settings

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MRATE	Messages per Second {1, 2, 5, 10}	10
PMSTN	Station Name (16 characters)	SEL-787 XFRMR 1
PMID	PMU Hardware ID (1–65534)	1
PHDATAV	Phasor Data Set, Voltages (V1, ALL, NA)	V1
VCOMP	Voltage Angle Comp Factor (–179.99 to 180 deg)	0.00
PHDATAI	Phasor Data Set, Currents (I1, ALL, NA)	NA
PHCURR[b]	Current Source (IW1, IW2, BOTH)	BOTH
IW1COMP	IW1 Angle Comp Factor (–179.99 to 180 deg)	0.00
IW2COMP	IW2 Angle Comp Factor (–179.99 to 180 deg)	0.00
NUMANA	Number of Analog Values (0–4)	0
NUMDSW	Number of 16-bit Digital Status Words (0, 1)	0
TREA1	Trigger Reason Bit 1 (SELOGIC)	TRIP or ER
TREA2	Trigger Reason Bit 2 (SELOGIC)	81D1T OR 81D2T OR 81D3T OR 81D4T
TREA3	Trigger Reason Bit 3 (SELOGIC)	59P1T OR 59P2T OR 59Q1T OR 59Q2T
TREA4	Trigger Reason Bit 4 (SELOGIC)	27P1T OR 27P2T
PMTRIG	Trigger (SELOGIC)	TREA1 OR TREA2 OR TREA3 OR TREA4
IRIGC	IRIG-B Control Bits Definition (NONE, C37.118)	NONE

[a] Set EPMU := Y to access the remaining settings.
[b] Setting hidden when PHDATAI := NA.

Certain settings in *Table I.1* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the PHCURR setting is hidden to limit the number of settings for your synchrophasor application.

The Port settings for PROTO := PMU, shown in *Table I.2*, do not include the settings DATABIT and PARITY; these two settings are internally fixed as

DATABIT := 8, PARITY := N (None). See *Section 7: Communications* for descriptions of these functions.

Table I.2 SEL-787 Serial Port Settings for Synchrophasors

Setting	Description	Default
PROTO	Protocol (SEL, MOD, EVMSG, PMU, MBA, MBB, MB8A, MB8B, MBTA, MBTB)[a, b]	SEL[c]
SPEED	Data Speed (300, 1200, 2400, 4800, 9600, 19200, 38400 bps)	9600
STOPBIT	Stop Bits (1, 2)	1
RTSCTS	HDWR HANDSHAKING (Y, N)	N

[a] Some of the other PROTO setting choices may not be available.
[b] Setting choice PMU is not available on PORT 1.
[c] Set PROTO := PMU to enable (on this port) the synchrophasor protocol.

PROTO := PMU Does Not Allow Commands on That Serial Port

The PROTO := PMU settings choice in *Table I.2* can be made even when Global setting EPMU := N. However, in this situation, the serial port will not respond to any commands or requests. Either enable synchrophasors by making the *Table I.1* settings, or change the port PROTO setting to SEL.

If you use a computer terminal session or ACSELERATOR QuickSet SEL-5030 Software connected to a serial port, and then set that same serial port PROTO setting to PMU, you will lose the ability to communicate with the relay through ASCII commands or virtual file interface commands. If this happens, either connect via another serial port (that has PROTO := SEL) or use the front-panel HMI SET/SHOW screen to change the disabled port PROTO setting back to SEL.

Descriptions of Synchrophasor Settings

Definitions for the settings in *Table I.1* are as follows:

MRATE

Selects the message rate in messages per second for synchrophasor data streaming on serial ports.

Choose the MRATE setting that suits the needs of your PMU application. This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page I.12* for detailed information.

PMSTN and PMID

Defines the name and number of the PMU.

The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHDATAV and VCOMP

PHDATAV selects which voltage synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page I.12* for detailed information.

- PHDATAV := V1 will transmit only positive-sequence voltage, V_1
- PHDATAV := ALL will transmit V_1, V_A, V_B, and V_C
- PHDATAV := NA will not transmit any voltages

Table I.3 describes the order of synchrophasors inside the data packet.

The VCOMP setting allows correction for any steady-state voltage phase errors (from the potential transformers or wiring characteristics). See *Synchrophasor Measurement on page I.2* for details on this setting.

PHDATAI, PHCURR, IW1COMP, and IW2COMP

PHDATAI and PHCURR select which current synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. These settings are two of the six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page I.12* for detailed information.

- PHDATAI := I1 will transmit only positive-sequence current, I_1
- PHDATAI := ALL will transmit I_1, I_A, I_B, and I_C for the Windings selected by PHCURR
- PHDATAI := NA will not transmit any currents

PHCURR selects the source current(s) for the synchrophasor data selected by PHDATAI.

- PHCURR := IW1 uses the currents measured on the IAW1, IBW1, and ICW1 inputs
- PHCURR := IW2 uses the currents measured on the IAW2, IBW2, and ICW2 inputs
- PHCURR:= BOTH uses the currents measured on both the I_W1 inputs and I_W2 inputs

Table I.3 describes the order of synchrophasors inside the data packet.

The IW1COMP and IW2COMP settings allow correction for any steady-state phase errors (from the current transformers or wiring characteristics). See *Synchrophasor Measurement on page I.2* for details on these settings.

Table I.3 Synchrophasor Order in Data Stream (Voltages and Currents)

Synchrophasors[a]		Included When Global Settings Are as Follows:
Polar		
Magnitude	Angle	
V1	V1	PHDATAV := V1 or ALL
VA	VA	PHDATAV := ALL
VB	VB	
VC	VC	
I1W1	I1W1	PHDATAI := I1 or ALL **AND** (PHCURR := IW1 or BOTH)
IAW1	IAW1	PHDATAI := ALL **AND** (PHCURR := IW1 or BOTH)
IBW1	IBW1	
ICW1	ICW1	
I1W2	I1W2	(PHDATAI := I1 or ALL) **AND** (PHCURR := IW2 or BOTH)
IAW2	IAW2	PHDATAI := ALL **AND** (PHCURR := IW2 or BOTH)
IBW2	IBW2	
ICW2	ICW2	

[a] Synchrophasors are included in the order shown (i.e., voltages, if selected, will always precede currents).

NUMANA

Selects the number of user-definable analog values to be included in the synchrophasor data stream.

This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page I.12* for detailed information.

The choices for this setting depend on the synchrophasor system design.

- Setting NUMANA := 0 sends no user-definable analog values.
- Setting NUMANA := 1–4 sends the user-definable analog values, as listed in *Table I.4*.

The format of the user-defined analog data is always floating point, and each value occupies four bytes.

Table I.4 User-Defined Analog Values Selected by the NUMANA Setting

NUMANA Setting	Analog Quantities Sent	Total Number of Bytes Used for Analog Values
0	None	0
1	MV29	4
2	Above, plus MV30	8
3	Above, plus MV31	12
4	Above, plus MV32	16

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

This setting is one of six settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page I.12* for detailed information.

The choices for this setting depend on the synchrophasor system design. The inclusion of binary data can help indicate breaker status or other operational data to the synchrophasor processor.

- Setting NUMDSW := 0 sends no user-definable binary status words.
- Setting NUMDSW := 1 sends the user-definable binary status words, as listed in *Table I.5*.

Table I.5 User-Defined Digital Status Words Selected by the NUMDSW Setting

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
0	None	0
1	[SV32, SV31…SV17]	2

TREA1, TREA2, TREA3, TREA4, and PMTRIG

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations in the Global settings class. The SEL-787 evaluates these equations and places the results in Relay Word bits with the same names: TREA1–TREA4, and PMTRIG.

NOTE: The PM Trigger function is not associated with the SEL-787 Event Report Trigger ER, a SELOGIC control equation in the Report settings class.

The trigger reason equations represent the Trigger Reason bits in the STAT field of the data packet. After the trigger reason bits are set to convey a message, the PMTRIG Equation should be asserted for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The IEEE C37.118 standard defines the first eight of 16 binary combinations of these trigger reason bits (bits 0–3). The remaining eight binary combinations are available for user definition.

Table I.6 PM Trigger Reason Bits—IEEE C37.118 Assignments (Sheet 1 of 2)

TREA4	TREA3	TREA2	TREA1	Hexadecimal	Meaning[a]
(bit 3)	(bit 2)	(bit 1)	(bit 0)		
0	0	0	0	0x00	Manual
0	0	0	1	0x01	Magnitude Low
0	0	1	0	0x02	Magnitude High
0	0	1	1	0x03	Phase Angle Diff.
0	1	0	0	0x04	Frequency High/Low
0	1	0	1	0x05	df/dt High
0	1	1	0	0x06	Reserved
0	1	1	1	0x07	Digital

Table I.6 PM Trigger Reason Bits—IEEE C37.118 Assignments (Sheet 2 of 2)

TREA4 (bit 3)	TREA3 (bit 2)	TREA2 (bit 1)	TREA1 (bit 0)	Hexadecimal	Meaning[a]
1	0	0	0	0x08	User
1	0	0	1	0x09	User
1	0	1	0	0x0A	User
1	0	1	1	0x0B	User
1	1	0	0	0x0C	User
1	1	0	1	0x0D	User
1	1	1	0	0x0E	User
1	1	1	1	0x0F	User

[a] When PMTRIG is asserted. The terminology comes from IEEE C37.118.

The SEL-787 automatically sets the TREA1–TREA4 or PMTRIG Relay Word bits based on their default SELOGIC equation. To change the operation of these bits they must be programmed.

These bits may be used to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The SEL-787 synchrophasor processing and protocol transmission are not affected by the status of these bits.

IRIGC

Defines if IEEE C37.118 control bit extensions are in use. Control bit extensions contain information such as Leap Second, UTC time, Daylight-Saving Time, and Time Quality. When your satellite-synchronized clock provides these extensions your relay will be able adjust the synchrophasor time-stamp accordingly.

➤ IRIGC := NONE will ignore bit extensions

➤ IRIGC := C37.118 will extract bit extensions and correct synchrophasor time accordingly

Synchrophasor Relay Word Bits

Table I.7 and *Table I.8* list the SEL-787 Relay Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Relay Word bits in *Table I.7* follow the state of the SELOGIC control equations of the same name, listed at the bottom of *Table I.1*. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table I.5* for standard definitions for these settings.

Table I.7 Synchrophasor Trigger Relay Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC)
TREA4	Trigger Reason Bit 4 (SELOGIC)
TREA3	Trigger Reason Bit 3 (SELOGIC)
TREA2	Trigger Reason Bit 2 (SELOGIC)
TREA1	Trigger Reason Bit 1 (SELOGIC)

The Time Synchronization Relay Word bits in *Table I.8* indicate the present status of the timekeeping function of the SEL-787.

Table I.8 Time Synchronization Relay Word Bits

Name	Description
IRIGOK	Asserts while relay time is based on IRIG-B time source.
TSOK	Time Synchronization OK. Asserts while time is based on an IRIG-B time source of sufficient accuracy for synchrophasor measurement.
PMDOK	Phasor Measurement Data OK. Asserts when the SEL-787 is enabled and synchrophasors are enabled (Global setting EPMU := Y).

View Synchrophasors Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-787 synchrophasor measurements. See *MET Command (Metering Data) on page 7.31* for general information on the **MET** command.

There are multiple ways to use the **MET PM** command:

- As a test tool, to verify connections, phase rotation, and scaling
- As an analytical tool, to capture synchrophasor data at an exact time, in order to compare it with similar data captured in other phasor measurement unit(s) at the same time
- As a method of periodically gathering synchrophasor data through a communications processor

NOTE: In order to have the **MET PM xx:yy:zz** response transmitted from a serial port, the corresponding port must have the AUTO setting set to YES (Y). Also note that the **MET PM** response is not available on the Ethernet port.

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings PHDATAV, PHDATAI, and PHCURR. The **MET PM** command can function even when no serial ports are sending synchrophasor data—it is unaffected by serial port setting PROTO.

The **MET PM** command will only operate when the SEL-787 is in the IRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1.

Figure I.4 shows a sample **MET PM** command response. The synchrophasor data are also available via the **HMI > Meter PM** menu in QuickSet, and has a similar format to *Figure I.4*.

The **MET PM *time*** command can be used to direct the SEL-787 to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure I.4* occurring just after 14:14:12, with the time stamp 14:14:12.000.

See *Section 7: Communications* for complete command options, and error messages.

```
SEL-787                                 Date: 02/05/2008   Time: 17:22:07
TRNSFRMR RELAY                          Time Source: External


Time Quality   Maximum time synchronization error:    0.000 (ms)  TSOK = 1

Synchrophasors

                    Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)       134.14    131.64    128.60            131.45
ANG (DEG)      129.57     10.57   -111.89            129.47

                    Phase Currents            Pos. Sequence Current
                 IAW1      IBW1      ICW1              I1W1
MAG (A)        365.26    359.22    379.91            367.91
ANG (DEG)      114.03     -2.46   -120.25            117.03

                 IAW2      IBW2      ICW2              I1W2
MAG (A)        617.05    587.00    599.40            600.93
ANG (DEG)      136.34     13.93   -106.93            134.65

FREQ (Hz)  60.00
Rate-of-change of FREQ (Hz/s)    0.00

Digitals

SV24    SV23    SV22    SV21    SV20    SV19    SV18    SV17
 0       0       0       1       0       0       1       0
SV32    SV31    SV30    SV29    SV28    SV27    SV26    SV25
 0       1       0       0       0       1       0       0

Analogs

MV29      2.300  MV30      0.150  MV31     17.400  MV32      -9.230

=>
```

Figure I.4 Sample MET PM Command Response

C37.118 Synchrophasor Protocol

The SEL-787 complies with IEEE C37.118, Standard for Synchrophasors for Power Systems. The protocol is available on serial ports 2, 3, 4, and F by setting the corresponding Port setting PROTO := PMU.

This subsection does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The SEL-787 allows several options for transmitting synchrophasor data. These are controlled by Global settings described in *Settings for Synchrophasors on page I.4*. You can select how often to transmit the synchrophasor messages (MRATE) and which synchrophasors to transmit (PHDATAV, PHDATAI, and PHCURR). The SEL-787 automatically includes the frequency and rate-of-change-of-frequency in the synchrophasor messages.

The relay can include as many as four user-programmable analog values in the synchrophasor message, as controlled by Global setting NUMANA, and 0 or 16 digital status values, as controlled by Global setting NUMDSW.

The SEL-787 always includes the results of four synchrophasor trigger reason SELOGIC equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC equation result PMTRIG, in the synchrophasor message.

Communications Bandwidth

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors, analog values, or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

The C37.118 synchrophasor message format always includes 18 bytes for the message header and terminal ID, time information, status bits, and CRC value. The selection of synchrophasor data, numeric format, programmable analog, and programmable digital data will add to the byte requirements. *Table I.9* can be used to calculate the number of bytes in a synchrophasor message.

Table I.9 Size of a C37.118 Synchrophasor Message

Item	Possible Number of Quantities	Bytes per Quantity	Minimum Number of Bytes	Maximum Number of Bytes
Fixed			18	18
Synchrophasors	0, 1, 2, 3, 4, 5, 6, 8, 9, or 12	4	0	48
Frequency	2 (fixed)	2	4	4
Analog Values	0–4	4	0	16
Digital Status Words	0–1	2	0	2
Total (Minimum and Maximum)			22	88

Table I.10 lists the baud settings available on any SEL-787 serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 20 bytes.

Table I.10 Serial Port Bandwidth for Synchrophasors (in Bytes)

Global Setting MRATE	Port Setting SPEED							
	300	600	1200	2400	4800	9600	19200	38400
1	21	42	85	170	340	680	1360	2720
2		21	42	85	170	340	680	1360
5				34	68	136	272	544
10					34	68	136	272

Referring to *Table I.9* and *Table I.10*, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one digital status word, and this message would consume 24 bytes. This type of message could be sent at any message rate (MRATE) when SPEED := 4800 to 38400, as much as MRATE := 5 when SPEED := 2400, and as much as MRATE := 1 when SPEED := 600.

Another example application has messages comprised of eight synchrophasors, one digital status word, and two analog values. This type of message would consume 64 bytes. The 64-byte message could be sent at any message rate (MRATE) when SPEED := 9600.

Protocol Operation

The SEL-787 will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-787, with IEEE C37.118 commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor can automatically build a database structure.

NOTE: Only one serial port can be set to PROTO:=PMU at one time.

Transmit Mode Control

The SEL-787 will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The SEL-787 can also indicate when a configuration change occurs, so the synchrophasor processor can request a new configuration block and keep its database up-to-date.

The SEL-787 will only respond to configuration block request messages when it is in the non-transmitting mode.

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Appendix J
Relay Word Bits

Overview

The protection and control element results are represented by Relay Word bits in the SEL-787 Transformer Protection Relay. Each Relay Word bit has a label name and can be in either of the following states:

- 1 (logical 1)
- 0 (logical 0)

Logical 1 represents an element being picked up or otherwise asserted. Logical 0 represents an element being dropped out or otherwise deasserted.

Table J.1 and *Table J.2* show a list of Relay Word bits and corresponding descriptions. The Relay Word bit row numbers correspond to the row numbers used in the **TAR** command (see *TARGET Command (Display Relay Word Bit Status) on page 7.42*).

Any Relay Word bit (except Row 0) can be used in SELogic control equations (see *Section 4: Protection and Logic Functions*) and the Sequential Events Recorder (SER) trigger list settings (see *Section 9: Analyzing Events*).

Table J.1 SEL-787 Relay Word Bits (Sheet 1 of 4)

Bit/ Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
TAR 0	ENABLED	TRIP_LED	TLED_01	TLED_02	TLED_03	TLED_04	TLED_05	TLED_06
1	50P11T	50P12T	50P13T	50P14T	50P21T	50P22T	50P23T	50P24T
2	50G11T	50G12T	50Q11T	50Q12T	50G21T	50G22T	50Q21T	50Q22T
3	50N11T	50N12T	50NREF1	REF1E	50GREF1	REF1F	REF1R	REF1P
4	51P1T	51P2T	51G1T	51G2T	51Q1T	51Q2T	51N1T	a
5	87U1	87U2	87U3	87U	87R1	87R2	87R3	87R
6	TH5T	87AT	27P1T	27P2T	59P1T	59P2T	3PWR1T	3PWR2T
7	81D1T	81D2T	81D3T	81D4T	BFT1	BFT2	59Q1T	59Q2T
8	24D1	24D1T	24C2	24C2T	24CR	a	a	RTDT
9	REMTRIP	a	a	a	a	a	ORED50T	ORED51T
10	50P11P	50P12P	50P13P	50P14P	50P21P	50P22P	50P23P	50P24P
11	50G11P	50G12P	50Q11P	50Q12P	50G21P	50G22P	50Q21P	50Q22P
12	50N11P	50N12P	51P1AR	51P1BR	51P1CR	51P2AR	52A1	52A2
13	51P1P	51P2P	51G1P	51G2P	51Q1P	51Q2P	51N1P	51P2BR
14	51P1R	51P2R	51G1R	51G2R	51Q1R	51Q2R	51N1R	51P2CR

Table J.1 SEL-787 Relay Word Bits (Sheet 2 of 4)

Bit/ Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
15	2_4HB1	2_4HB2	2_4HB3	2_4HBL	5HB1	5HB2	5HB3	5HBL
16	87BL1	87BL2	87BL3	87HB	87HR1	87HR2	87HR3	87HR
17	TH5	87AP	27P1	27P2	59P1	59P2	3PWR1P	3PWR2P
18	AMBALRM	AMBTRIP	OTHALRM	OTHTRIP	BFI1	BFI2	59Q1	59Q2
19	TRIP	OUT101	OUT102	OUT103	OUT301	OUT302	OUT303	OUT304
20	OUT401	OUT402	OUT403	OUT404	OUT501	OUT502	OUT503	OUT504
21	IN101	IN102	a	a	a	a	a	a
22	IN301	IN302	IN303	IN304	IN305	IN306	IN307	IN308
23	IN401	IN402	IN403	IN404	IN405	IN406	IN407	IN408
24	IN501	IN502	IN503	IN504	IN505	IN506	IN507	IN508
25	LINKA	LINKB	PMDOK	SALARM	WARNING	TSOK	IRIGOK	FAULT
26	COMMIDLE	COMMLOSS	COMMFLT	CFGFLT	LINKFAIL	PASEL	PBSEL	LOP
27	FREQTRK	ER	a	a	RSTENRGY	RSTMXMN	RSTDEM	RSTPKDEM
28	RTDFLT	RTDIN	TRGTR	a	RTDA	DSABLSET	RSTTRGT	HALARM
29	RTD1A	RTD1T	RTD2A	RTD2T	RTD3A	RTD3T	RTD4A	RTD4T
30	RTD5A	RTD5T	RTD6A	RTD6T	RTD7A	RTD7T	RTD8A	RTD8T
31	RTD9A	RTD9T	RTD10A	RTD10T	RTD11A	RTD11T	RTD12A	RTD12T
32	CLOSE1	CF1	CC1	a	a	CLOSE2	CF2	CC2
33	SG1	SG2	SG3	SG4	TREA1	TREA2	TREA3	TREA4
34	OC1	OC2	TR1	TR2	TRXFMR	TRIP1	TRIP2	TRIPXFMR
35	CL1	CL2	ULTRIP1	ULTRIP2	ULTRXFMR	ULCL1	ULCL2	PMTRIG
36	DNAUX1	DNAUX2	DNAUX3	DNAUX4	DNAUX5	DNAUX6	DNAUX7	DNAUX8
37	DNAUX9	DNAUX10	DNAUX11	RELAY_EN	a	INR1	INR2	INR3
38	PB01	PB02	PB03	PB04	PB01_PUL	PB02_PUL	PB03_PUL	PB04_PUL
39	PB1A_LED	PB1B_LED	PB2A_LED	PB2B_LED	PB3A_LED	PB3B_LED	PB4A_LED	PB4B_LED
40	a	a	T01_LED	T02_LED	T03_LED	T04_LED	T05_LED	T06_LED
41	PHDEM	3I2DEM	GNDEM	a	a	TFLTALA	TFLTALB	TFLTALC
42	LB01	LB02	LB03	LB04	LB05	LB06	LB07	LB08
43	LB09	LB10	LB11	LB12	LB13	LB14	LB15	LB16
44	LB17	LB18	LB19	LB20	LB21	LB22	LB23	LB24
45	LB25	LB26	LB27	LB28	LB29	LB30	LB31	LB32
46	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
47	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
48	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
49	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
50	SV01	SV02	SV03	SV04	SV05	SV06	SV07	SV08
51	SV01T	SV02T	SV03T	SV04T	SV05T	SV06T	SV07T	SV08T
52	SV09	SV10	SV11	SV12	SV13	SV14	SV15	SV16
53	SV09T	SV10T	SV11T	SV12T	SV13T	SV14T	SV15T	SV16T
54	SV17	SV18	SV19	SV20	SV21	SV22	SV23	SV24

Table J.1 SEL-787 Relay Word Bits (Sheet 3 of 4)

Bit/ Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
55	SV17T	SV18T	SV19T	SV20T	SV21T	SV22T	SV23T	SV24T
56	SV25	SV26	SV27	SV28	SV29	SV30	SV31	SV32
57	SV25T	SV26T	SV27T	SV28T	SV29T	SV30T	SV31T	SV32T
58	LT01	LT02	LT03	LT04	LT05	LT06	LT07	LT08
59	LT09	LT10	LT11	LT12	LT13	LT14	LT15	LT16
60	LT17	LT18	LT19	LT20	LT21	LT22	LT23	LT24
61	LT25	LT26	LT27	LT28	LT29	LT30	LT31	LT32
62	SC01QU	SC02QU	SC03QU	SC04QU	SC05QU	SC06QU	SC07QU	SC08QU
63	SC01QD	SC02QD	SC03QD	SC04QD	SC05QD	SC06QD	SC07QD	SC08QD
64	SC09QU	SC10QU	SC11QU	SC12QU	SC13QU	SC14QU	SC15QU	SC16QU
65	SC09QD	SC10QD	SC11QD	SC12QD	SC13QD	SC14QD	SC15QD	SC16QD
66	SC17QU	SC18QU	SC19QU	SC20QU	SC21QU	SC22QU	SC23QU	SC24QU
67	SC17QD	SC18QD	SC19QD	SC20QD	SC21QD	SC22QD	SC23QD	SC24QD
68	SC25QU	SC26QU	SC27QU	SC28QU	SC29QU	SC30QU	SC31QU	SC32QU
69	SC25QD	SC26QD	SC27QD	SC28QD	SC29QD	SC30QD	SC31QD	SC32QD
70	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
71	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
72	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
73	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
74	LBOKB	CBADB	RBADB	ROKB	LBOKA	CBADA	RBADA	ROKA
75	VB001	VB002	VB003	VB004	VB005	VB006	VB007	VB008
76	VB009	VB010	VB011	VB012	VB013	VB014	VB015	VB016
77	VB017	VB018	VB019	VB020	VB021	VB022	VB023	VB024
78	VB025	VB026	VB027	VB028	VB029	VB030	VB031	VB032
79	VB033	VB034	VB035	VB036	VB037	VB038	VB039	VB040
80	VB041	VB042	VB043	VB044	VB045	VB046	VB047	VB048
81	VB049	VB050	VB051	VB052	VB053	VB054	VB055	VB056
82	VB057	VB058	VB059	VB060	VB061	VB062	VB063	VB064
83	VB065	VB066	VB067	VB068	VB069	VB070	VB071	VB072
84	VB073	VB074	VB075	VB076	VB077	VB078	VB079	VB080
85	VB081	VB082	VB083	VB084	VB085	VB086	VB087	VB088
86	VB089	VB090	VB091	VB092	VB093	VB094	VB095	VB096
87	VB097	VB098	VB099	VB100	VB101	VB102	VB103	VB104
88	VB105	VB106	VB107	VB108	VB109	VB110	VB111	VB112
89	VB113	VB114	VB115	VB116	VB117	VB118	VB119	VB120
90	VB121	VB122	VB123	VB124	VB125	VB126	VB127	VB128
91	AILW1	AILW2	AILAL	50P11AP	AIHW1	AIHW2	AIHAL	50P11AT
92	AI301LW1	AI301LW2	AI301LAL	50P11BP	AI301HW1	AI301HW2	AI301HAL	50P11BT
93	AI302LW1	AI302LW2	AI302LAL	50P11CP	AI302HW1	AI302HW2	AI302HAL	50P11CT
94	AI303LW1	AI303LW2	AI303LAL	50P21AP	AI303HW1	AI303HW2	AI303HAL	50P21AT

Table J.1 SEL-787 Relay Word Bits (Sheet 4 of 4)

Bit/ Row	Relay Word Bits							
	7	6	5	4	3	2	1	0
95	AI304LW1	AI304LW2	AI304LAL	50P21BP	AI304HW1	AI304HW2	AI304HAL	50P21BT
96	AI401LW1	AI401LW2	AI401LAL	50P21CP	AI401HW1	AI401HW2	AI401HAL	50P21CT
97	AI402LW1	AI402LW2	AI402LAL	51P1AP	AI402HW1	AI402HW2	AI402HAL	51P1AT
98	AI403LW1	AI403LW2	AI403LAL	51P1BP	AI403HW1	AI403HW2	AI403HAL	51P1BT
99	AI404LW1	AI404LW2	AI404LAL	51P1CP	AI404HW1	AI404HW2	AI404HAL	51P1CT
100	AI501LW1	AI501LW2	AI501LAL	51P2AP	AI501HW1	AI501HW2	AI501HAL	51P2AT
101	AI502LW1	AI502LW2	AI502LAL	51P2BP	AI502HW1	AI502HW2	AI502HAL	51P2BT
102	AI503LW1	AI503LW2	AI503LAL	51P2CP	AI503HW1	AI503HW2	AI503HAL	51P2CT
103	AI504LW1	AI504LW2	AI504LAL	[a]	AI504HW1	AI504HW2	AI504HAL	[a]
104	DI_A1	DI_B1	DI_C1	DI_A2	DI_B2	DI_C2	[a]	MATHERR
105	TQUAL1	TQUAL2	TQUAL4	TQUAL8	DST	DSTP	LPSEC	LPSECP
106	TSNTPB	TSNTPP	TUTCS	TUTC1	TUTC2	TUTC4	TUTC8	TUTCH

[a] Reserved for future use.

Definitions

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 1 of 10)

Bit	Definition	Row
[a]	Reserved	—
2_4HB1	Second or Fourth Harmonic block asserted for differential element 1	15
2_4HB2	Second or Fourth Harmonic block asserted for differential element 2	15
2_4HB3	Second or Fourth Harmonic block asserted for differential element 3	15
2_4HBL	Second or Fourth Harmonic block asserted (2_4HB1 OR 2_4HB2 OR 2_4HB3)	15
24C2	Level 2 Volts/Hertz composite element pickup	8
24C2T	Level 2 Volts/Hertz composite element timed out	8
24CR	Level 2 Volts/Hertz element fully reset	8
24D1	Level 1 Volts/Hertz instantaneous pickup	8
24D1T	Level 1 Volts/Hertz definite-time element timed out	8
27P1	Level 1 phase undervoltage element pickup	17
27P1T	Level 1 phase undervoltage element trip	6
27P2	Level 2 phase undervoltage element pickup	17
27P2T	Level 2 phase undervoltage element trip	6
3I2DEM	Negative-sequence current demand pickup	41
3PWR1P	Three phase power element 1 pickup	17
3PWR1T	Three phase power element 1 trip	6
3PWR2P	Three phase power element 2 pickup	17

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 2 of 10)

Bit	Definition	Row
3PWR2T	Three phase power element 2 trip	6
50G11P	Level 1 residual ground instantaneous overcurrent element pickup—Winding 1	11
50G11T	Level 1 residual ground instantaneous overcurrent element trip—Winding 1	2
50G12P	Level 2 residual ground instantaneous overcurrent element pickup —Winding 1	11
50G12T	Level 2 residual ground instantaneous overcurrent element trip—Winding 1	2
50G21P	Level 1 residual ground instantaneous overcurrent element pickup—Winding 2	11
50G21T	Level 1 residual ground instantaneous overcurrent element trip—Winding 2	2
50G22P	Level 2 residual ground instantaneous overcurrent element pickup —Winding 2	11
50G22T	Level 2 residual ground instantaneous overcurrent element trip—Winding 2	2
50GREF1	Normalized residual current sensitivity threshold exceeded	3
50N11P	Level 1 neutral ground instantaneous overcurrent element pickup—Input 1	12
50N11T	Level 1 neutral ground instantaneous overcurrent element trip—Input 1	3
50N12P	Level 2 neutral ground instantaneous overcurrent element pickup—Input 1	12
50N12T	Level 2 neutral ground instantaneous overcurrent element trip—Input 1	3
50NREF1	Neutral current sensitivity threshold exceeded	3
50P11P	Level 1 maximum phase instantaneous overcurrent element pickup—Winding 1	10
50P11T	Level 1 maximum phase instantaneous overcurrent element trip—Winding 1	1
50P11AP	Level 1 A-phase instantaneous overcurrent element pickup—Winding 1	91
50P11AT	Level 1 A-phase instantaneous overcurrent element trip—Winding 1	91
50P11BP	Level 1 B-phase instantaneous overcurrent element pickup—Winding 1	92
50P11BT	Level 1 B-phase instantaneous overcurrent element trip—Winding 1	92
50P11CP	Level 1 C-phase instantaneous overcurrent element pickup—Winding 1	93
50P11CT	Level 1 C-phase instantaneous overcurrent element trip—Winding 1	93
50P12P	Level 2 maximum phase instantaneous overcurrent element pickup—Winding 1	10
50P12T	Level 2 maximum phase instantaneous overcurrent element trip—Winding 1	1
50P13P	Level 3 maximum phase instantaneous overcurrent element pickup—Winding 1	10
50P13T	Level 3 maximum phase instantaneous overcurrent element trip—Winding 1	1
50P14P	Level 4 maximum phase instantaneous overcurrent element pickup—Winding 1	10
50P14T	Level 4 maximum phase instantaneous overcurrent element trip—Winding 1	1
50P21P	Level 1 maximum phase instantaneous overcurrent element pickup—Winding 2	10
50P21T	Level 1 maximum phase instantaneous overcurrent element trip—Winding 2	1
50P21AP	Level 1 A-phase instantaneous overcurrent element pickup—Winding 2	94
50P21AT	Level 1 A-phase instantaneous overcurrent element trip—Winding 2	94
50P21BP	Level 1 B-phase instantaneous overcurrent element pickup—Winding 2	95
50P21BT	Level 1 B-phase instantaneous overcurrent element trip—Winding 2	95
50P21CP	Level 1 C-phase instantaneous overcurrent element pickup—Winding 2	96
50P21CT	Level 1 C-phase instantaneous overcurrent element trip—Winding 2	96
50P22P	Level 2 maximum phase instantaneous overcurrent element pickup—Winding 2	10

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 3 of 10)

Bit	Definition	Row
50P22T	Level 2 maximum phase instantaneous overcurrent element trip—Winding 2	1
50P23P	Level 3 maximum phase instantaneous overcurrent element pickup—Winding 2	10
50P23T	Level 3 maximum phase instantaneous overcurrent element trip—Winding 2	1
50P24P	Level 4 maximum phase instantaneous overcurrent element pickup—Winding 2	10
50P24T	Level 4 maximum phase instantaneous overcurrent element trip—Winding 2	1
50Q11P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 1	11
50Q11T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 1	2
50Q12P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 1	11
50Q12T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 1	2
50Q21P	Level 1 negative-sequence instantaneous overcurrent element pickup—Winding 2	11
50Q21T	Level 1 negative-sequence instantaneous overcurrent element trip—Winding 2	2
50Q22P	Level 2 negative-sequence instantaneous overcurrent element pickup—Winding 2	11
50Q22T	Level 2 negative-sequence instantaneous overcurrent element trip—Winding 2	2
51G1P	Residual ground time-overcurrent element pickup—Winding 1	13
51G1R	Residual ground time-overcurrent element reset—Winding 1	14
51G1T	Residual ground time-overcurrent element trip—Winding 1	4
51G2P	Residual ground time-overcurrent element pickup—Winding 2	13
51G2R	Residual ground time-overcurrent element reset—Winding 2	14
51G2T	Residual ground time-overcurrent element trip—Winding 2	4
51N1P	Neutral ground time-overcurrent element pickup—Input 1	13
51N1R	Neutral ground time-overcurrent element reset	14
51N1T	Neutral ground time-overcurrent element trip—Input 1	4
51P1P	Maximum phase time-overcurrent element pickup—Winding 1	13
51P1R	Maximum phase time-overcurrent element reset—Winding 1	14
51P1T	Maximum phase time-overcurrent element trip—Winding 1	4
51P1AP	A-phase time-overcurrent element pickup—Winding 1	97
51P1AR	A-phase time-overcurrent element reset—Winding 1	12
51P1AT	A-phase time-overcurrent element trip—Winding 1	97
51P1BP	B-phase time-overcurrent element pickup—Winding 1	98
51P1BR	B-phase time-overcurrent element reset—Winding 1	12
51P1BT	B-phase time-overcurrent element trip—Winding 1	98
51P1CP	C-phase time-overcurrent element pickup—Winding 1	99
51P1CR	C-phase time-overcurrent element reset—Winding 1	12
51P1CT	C-phase time-overcurrent element trip—Winding 1	99
51P2P	Maximum phase time-overcurrent element pickup—Winding 2	13
51P2R	Maximum phase time-overcurrent element reset—Winding 2	14
51P2T	Maximum phase time-overcurrent element trip—Winding 2	4
51P2AP	A-phase time-overcurrent element pickup—Winding 2	100

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 4 of 10)

Bit	Definition	Row
51P2AR	A-phase time-overcurrent element reset—Winding 2	12
51P2AT	A-phase time-overcurrent element trip—Winding 2	100
51P2BP	B-phase time-overcurrent element pickup—Winding 2	101
51P2BR	B-phase time-overcurrent element reset—Winding 2	13
51P2BT	C-phase time-overcurrent element trip—Winding 2	101
51P2CP	C-phase time-overcurrent element pickup—Winding 2	102
51P2CR	C-phase time-overcurrent element reset—Winding 2	14
51P2CT	C-phase time-overcurrent element trip—Winding 2	102
51Q1P	Negative-sequence time-overcurrent element pickup—Winding 1	13
51Q1R	Negative-sequence time-overcurrent element reset—Winding 1	14
51Q1T	Negative-sequence time-overcurrent element trip—Winding 1	4
51Q2P	Negative-sequence time-overcurrent element pickup—Winding 2	13
51Q2R	Negative-sequence time-overcurrent element reset—Winding 2	14
51Q2T	Negative-sequence time-overcurrent element trip—Winding 2	4
52A1	Circuit breaker 1, contact A	12
52A2	Circuit breaker 2, contact A	12
59P1	Level 1 phase overvoltage element pickup	17
59P1T	Level 1 phase overvoltage element trip	6
59P2	Level 2 phase overvoltage element pickup	17
59P2T	Level 2 phase overvoltage element trip	6
59Q1	Level 1 negative-sequence overvoltage element pickup	18
59Q1T	Level 1 negative-sequence overvoltage element trip	7
59Q2	Level 2 negative-sequence overvoltage element pickup	18
59Q2T	Level 2 negative-sequence overvoltage element trip	7
5HB1	Fifth Harmonic block asserted for differential element 1	15
5HB2	Fifth Harmonic block asserted for differential element 2	15
5HB3	Fifth Harmonic block asserted for differential element 3	15
5HBL	Fifth Harmonic block asserted (5HB1 OR 5HB2 OR 5HB3)	15
81D1T	Level 1 definite-time over/under frequency trip	7
81D2T	Level 2 definite-time over/under frequency trip	7
81D3T	Level 3 definite-time over/under frequency trip	7
81D4T	Level 4 definite-time over/under frequency trip	7
87AP	Differential Current Alarm element pickup	17
87AT	Differential Current Alarm element trip	6
87BL1	Harmonic block asserted for differential element 1	16
87BL2	Harmonic block asserted for differential element 2	16
87BL3	Harmonic block asserted for differential element 3	16
87HB	Harmonic block differential element asserted	16

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 5 of 10)

Bit	Definition	Row
87HR	Harmonic restrained element (HR1 OR HR2 OR HR3)[b]	16
87HR1	Harmonic restrained element 1	16
87HR2	Harmonic restrained element 2	16
87HR3	Harmonic restrained element 3	16
87R	Restrained differential element Trip (87HR OR 87HB)	5
87R1	Restrained differential element 1 (not considering harmonic blocks)	5
87R2	Restrained differential element 2 (not considering harmonic blocks)	5
87R3	Restrained differential element 3 (not considering harmonic blocks)	5
87U	Unrestrained differential element Trip (87U1 OR 87U2 OR 87U3)	5
87U1	Unrestrained differential element 1 Trip	5
87U2	Unrestrained differential element 2 Trip	5
87U3	Unrestrained differential element 3 Trip	5
AIHAL	Analog inputs High Alarm Limit. If any AI*nnn*HAL = 1, then AIHAL = 1	91
AIHW1	Analog inputs High Warning, Level 1. If any Ai*nnn*HW1 = 1, then AIHW1 = 1	91
AIHW2	Analog inputs High Warning, Level 2. If any Ai*nnn*HW2 = 1, then AIHW2 = 1	91
AILAL	Analog inputs Low Alarm Limit. If any AI*nnn*LAL = 1, then AILAL = 1	91
AILW1	Analog inputs Low Warning, Level 1. If any Ai*nnn*LW1 = 1, then AILW1 = 1	91
AILW2	Analog inputs Low Warning, Level 2. If any Ai*nnn*LW2 = 1, then AILW2 = 1	91
AI*nnn*HAL	Analog inputs 301–504 Warnings/Alarms (where *nnn* = 301–504) High Alarm Limit	92-103
AI*nnn*HW1	Analog inputs 301–504 Warnings/Alarms (where *nnn* = 301–504) High Warning, Level 1	92-103
AI*nnn*HW2	Analog inputs 301–504 Warnings/Alarms (where *nnn* = 301–504) High Warning, Level 2	92-103
AI*nnn*LAL	Analog inputs 301–504 Warnings/Alarms (where *nnn* = 301–504) Low Alarm Limit	92-103
AI*nnn*LW1	Analog inputs 301–504 Warnings/Alarms (where *nnn* = 301–504) Low Warning, Level 1	92-103
AI*nnn*LW2	Analog inputs 301–504 Warnings/Alarms (where *nnn* = 301–504) Low Warning, Level 2	92-103
AMBALRM	Ambient Temperature Alarm. AMBALRM asserts if the healthy ambient RTD temperature exceeds its alarm set point.	18
AMBTRIP	Ambient Temperature Trip. AMBTRIP asserts when the healthy Ambient RTD temperature exceeds its trip set point.	18
BFI1	Breaker 1 Failure Initiation. Asserts when the SELOGIC control equation BFI1 results in a logical 1. Use to indicate that the Breaker 2 Failure logic has started.	18
BFI2	Breaker 2 Failure Initiation. Asserts when the SELOGIC control equation BFI2 results in a logical 1. Use to indicate that the Breaker 1 Failure logic has started.	18
BFT1	Breaker 1 Failure Trip. Asserts when the relay issues a Breaker 1 Failure trip.	7
BFT2	Breaker 2 Failure Trip. Asserts when the relay issues a Breaker 2 Failure trip.	7
CBADA	Channel A, channel unavailability over threshold	74
CBADB	Channel B, channel unavailability over threshold	74
CC1	Close command. Asserts when serial port command CC1 (CLOSE Breaker1) or front-panel or Modbus/ DeviceNet **CLOSE** command is issued to Close Breaker1.	32
CC2	Close command. Asserts when serial port command CC2 (CLOSE Breaker2) or front-panel or Modbus/ DeviceNet **CLOSE** command is issued to Close Breaker2.	32
CF1	Breaker 1 Close condition failure on	32

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 6 of 10)

Bit	Definition	Row
CF2	Breaker 2 Close condition failure on	32
CFGFLT	Asserts on failed settings interdependency check during Modbus setting change	26
CL1	Close SELOGIC control equation CL1	35
CL2	Close SELOGIC control equation CL2	35
CLOSE1	Close logic output for Breaker1	32
CLOSE2	Close logic output for Breaker2	32
COMMFLT	Time-out of internal communication between CPU board and DeviceNet board	26
COMMIDLE	DeviceNet card in programming mode	26
COMMLOSS	DeviceNet communication failure	26
DI_*xn*	Distortion index, where *x* = phase A, B, or C and *n* = winding 1 or 2	104
DNAUX*n*	DeviceNet/Modbus AUX*n* assert bit, where *n* = 1 through 8	36
DNAUX*n*	DeviceNet/Modbus AUX*n* assert bit, where *n* = 9 through 11	37
DSABLSET	SELOGIC control equation: Do not allow settings changes from front-panel interface when asserted	28
DST	Daylight-Saving Time	105
DSTP	Daylight-Saving Time Pending	105
ER	Event report trigger SELOGIC control equation	27
FAULT	Indicates fault condition. Asserts when SELOGIC control equation FAULT result in a logical 1.	25
FREQTRK	Frequency tracking enable bit-tracking enabled when bit is asserted	27
GNDEM	Zero sequence current demand pickup	41
HALARM	Diagnostics failure	28
IN301–IN304	Contact inputs IN301–IN304 (available only with optional I/O module	22
IN305–IN308	Contact inputs IN305–IN308 (available only with optional I/O module	22
IN401–IN404	Contact inputs IN401–IN404 (available only with optional I/O module	23
IN405–IN408	Contact inputs IN405–IN408 (available only with optional I/O module	23
IN501–IN504	Contact inputs IN501–IN504 (available only with optional I/O module	24
IN505–IN508	Contact inputs IN505–IN508 (available only with optional I/O module	24
IN*nnn*	Contact inputs IN101 and IN102	21
INR1	87-1 Differential element in high security mode (see *Figure 4.4*)	37
INR2	87-2 Differential element in high security mode (see *Figure 4.4*)	37
INR3	87-3 Differential element in high security mode (see *Figure 4.4*)	37
IRIGOK	IRIG-B time synch input data are valid	25
LB01–LB08	Local Bits 01 through 08	42
LB09–LB16	Local Bits 09 through 16	43
LB17–LB24	Local Bits 17 through 24	44
LB25–LB32	Local Bits 25 through 32	45
LBOKA	Channel A, looped back OK	74
LBOKB	Channel B, looped back OK Channel B, channel unavailability over threshold	74
LINKA	Assert if Ethernet Port A detects link	25

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 7 of 10)

Bit	Definition	Row
LINKB	Assert if Ethernet Port B detects link	25
LINKFAIL	Failure of active Ethernet port link	26
LOP	Loss-of-Potential	26
LPSEC	Direction of the upcoming leap second. During the time that LPSECP is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.	105
LPSECP	Leap second pending	105
LT01–LT08	Latch bits 1through 8	58
LT09–LT16	Latch bits 09 through 16	59
LT17–LT24	Latch bits 17 through 24	60
LT25–LT32	Latch bits 25 through 32	61
MATHERR	SELOGIC math error bit asserted for divide-by-zero, etc., in SELOGIC math functions	104
OC1	Open command. Asserts when serial port command Open Breaker1 or Front Panel or Modbus/ DeviceNet Open Breaker1 command is issued.	34
OC2	Open command. Asserts when serial port command Open Breaker2 or Front Panel or Modbus/ DeviceNet Open Breaker2 command is issued.	34
ORED50T	Logical OR of all the instantaneous overcurrent elements Tripped outputs	9
ORED51T	Logical OR of all the time overcurrent elements Tripped outputs	9
OTHALRM	Other Temperature Alarm. OTHALRM asserts when any healthy other RTD temperature exceeds its alarm set point.	18
OTHTRIP	Other RTD temperatures exceed their trip set points	18
OUT101–OUT103	SELOGIC control equation for contact outputs OUT101 through OUT103	19
OUT301–OUT304	SELOGIC control equation for contact outputs OUT301 through OUT304 (available only with optional I/O module)	19
OUT401–OUT404	SELOGIC control equation for contact outputs OUT401 through OUT404 (available only with optional I/O module)	20
OUT501–OUT504	Control equation for contact outputs OUT501 through OUT504 (available only with optional I/O module)	20
PASEL	Ethernet Port A is selected for communications	26
PB01	Front-panel pushbutton 1 bit (asserted when PB01 is pressed)	38
PB01_PUL	Front-panel pushbutton 1 pulse bit (asserted for one processing interval when PB01 is pressed)	38
PB02	Front-panel pushbutton 2 bit (asserted when PB02 is pressed)	38
PB02_PUL	Front-panel pushbutton 2 pulse bit (asserted for one processing interval when PB02 is pressed)	38
PB03	Front-panel pushbutton 3 bit (asserted when PB03 is pressed)	38
PB03_PUL	Front-panel pushbutton 3 pulse bit (asserted for one processing interval when PB03 is pressed)	38
PB04	Front-panel pushbutton 4 bit (asserted when PB04 is pressed)	38
PB04_PUL	Front-panel pushbutton 4 pulse bit (asserted for one processing interval when PB04 is pressed)	38
PB1A_LED	SELOGIC control equation: drives LED PB1A	39
PB1B_LED	SELOGIC control equation: drives LED PB1B	39
PB2A_LED	SELOGIC control equation: drives LED PB2A	39
PB2B_LED	SELOGIC control equation: drives LED PB2B	39
PB3A_LED	SELOGIC control equation: drives LED PB3A	39

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 8 of 10)

Bit	Definition	Row
PB3B_LED	SELOGIC control equation: drives LED PB3B	39
PB4A_LED	SELOGIC control equation: drives LED PB4A	39
PB4B_LED	SELOGIC control equation: drives LED PB4B	39
PBSEL	Ethernet Port B is selected for communications	26
PHDEM	Phase current demand pickup	41
PMDOK	Assert if data acquisition system is operating correctly	25
PMTRIG	Trigger for synchrophasors	35
RB01–RB08	Remote Bits 01 through 08	46
RB09–RB16	Remote Bits 09 through 16	47
RB17–RB24	Remote Bits 17 through 24	48
RB25–RB32	Remote Bits 25 through 32	49
RBADA	Channel A, outage duration over threshold	74
RBADB	Channel B, outage duration over threshold	74
REF1E	Internal enable for the REF element	3
REF1F	REF element forward (internal) fault declaration	3
REF1P	Restricted earth fault inverse-time O/C element timed-out	3
REF1R	REF element reverse (external) fault declaration	3
RELAY_EN	Relay OK flag. RELAY_EN status follows the **ENABLED** LED status.	37
REMTRIP	Remote Trip	9
RMB*n*A	Channel A receive mirror bits RMB1A through RMB8A	70
RMB*n*B	Channel B receive mirror bits RMB1B through RMB8B	72
ROKA	Channel A, received data OK	74
ROKB	Channel B, received data OK	74
RSTDEM	Reset demand meter	27
RSTENRGY	Reset Energy metering. Assert when the SELOGIC control equation RSTENRG result is logical 1.	27
RSTMXMN	Reset Max Min metering. Assert when the SELOGIC control equation RSTMXMN result is logical 1.	27
RSTPKDEM	Reset peak demand meter	27
RSTTRGT	SELOGIC control equation: reset trip logic and targets when asserted	28
RTDA	Asserts when any RTD alarm (RTD_A) is asserted	28
RTDFLT	Asserts when an open or short circuit condition is detected on any enabled RTD input, or communication with the external RTD module has been interrupted	28
RTDIN	Indicates status of contact connected to SEL-2600A RTD module	28
RTD*n*A	RTD1A through RTD4A (Alarms)	29
RTD*n*A	RTD5A through RTD8A (Alarms)	30
RTD*n*A	RTD9A through RTD12A (Alarms)	31
RTD*n*T	RTD1T through RTD4T (Trips)	29
RTD*n*T	RTD5T through RTD8T (Trips)	30
RTD*n*T	RTD9T through RTD12T (Trips)	31

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 9 of 10)

Bit	Definition	Row
RTDT	Asserts when any RTD trip (RTD_T) is asserted	8
SALARM	Software Alarms: invalid password, changing access levels, settings changes, active group changes, copy commands, and password changes	25
SC*nn*QD	SELOGIC Counters 01 through 08 asserted when counter = 0	63
SC*nn*QD	SELOGIC Counters 09 through 16 asserted when counter = 0	65
SC*nn*QD	SELOGIC Counters 17 through 24 asserted when counter = 0	67
SC*nn*QD	SELOGIC Counters 25 through 32 asserted when counter = 0	69
SC*nn*QU	SELOGIC Counters 01 through 08 asserted when counter = preset value	62
SC*nn*QU	SELOGIC Counters 09 through 16 asserted when counter = preset value	64
SC*nn*QU	SELOGIC Counters 17 through 24 asserted when counter = preset value	66
SC*nn*QU	SELOGIC Counters 25 through 32 asserted when counter = preset value	68
SG1	Asserts when setting group 1 is active	33
SG2	Asserts when setting group 2 is active	33
SG3	Asserts when setting group 3 is active	33
SG4	Asserts when setting group 4 is active	33
SV01–SV08	SELOGIC control equation variables SV01 through SV08	50
SV01T–SV08T	SELOGIC control equation variable SV01T through SV08T with settable pickup and dropout time delay	51
SV09–SV16	SELOGIC control equation variables SV09 through SV16	52
SV09T–SV16T	SELOGIC control equation variable SV09T through SV16T with settable pickup and dropout time delay	53
SV17–SV24	SELOGIC control equation variables SV17 through SV24	54
SV17T–SV24T	SELOGIC control equation variable SV17T through SV24T with settable pickup and dropout time delay	55
SV25–SV32	SELOGIC control equation variables SV25 through SV32	56
SV25T–SV32T	SELOGIC control equation variable SV25T through SV32T with settable pickup and dropout time delay	57
T01_LED–T06_LED	SELOGIC control equation: drives T01_LED through T06_LED	40
TFLTALA	Through fault alarm, phase A	41
TFLTALB	Through fault alarm, phase B	41
TFLTALC	Through fault alarm, phase C	41
TH5	Fifth Harmonic alarm threshold exceeded	17
TH5T	Fifth Harmonic alarm threshold exceeded for longer than TH5D	6
TMB*n*A	Channel A transmit mirror bits TMB1A through TMB8A	71
TMB*n*B	Channel B transmit mirror bits TMB1B through TMB8B	73
TQUAL1	Time Quality Bit, add 1 when asserted	105
TQUAL2	Time Quality Bit, add 2 when asserted	105
TQUAL4	Time Quality Bit, add 4 when asserted	105
TQUAL8	Time Quality Bit, add 8 when asserted	105
TR1	Trip SELOGIC control equation TR1 (Also has been referred to as TRIPEQ1)	34

Table J.2 Relay Word Bit Definitions for the SEL-787 (Sheet 10 of 10)

Bit	Definition	Row
TR2	Trip SELOGIC control equation TR2 (Also has been referred to as TRIPEQ2)	34
TREA1	Trigger Reason Bit 1 for synchrophasors	33
TREA2	Trigger Reason Bit 2 for synchrophasors	33
TREA3	Trigger Reason Bit 3 for synchrophasors	33
TREA4	Trigger Reason Bit 4 for synchrophasors	33
TRGTR	Target Reset. Asserts for one quarter-cycle when you execute a front-panel, serial port target reset command, or Modbus target reset.	28
TRIP	Trip Logic Output	19
TRIP1	Trip1 Logic Output	34
TRIP2	Trip2 Logic Output	34
TRIPXFMR	TripXFMR Logic Output	34
TRXFMR	Trip SELOGIC control equation TRXFMR (Also has been referred to as TRXFMREQ)	34
TSNTPB	SNTP Secondary Server is active	106
TSNTPP	SNTP Primary Server is active	106
TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements	25
TUTC1	Offset hours from UTC time, binary, add 1 if asserted	106
TUTC2	Offset hours from UTC time, binary, add 2 if asserted	106
TUTC4	Offset hours from UTC time, binary, add 4 if asserted	106
TUTC8	Offset hours from UTC time, binary, add 8 if asserted	106
TUTCH	Offset half-hour from UTC time, binary, add 0.5 if asserted	106
TUTCS	Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted; otherwise, add	106
ULCL1	Unlatch close conditions SELOGIC control equation CL1 state	35
ULCL2	Unlatch close conditions SELOGIC control equation CL2 state	35
ULTRIP1	Unlatch (auto reset) trip from SELOGIC control equation TR1	35
ULTRIP2	Unlatch (auto reset) trip from SELOGIC control equation TR2	35
ULTRXFMR	Unlatch (auto reset) trip from SELOGIC control equation TRXFMR	35
VB*nnn*	Virtual Bits used for Incoming GOOSE messages (*nnn* = 1 through 128)	75-90
WARNING	Warning bit asserts for possible warning conditions, as shown in *Table 8.3*. These conditions also trigger a flashing TRIP LED.	25

[a] Reserved.
[b] Harmonic restraint enabled.

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Appendix K
Analog Quantities

The SEL-787 Transformer Protection Relay contains several analog quantities that can be used for more than one function.

The actual analog quantities available depend on the part number of the relay used. Analog quantities are typically generated and used by a primary function, such as, metering and selected quantities are made available for one or more supplemental functions, for example, the load profile.

Note that all analog quantities available for use in SELOGIC are processed every 100 ms and may not be suitable for fast-response control and protection applications. Analog Quantities for RMS data are determined using data that is averaged over the previous 8 cycles.

Table K.1 lists analog quantities that can be used in the following specific functions:

- SELOGIC control equations (see *Section 4: Protection and Logic Functions*)
- Display points (see *Section 8: Front-Panel Operations*)
- Load profile recorder (see *Section 5: Metering and Monitoring*)
- DNP (see *Appendix D: DNP3 Communications*)
- Fast Meter (see *Appendix C: SEL Communications Processors*)

For a list of analog quantities available for Modbus communications, see *Appendix E: Modbus Communications*.

Table K.1 Analog Quantities (Sheet 1 of 6)

Label	Description	Units	Display Points	SELOGIC	Load Profile	DNP	Fast Meter
Fundamental Instantaneous Metering							
IAW1_MAG	Winding 1 current, A-phase, magnitude	A primary	x	x	x	x	x
IAW1_ANG	Winding 1 current, A-phase, angle	degrees	x	x	x	x	
IBW1_MAG	Winding 1 current, B-phase, magnitude	A primary	x	x	x	x	x
IBW1_ANG	Winding 1 current, B-phase, angle	degrees	x	x	x	x	
ICW1_MAG	Winding 1 current, C-phase, magnitude	A primary	x	x	x	x	x
ICW1_ANG	Winding 1 current, C-phase, angle	degrees	x	x	x	x	
IAVW1MAG	Winding 1 average current, magnitude	A primary	x	x	x	x	
IGW1_MAG	Winding 1 current, calculated-residual, magnitude	A primary	x	x	x	x	
IGW1_ANG	Winding 1 current, calculated-residual, angle	degrees	x	x	x	x	
3I2W1MAG	Winding 1 current, negative-sequence, magnitude	A primary	x	x	x	x	
IAW2_MAG	Winding 2 current, A-phase, magnitude	A primary	x	x	x	x	x

Table K.1 Analog Quantities (Sheet 2 of 6)

Label	Description	Units	Display Points	SELogic	Load Profile	DNP	Fast Meter
IAW2_ANG	Winding 2 current, A-phase, angle	degrees	x	x	x	x	
IBW2_MAG	Winding 2 current, B-phase, magnitude	A primary	x	x	x	x	x
IBW2_ANG	Winding 2 current, B-phase, angle	degrees	x	x	x	x	
ICW2_MAG	Winding 2 current, C-phase, magnitude	A primary	x	x	x	x	x
ICW2_ANG	Winding 2 current, C-phase, angle	degrees	x	x	x	x	
IAVW2MAG	Winding 2 average current, magnitude	A primary	x	x	x	x	
IGW2_MAG	Winding 2 current, calculated-residual, magnitude	A primary	x	x	x	x	
IGW2_ANG	Winding 2 current, calculated-residual, angle	degrees	x	x	x	x	
3I2W2MAG	Winding 2 current, negative-sequence, magnitude	A primary	x	x	x	x	
IN_MAG	Current, neutral, magnitude	A primary	x	x	x	x	x
IN_ANG	Current, neutral, angle	degrees	x	x	x	x	
VA_MAG	Voltage, A-phase-to-neutral, magnitude	V primary	x	x	x	x	x
VA_ANG	Voltage, A-phase-to-neutral, angle	degrees	x	x	x	x	
VB_MAG	Voltage, B-phase-to-neutral, magnitude	V primary	x	x	x	x	x
VB_ANG	Voltage, B-phase-to-neutral, angle	degrees	x	x	x	x	
VC_MAG	Voltage, C-phase-to-neutral, magnitude	V primary	x	x	x	x	x
VC_ANG	Voltage, C-phase-to-neutral, angle	degrees	x	x	x	x	
VAB_MAG	Voltage, A-to-B-phase, magnitude	V primary	x	x	x	x	x
VAB_ANG	Voltage, A-to-B-phase, angle	degrees	x	x	x	x	
VBC_MAG	Voltage, B-to-C-phase, magnitude	V primary	x	x	x	x	x
VBC_ANG	Voltage, B-to-C-phase, angle	degrees	x	x	x	x	
VCA_MAG	Voltage, C-to-A-phase, magnitude	V primary	x	x	x	x	x
VCA_ANG	Voltage, C-to-A-phase, angle	degrees	x	x	x	x	
VG_MAG	Zero Sequence Voltage, magnitude	V primary	x	x	x	x	x
VG_ANG	Zero Sequence Voltage, angle	degrees	x	x	x	x	
VAVE_MAG	Average voltage, magnitude	V primary	x	x	x	x	
3V2_MAG	Voltage, negative-sequence, magnitude	V primary	x	x	x	x	
P	Real power magnitude, three-phase	kW primary	x	x	x	x	
		W primary					x
Q	Reactive power magnitude, three-phase	kVAR primary	x	x	x	x	
		VAR primary					x
S	Apparent power magnitude, three-phase	kVA primary	x	x	x	x	
		VA primary					x
PF	Power factor, magnitude three-phase	unitless	x	x	x	x	x
FREQ	Frequency	Hz	x	x	x	x	x
VHZ	V/Hz	%	x	x	x	x	x

Table K.1 Analog Quantities (Sheet 3 of 6)

Label	Description	Units	Display Points	SELogic	Load Profile	DNP	Fast Meter
Thermal Metering							
NOTE: Use caution when assigning RTD analog quantities to SELogic control equations or math variables because the conditions RTD open, short, comm fail, stat fail, fail, and NA will be reported as +32767, –32768, +32764, +32760, +32766, and +32752, respectively.							
RTDAMB[a]	Ambient RTD temperature	°C	x	x	x	x	
RTDOTHMX[a]	Other maximum RTD temperature	°C	x	x	x	x	
RTD1 to RTD12	RTD1 to RTD12 temperature[b]	°C	x	x	x	x	
Analog Input Metering							
AI301 to AI304	Analog inputs for an analog input card in Slot C[c]	EU	x	x	x	x	
AI401 to AI404	Analog inputs for an analog input card in Slot D[b]	EU	x	x	x	x	
AI501 to AI504	Analog inputs for an analog input card in Slot E[b]	EU	x	x	x	x	
Energy Metering							
EM_LRDH	Energy Last Reset Date/Time High Word					x	
EM_LRDM	Energy Last Reset Date/Time Middle Word					x	
EM_LRDL	Energy Last Reset Date/Time Low Word					x	
MWHP	Real energy, three-phase positive	MWh primary	x	x		x	
MWHN	Real energy, three-phase negative	MWh primary	x	x		x	
MVARHP	Reactive energy, three-phase positive	MVARh primary	x	x		x	
MVARHN	Reactive energy, three-phase negative	MVARh primary	x	x		x	
Maximum/minimum Metering							
MM_LRDH	Max/Min Last Reset Date/Time High Word					x	
MM_LRDM	Max/Min Last Reset Date/Time Middle Word					x	
MM_LRDL	Max/Min Last Reset Date/Time Low Word					x	
IAW1MX	Winding 1 Current, A-phase, maximum magnitude	A primary	x	x		x	
IBW1MX	Winding 1 Current, B-phase, maximum magnitude	A primary	x	x		x	
ICW1MX	Winding 1 Current, C-phase, maximum magnitude	A primary	x	x		x	
IGW1MX	Winding 1 Current, residual, maximum magnitude	A primary	x	x		x	
IAW2MX	Winding 2 Current, A-phase, maximum magnitude	A primary	x	x		x	
IBW2MX	Winding 2 Current, B-phase, maximum magnitude	A primary	x	x		x	
ICW2MX	Winding 2 Current, C-phase, maximum magnitude	A primary	x	x		x	
IGW2MX	Winding 2 Current, residual, maximum magnitude	A primary	x	x		x	
INMX	Current, neutral, maximum magnitude	A primary	x	x		x	
IAW1MN	Winding 1 Current, A-phase, minimum magnitude	A primary	x	x		x	
IBW1MN	Winding 1 Current, B-phase, minimum magnitude	A primary	x	x		x	
ICW1MN	Winding 1 Current, C-phase, minimum magnitude	A primary	x	x		x	
IGW1MN	Winding 1 Current, residual, minimum magnitude	A primary	x	x		x	
IAW2MN	Winding 2 Current, A-phase, minimum magnitude	A primary	x	x		x	

Table K.1 Analog Quantities (Sheet 4 of 6)

Label	Description	Units	Display Points	SELogic	Load Profile	DNP	Fast Meter
IBW2MN	Winding 2 Current, B-phase, minimum magnitude	A primary	x	x		x	
ICW2MN	Winding 2 Current, C-phase, minimum magnitude	A primary	x	x		x	
IGW2MN	Winding 2 Current, residual, minimum magnitude	A primary	x	x		x	
INMN	Current, neutral, minimum magnitude	A primary	x	x		x	
VABMX	Voltage, A-to-B-phase, maximum magnitude	V primary	x	x		x	
VBCMX	Voltage, B-to-C-phase, maximum magnitude	V primary	x	x		x	
VCAMX	Voltage, C-to-A-phase, maximum magnitude	V primary	x	x		x	
VAMX	Voltage, A-phase-to-neutral, maximum magnitude	V primary	x	x		x	
VBMX	Voltage, B-phase-to-neutral, maximum magnitude	V primary	x	x		x	
VCMX	Voltage, C-phase-to-neutral, maximum magnitude	V primary	x	x		x	
VABMN	Voltage, A-to-B-phase, minimum magnitude	V primary	x	x		x	
VBCMN	Voltage, B-to-C-phase, minimum magnitude	V primary	x	x		x	
VCAMN	Voltage, C-to-A-phase, minimum magnitude	V primary	x	x		x	
VAMN	Voltage, A-phase-to-neutral, minimum magnitude	V primary	x	x		x	
VBMN	Voltage, B-phase-to-neutral, minimum magnitude	V primary	x	x		x	
VCMN	Voltage, C-phase-to-neutral, minimum magnitude	V primary	x	x		x	
KVA3PMX	Apparent power magnitude, three-phase, maximum	kVA primary	x	x		x	
KW3PMX	Real power magnitude, three-phase, maximum	kW primary	x	x		x	
KVAR3PMX	Reactive power magnitude, three-phase, maximum	kVAR primary	x	x		x	
KVA3PMN	Apparent power magnitude, three-phase, minimum	kVA primary	x	x		x	
KW3PMN	Real power magnitude, three-phase, minimum	kW primary	x	x		x	
KVAR3PMN	Reactive power magnitude, three-phase, minimum	kVAR primary	x	x		x	
FREQMX	Maximum frequency	Hz	x	x		x	
FREQMN	Minimum frequency	Hz	x	x		x	
RTD1MX to RTD12MX	RTD1 maximum to RTD12 maximum	°C	x	x		x	
RTD1MN to RTD12MN	RTD1 minimum to RTD12 minimum	°C	x	x		x	
AI301MX to AI304MX	Analog transducer input 301–304 maximum[b]	EU	x	x		x	
AI301MN to AI304MN	Analog transducer input 301–304 minimum[b]	EU	x	x		x	
AI401MX to AI404MX	Analog transducer input 401–404 maximum[b]	EU	x	x		x	
AI401MN to AI404MN	Analog transducer input 401–404 minimum[b]	EU	x	x		x	
AI501MX to AI504MX	Analog transducer input 501–504 maximum[b]	EU	x	x		x	
AI501MN to AI504MN	Analog transducer input 501–504 minimum[b]	EU	x	x		x	

Table K.1 Analog Quantities (Sheet 5 of 6)

Label	Description	Units	Display Points	SELogic	Load Profile	DNP	Fast Meter
RMS Metering							
IAW1RMS	Winding 1 rms current, A-phase, magnitude	A primary	x	x	x	x	
IBW1RMS	Winding 1 rms current, B-phase, magnitude	A primary	x	x	x	x	
ICW1RMS	Winding 1 rms current, C-phase, magnitude	A primary	x	x	x	x	
IAW2RMS	Winding 2 rms current, A-phase, magnitude	A primary	x	x	x	x	
IBW2RMS	Winding 2 rms current, B-phase, magnitude	A primary	x	x	x	x	
ICW2RMS	Winding 2 rms current, C-phase, magnitude	A primary	x	x	x	x	
INRMS	Neutral rms current, magnitude	A primary	x	x	x	x	
VARMS	RMS Voltage, A-phase-to-neutral, magnitude	V primary	x	x	x	x	
VBRMS	RMS Voltage, B-phase-to-neutral, magnitude	V primary	x	x	x	x	
VCRMS	RMS Voltage, C-phase-to-neutral, magnitude	V primary	x	x	x	x	
VABRMS	RMS Voltage, A-to-B-phase, magnitude	V primary	x	x	x	x	
VBCRMS	RMS Voltage, B-to-C-phase, magnitude	V primary	x	x	x	x	
VCARMS	RMS Voltage, C-to-A-phase, magnitude	V primary	x	x	x	x	
Demand Metering							
IAD	Phase A Current Demand	A primary	x	x		x	x
IBD	Phase B Current Demand	A primary	x	x		x	x
ICD	Phase C Current Demand	A primary	x	x		x	x
IGD	Residual Current Demand	A primary	x	x		x	x
3I2D	Negative-Sequence Current Demand	A primary	x	x		x	x
Peak Demand Metering							
PM_LRDH	Peak Demand Last Reset Date/Time High Word					x	
PM_LRDM	Peak Demand Last Reset Date/Time Middle Word					x	
PM_LRDL	Peak Demand Last Reset Date/Time Low Word					x	
IAPD	Phase A Current Peak Demand	A primary	x	x		x	x
IBPD	Phase B Current Peak Demand	A primary	x	x		x	x
ICPD	Phase C Current Peak Demand	A primary	x	x		x	x
IGPD	Residual Current Peak Demand	A primary	x	x		x	x
3I2PD	Negative-Sequence Current Peak Demand	A primary	x	x		x	x
Date/Time							
DATE	Present date[d]		x			x	
TIME	Present time[c]		x			x	
YEAR	Year number (0000–9999)			x			
DAYY	Day of Year number (1–366)			x			
WEEK	Week number (1–52)			x			
DAYW	Day of Week number (1–7)			x			
MINSM	Minutes since Midnight			x			
RID/TID							
RID	Relay Identifier		x				
TID	Terminal Identifier		x				

Table K.1 Analog Quantities (Sheet 6 of 6)

Label	Description	Units	Display Points	SELogic	Load Profile	DNP	Fast Meter
Setting Group							
GROUP	Active Setting Group #		x	x		x	
Math Variables							
MV01 to MV32	Math Variable 01 to Math Variable 32		x	x	x	x	
SELogic Counters[e]							
SC01 to SC32	SELogic Counter 01 to SELogic Counter 32		x	x	x	x	

[a] SEL Fast Message Label names for RTDAMB and RTDOTHMX are AMB and OTH, respectively.
[b] RTD open is equivalent to +32767 and RTD short is equivalent to –32768 when RTDs are monitored via LDP.
[c] See the Engineering Unit settings (e.g., AI301EU) of the respective analog input.
[d] Also available via DNP object 50.
[e] Also available as DNP counter object.

Appendix L
Protection Application Examples

Overview

This section provides instructions for setting the SEL-787 Relay protection functions. Use these application examples to help familiarize yourself with the relay and assist you with your own protection settings calculations. This section is not intended to provide a complete settings guide for the relay.

Transformer Winding and CT Connection Compensation Settings Examples

In electromechanical and solid-state transformer differential relays, the standard current transformer (CT) configuration was wye connected on the delta winding of the transformer and delta connected on the wye winding of the transformer. The CT delta connection was constructed based on the power transformer delta to compensate for the phase shift that occurred on the system primary currents because of the power transformer connection. The CT configuration allowed the currents entering the relay for through-load or external faults to be 180 degrees out-of-phase so that the phasor sum of the currents added to zero (no differential current) in an electromechanical differential relay. Taps on the relay current inputs compensated for magnitude differences. Modern digital relays perform both the connection (or phase) and magnitude compensation mathematically so all CTs can be connected in wye.

NOTE: In this settings guideline, the term "phase rotation" is synonymous with "phase sequence." This settings guideline uses "phase rotation" to be consistent with the relay Global setting, PHROT.

This section provides a procedure for SEL-787 Relays to determine and set the Terminal *n* CT connection compensation settings, W*n*CTC (where *n* = 1 or 2), to compensate for the phase shift across the transformer. Each of the connection compensation settings offer thirteen 3x3 matrices, CTC(0)–CTC(12), permitting CT connection compensation from 0 degrees to 360 degrees, in increments of 30 degrees, respectively. Refer to *Section 4: Protection and Logic Functions* (*Table 4.5*) for each of the compensation matrices. When applied on a system with an ABC phase rotation, these matrices perform phase angle correction in a counterclockwise (CCW) direction in multiples of 30 degrees, as shown in *Table L.1*. For a system with an ACB phase rotation, the direction of correction is clockwise (CW). See *Special Cases* for a compensation settings example on a system with an ACB phase rotation.

Table L.1 WnCTC Setting: Corresponding Phase and Direction of Correction

WnCTC Setting[a]	Matrix	Amount and Direction of Correction	
		ABC Phase Rotation	ACB Phase Rotation
0	CTC(0)	0°	0°
1	CTC(1)	30° CCW	30° CW
2	CTC(2)	60° CCW	60° CW
3	CTC(3)	90° CCW	90° CW
4	CTC(4)	120° CCW	120° CW
5	CTC(5)	150° CCW	150° CW
6	CTC(6)	180° CCW	180° CW
7	CTC(7)	210° CCW	210° CW
8	CTC(8)	240° CCW	240° CW
9	CTC(9)	270° CCW	270° CW
10	CTC(10)	300° CCW	300° CW
11	CTC(11)	330° CCW	330° CW
12	CTC(12)	0° (360°) CCW	0° (360°) CW

[a] n = 1 or 2.

As shown in *Section 4: Protection and Logic Functions* (*Table 4.5*), compensation matrix CTC(0) multiplies the currents by the identity matrix and creates no change in the currents. Compensation matrix CTC(12) is similar to CTC(0) in that it produces no phase shift (or, more correctly, 360 degrees of shift) in a balanced set of phasors separated by 120 degrees. However, CTC(12) removes zero-sequence components from the measured current, as do all of the matrices with non-zero values.

Transformer Nameplates and System Connections

To determine the phase shift seen by the relay, the following information is required:

- Transformer phasor (vector) diagram (transformer nameplate)
- Three-line connection diagram showing:
  - System phase-to-transformer bushing connections
  - CT connections
  - CT-to-relay connections

Figure L.1 shows the key information from a typical nameplate for a two-winding transformer. The winding connection diagram and the phasor (vector) diagram are needed to determine the winding compensation settings in the relay.

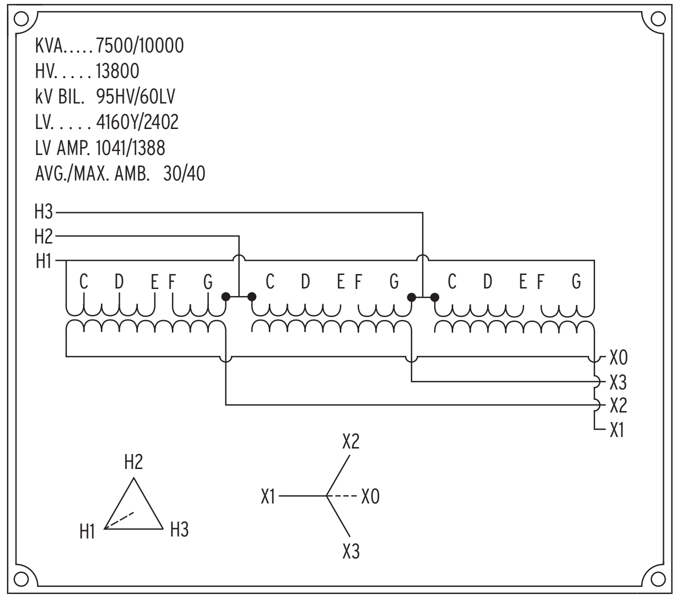

Figure L.1 Transformer Nameplate

Note that there is no phase designation nor any phase rotation designation on the nameplate. However, the phasor diagram is representative of an H1-H2-H3 sequence. The phase shift on the power system depends on the transformer winding connections, the system phase-to-transformer bushing connections, and the system phase rotation.

Figure L.2 shows a three line connection diagram with the transformer shown in *Figure L.1* with what this guideline refers to as standard connections. Standard phase-to-bushing connections are A-phase to H1, B-phase to H2, C-phase to H3, a-phase to X1, b-phase to X2, and c-phase to X3. Standard CT connections include wye-connected CTs with polarity marks of both CTs away from or towards the transformer. *Figure L.2* shows both H-side and X-side CTs connected in wye and the polarity marks away from the transformer. A CT-to-relay connection is considered to be standard when the polarity of the CT is connected to the polarity of the relay analog current input and the primary system phase current is connected to the same phase input on the relay (e.g., IA system to IAW1). Unless otherwise noted, an ABC phase rotation is assumed for the following discussion.

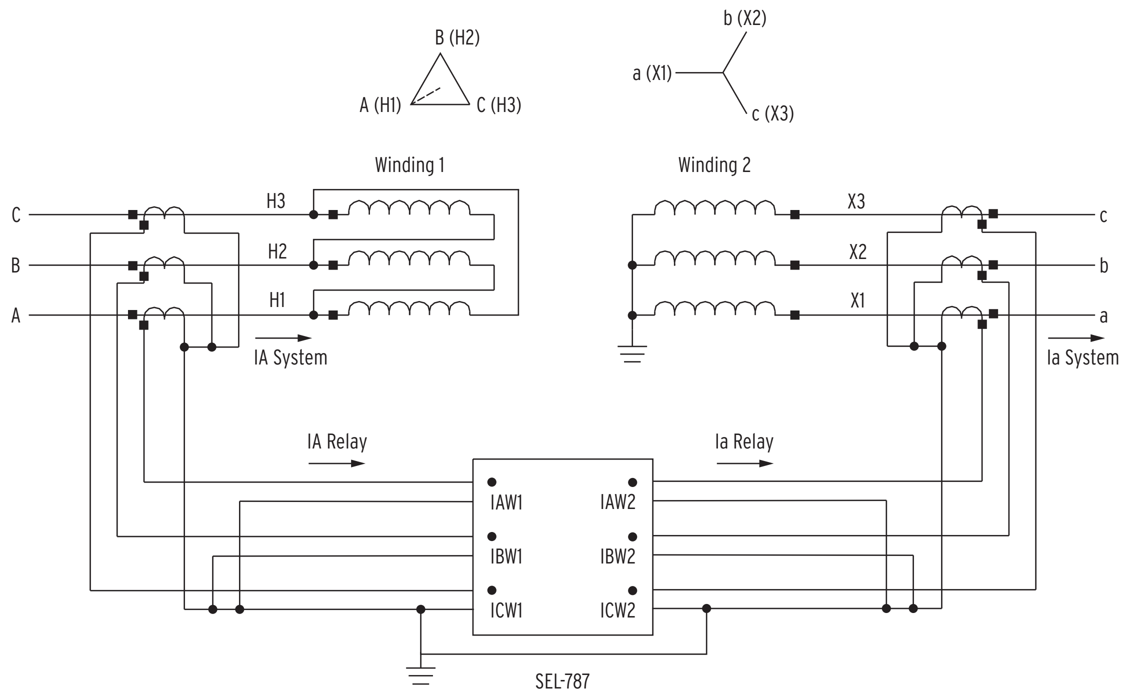

Figure L.2 Three-Line Diagram Showing System Phase-to-Transformer Bushing, CT, and CT-to-Relay Connections

If all the connections are standard as shown in *Figure L.2*, under a through-load condition the phase relationship between the system primary currents (Ia system and IA system) and corresponding secondary currents as seen by the relay (IAW2 and IAW1) will look like as shown in *Figure L.3* (Ia lags IA by 30 degrees) and *Figure L.4* (IAW2 lags IAW1 by 210 degrees), respectively. The goal of the compensation settings is to compensate IAW2 so as to bring IAW2_compensated 180 degrees out-of-phase with IAW1 for proper application of the differential function.

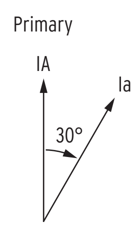

Figure L.3 Primary Current Phasors

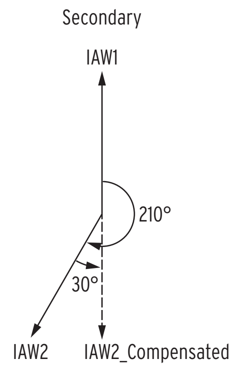

Figure L.4 Current at the Relay Terminals

Many applications do not conform to the standard connections, but compensation settings are adaptable to fit any application. The subsequent sections outline the procedure to determine the phase shift and current transformer compensation settings, and also discuss what to do with non-standard phase-to-bushing, CT, and CT-to-relay connections.

Steps to Determine the Compensation Settings (WnCTC)

Use the following guidelines to determine compensation settings for your application(s).

Step 1. Determine the phase shift as seen by the relay.
  a. Determine the phase shift in the primary load current.
  b. Determine if there are non-standard CT connections.

Step 2. Select the reference winding and associated relay terminal.
  a. If a delta winding exists and is wired into the relay, choose it as the reference winding. Select matrix CTC(0) for the compensation of the delta winding. If a zig zag grounding transformer exists on the delta side of the transformer and is within the zone of protection, then select matrix CTC(12).
  b. If a delta winding does not exist, select one of the wye windings as the reference and choose matrix CTC(11) for the compensation.

Step 3. Determine the required compensation setting for all other windings. Select matrix CTC(0) for delta windings. Use odd matrices for compensating wye-windings. Avoid the use of even matrices when possible.

There may be applications that require the guidelines to be violated, but they should be followed when possible.

The rest of this section discusses each of the guidelines in detail. Examples and special cases are provided to illustrate the application of the guidelines in determining the compensation settings.

Step 1. Determine the Phase Shift as Seen by the Relay

Determine the Phase Shift in the Primary Load Current

The first step in selecting the compensation setting in the relay is to determine the phase shift in the primary load current.

Standard System Phase-to-Transformer Bushing Connections.

NOTE: Unless otherwise stated, this discussion assumes an ABC system phase rotation.

Consider the transformer in *Figure L.1* and the phase-to-bushing connections in *Figure L.2*. Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic, as shown in *Figure L.5*. The currents on the H-side (delta-winding) of the transformer are Ia/N, Ib/N, and Ic/N where N is the turns ratio of the transformer. Because the discussion focuses on the phase shift and not the magnitude, you can assume N = 1 for this discussion.

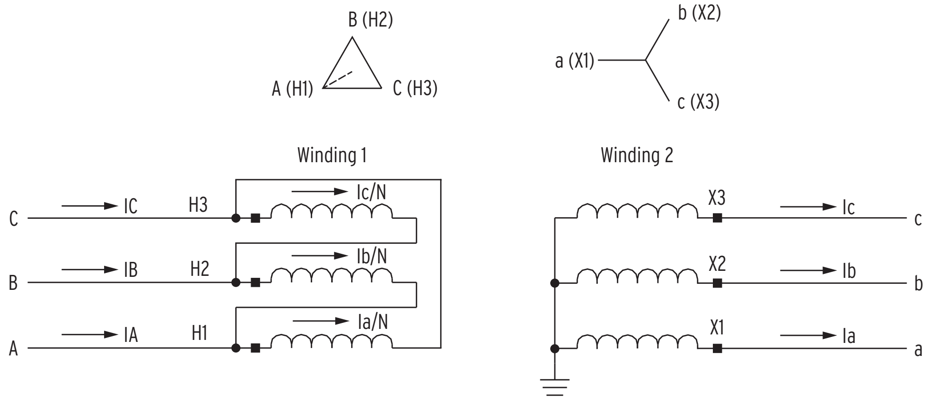

Figure L.5 Standard System Phase-to-Transformer Bushing Connections

Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

IA = Ia – Ib

IB = Ib – Ic

IC = Ic – Ia

The following examples start with the currents on the wye-side of the transformer to graphically derive the currents on the delta side of the transformer. *Figure L.6* shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees.

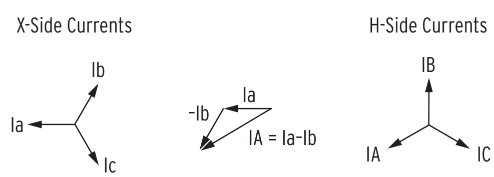

Figure L.6 X- and H-Side Current Phasors for Figure L.5

The primary load phase shift determined in *Figure L.6* applies for the phase-to-bushing connections shown in *Table L.2*. In each of these phase-to-bushing connections, the order of the phases (A, B, C) matches the order of the bushings (H1, H2, H3).

Table L.2 (A, B, C) to (H1, H2, H3) Phase-to-Bushing Connections

	Bushing					
	H1	H2	H3	X1	X2	X3
System Phase	A	B	C	a	b	c
	B	C	A	b	c	a
	C	A	B	c	a	b

Non-Standard Phase-to-Bushing Connections. Consider the transformer connections in *Figure L.7*. This is the same transformer discussed in *Figure L.5*, but with different phase-to-bushing connections: A-phase to H3, B-phase to H2, C-phase to H1, a-phase to X3, b-phase to X2, and c-phase to X1.

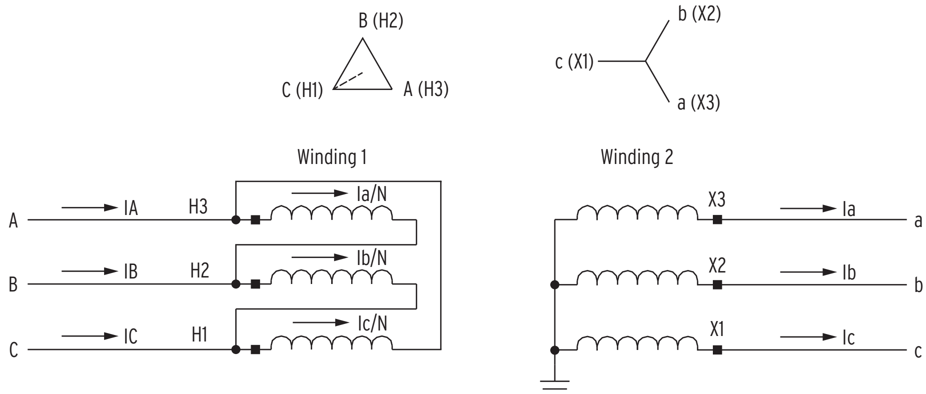

Figure L.7 Non-Standard System Phase-to-Transformer Bushing Connections

Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic. Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

IA = Ia – Ic

IB = Ib – Ia

IC = Ic – Ib

Figure L.8 shows that system primary current Ia (X-side) leads the system primary current IA (H-side) by 30 degrees.

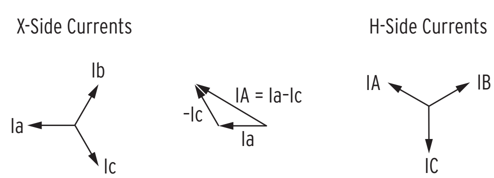

Figure L.8 X- and H-Side Current Phasors for Figure L.7

The primary load phase shift determined in *Figure L.8* applies for the phase-to-bushing connections shown in *Table L.3*. In each of these phase-to-bushing connections, the order of the phase connections (A, C, B) is opposite the order of the bushings (H1, H2, H3).

Table L.3 (A, C, B) to (H1, H2, H3) Phase-to-Bushing Connections

	Bushing					
	H1	H2	H3	X1	X2	X3
System Phase	C	B	A	c	b	a
	B	A	C	b	a	c
	A	C	B	a	c	b

The system phase-to-transformer bushing connection diagrams in *Figure L.5* and *Figure L.7* are on the same transformer, but with a different order of the phases connected to the transformer bushings. As a result, the X-side primary current shifts 30 degrees in opposite directions in the two systems.

Combination of Standard and Non-Standard Phase-to-Bushing Connections. Consider the transformer connections shown in *Figure L.9*. The transformer is the same as in previous examples. However, in this example, the H-side phase-to-bushing connections are standard: A-phase to H1, B-phase to H2, and C-phase to H3. The X-side connections are non-standard: a-phase to X2, b-phase to X3, and c-phase to X1.

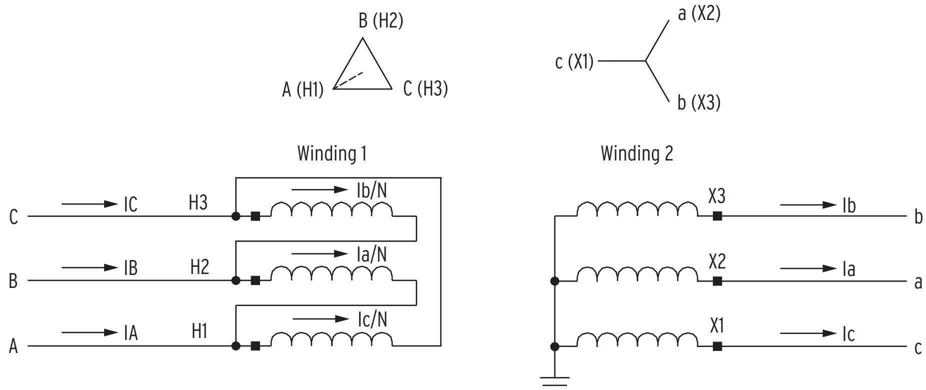

Figure L.9 Combination of Standard and Non-Standard Phase-to-Bushing Connection Diagram

Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic. Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

IA = Ic – Ia

IB = Ia – Ib

IC = Ib – Ic

Figure L.10 shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 150 degrees.

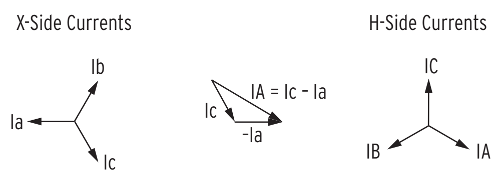

Figure L.10 X- and H-Side Current Phasors for Figure L.9

These three examples show that the same transformer winding connections can produce different phase shifts in the system primary load current based on the phase-to-bushing connections.

Determine if There Are Non-Standard CT Connections

Figure L.11 shows the transformer of *Figure L.2* with a standard current transformer configuration; that is, both the H-side and X-side CTs are connected in wye and the polarity marks are away from the power transformer.

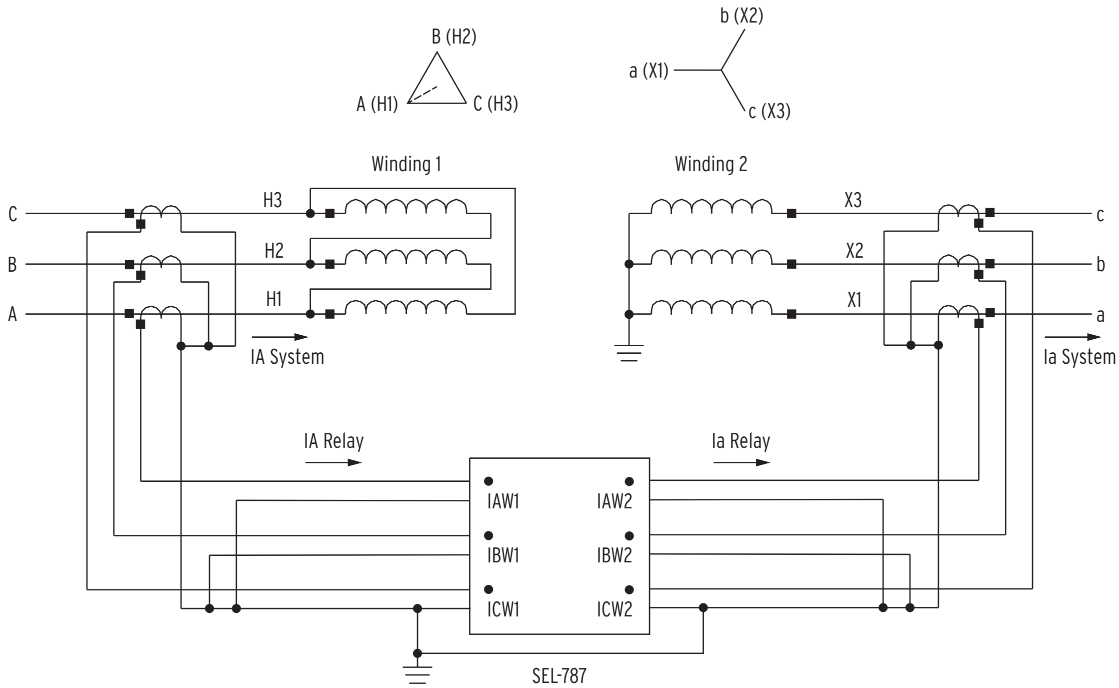

Figure L.11 Standard CT Connections

Standard CT Connections. In *Figure L.11*, the polarity of the CT connects to the polarity of the relay current input, and the primary system phase current connects to the same phase input on the relay (e.g., IA system to IAW1 relay input). While the H-side currents connect to the W1-terminal and the X-side currents connect to W2-terminal, they could be connected to any two sets of current inputs on the relay. *Figure L.11* represents the standard connections for the transformer, CTs, and relay.

Figure L.11 also shows the primary system currents (IA system, Ia system) and the CT secondary currents seen by the relay (IA relay, Ia relay) based on the currents of *Figure L.6*. For these connections, with power flow from the H-side to the X-side of the transformer, currents enter the relay at the polarity mark on the H-side, and leave the relay at the polarity mark on the X-side. Thus, on the primary system, Ia lags IA by 30 degrees, but at the relay, IAW2 leads IAW1 by 150 degrees, as shown in *Figure L.12*. B- and C-phases follow this relationship. Only A-phase is discussed for simplicity, but the concept is the same.

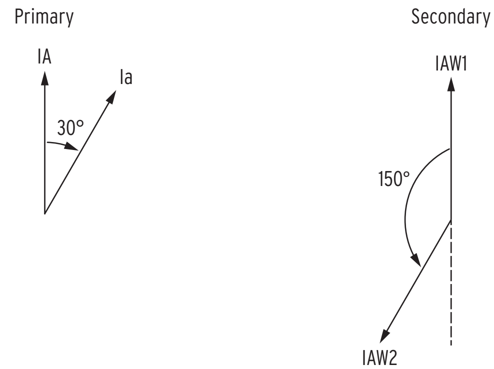

Figure L.12 Primary System Currents and Currents as seen by the Relay

Non-Standard CT Connections: Reversed CT Polarity. *Figure L.13* shows the X-side CT polarity marks toward the transformer. However, because the connections to the relay remain the same, the relay currents flow the same, as in *Figure L.12*. No additional adjustments need to be made because of this type of non-standard CT connection.

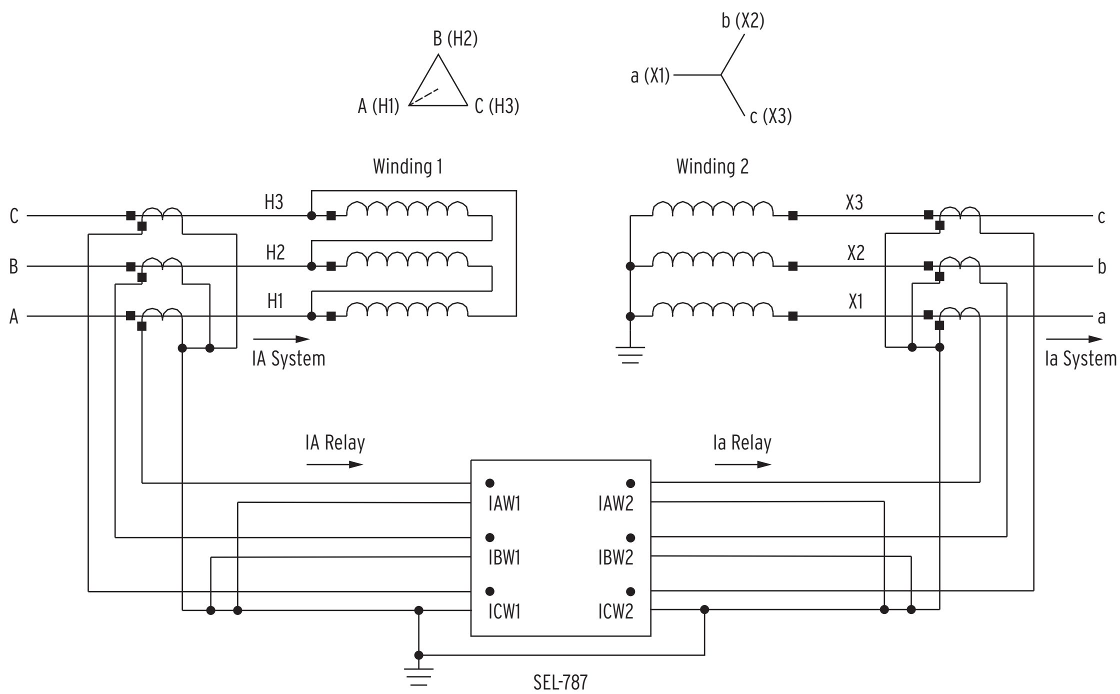

Figure L.13 Current Flow With Reversed X-Side CT Polarity

Non-Standard CT Connections: Reversed CT Polarity and Reversed Connections. In *Figure L.14*, the polarity marks of the X-side CTs are toward the transformer, as in *Figure L.13*, but the neutral sides of the CTs are away from the transformer. With these connections, the H-side and X-side currents are both entering the relay at the relay polarity mark.

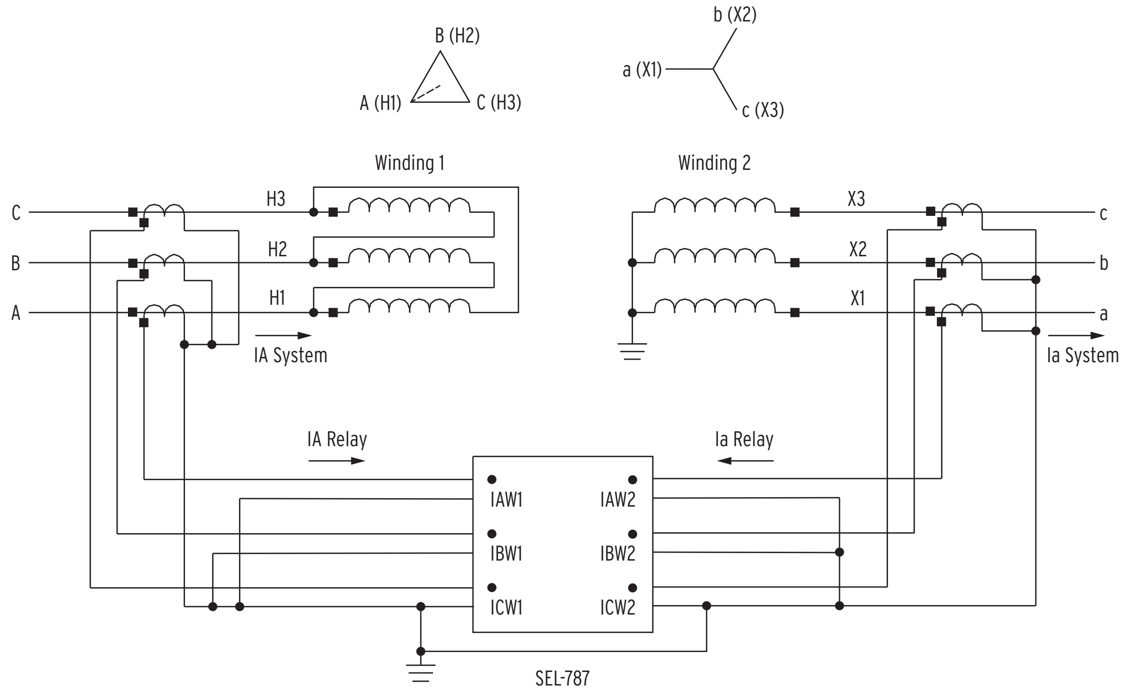

Figure L.14 Current Flow With Reversed X-Side CT Polarity and Reversed Connections

As shown in *Figure L.15*, the resulting IAW2 current measured by the relay is now shifted 180 degrees, as compared to *Figure L.12*.

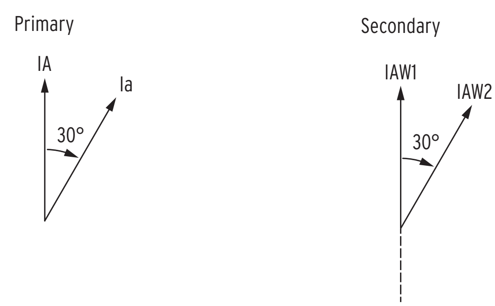

Figure L.15 Results of Reversed X-Side CT Polarity and Reversed Connections

One method to correct this is to reverse the current connections at the relay. Connect the non-polarity terminal of the CT to the polarity terminal of the relay current input and the polarity terminal of the CT to the non-polarity terminal of the relay current input. These changes result in the connections shown in *Figure L.13*.

An alternate method to correct the phase shift is to use the CT compensation setting, W*n*CTC. As shown in *Table L.1*, each CTC setting results in a counter-clockwise phase shift that is a multiple of 30 degrees for an ABC system phase rotation. Selecting a compensation setting of 6 effectively shifts the current by 180 degrees (6 • 30° = 180°). Further explanation for selecting the final settings for non-standard CT connections is provided in *Example L.3*.

Step 2. Select the Reference Winding and Associated Relay Terminal

If there is a delta winding on the power transformer, the delta winding should be selected as the reference winding regardless of whether it is the high- or low-voltage winding. The reference winding can be associated with any analog current measurement terminal on the relay. For example, if the delta winding current is measured by the W1-terminal inputs on the relay, W1CTC is the setting that corresponds to the reference winding.

The compensation for the delta winding should be set to matrix CTC(0) (W*n*CTC = 0) unless there is a grounding bank on the delta winding within the differential zone. Grounding banks are a source of zero-sequence current and this current needs to be filtered to avoid operation of the differential element for external ground faults. If there is a grounding bank within the differential zone, use W*n*CTC = 12. Both W*n*CTC = 0 and W*n*CTC = 12 result in no phase shift, but W*n*CTC = 12 additionally removes zero-sequence current from the differential calculation.

If there is no delta winding, select one of the wye windings as the reference and set the compensation setting to 11 (W*n*CTC = 11) for the reference winding.

Step 3. Determine the Required Compensation Settings for All Other Windings

Use the following guidelines for choosing the remaining CT compensation settings.

1. Compensate delta windings with matrix CTC(0)
2. Compensate wye windings with odd matrices
3. Avoid the use of even matrices

There may be applications that require one or more of the guidelines to be violated, but they should be followed when possible. The following examples illustrate the steps required to determine the compensation setting(s) for the remaining winding(s).

Application Examples

EXAMPLE L.1 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

Consider the system shown in Figure L.16. The primary current phase shift for these connections was determined in Figure L.6. Figure L.17 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay. The system primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 leading IAW1 by 150 degrees.

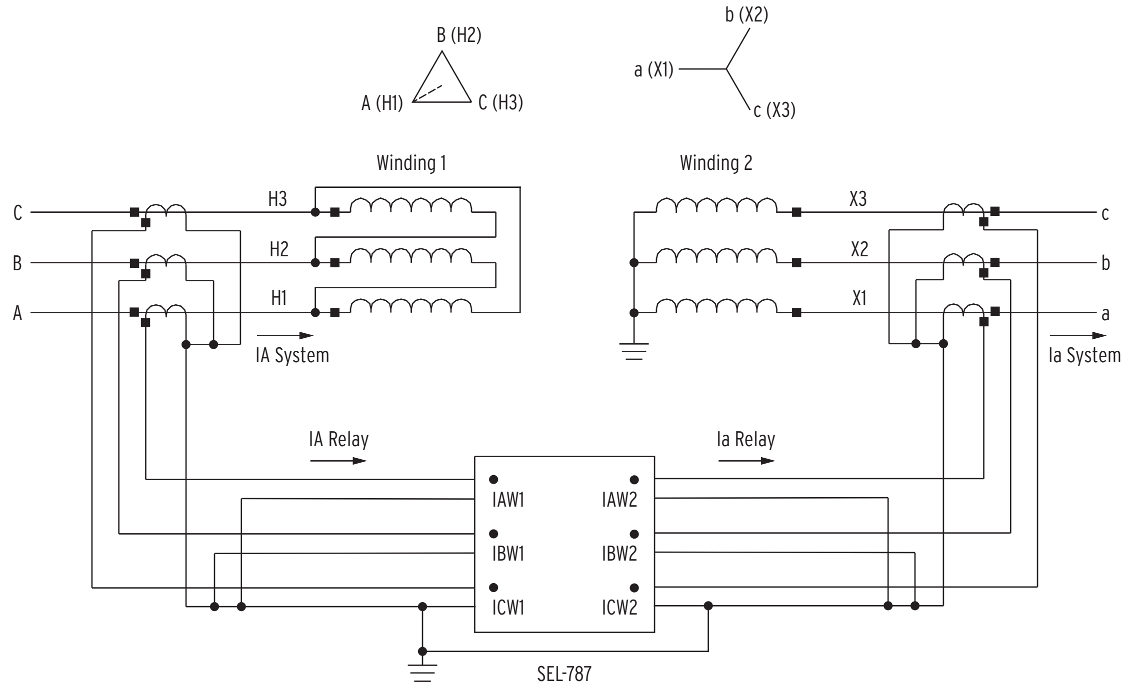

Figure L.16 Delta-Wye Transformer With Standard Phase-to-Bushing Connections

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-787 Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2 of the SEL-787 Relay, so W2CTC must be determined.

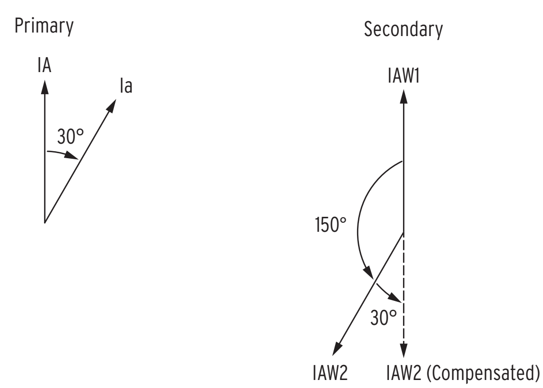

Figure L.17 Primary Currents and Secondary Currents as Measured by the Relay

IAW2 must be rotated 30 degrees (1 multiple of 30 degrees) in the counterclockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 1. The resulting compensation settings for this system are W1CTC = 0 and W2CTC = 1.

EXAMPLE L.2 Delta-Wye Transformer With Non-Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

This example uses the transformer and relay connections of Figure L.18. This is the same transformer as in Example L.1, but with non-standard phase-to-bushing connections. Figure L.19 shows that for this connection, the system current Ia (X-side) leads the system current IA (H-side) by 30 degrees, or lags by 330 degrees. The CT connections are standard, which results in IAW2 lagging IAW1 by

150 degrees. Figure L.19 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

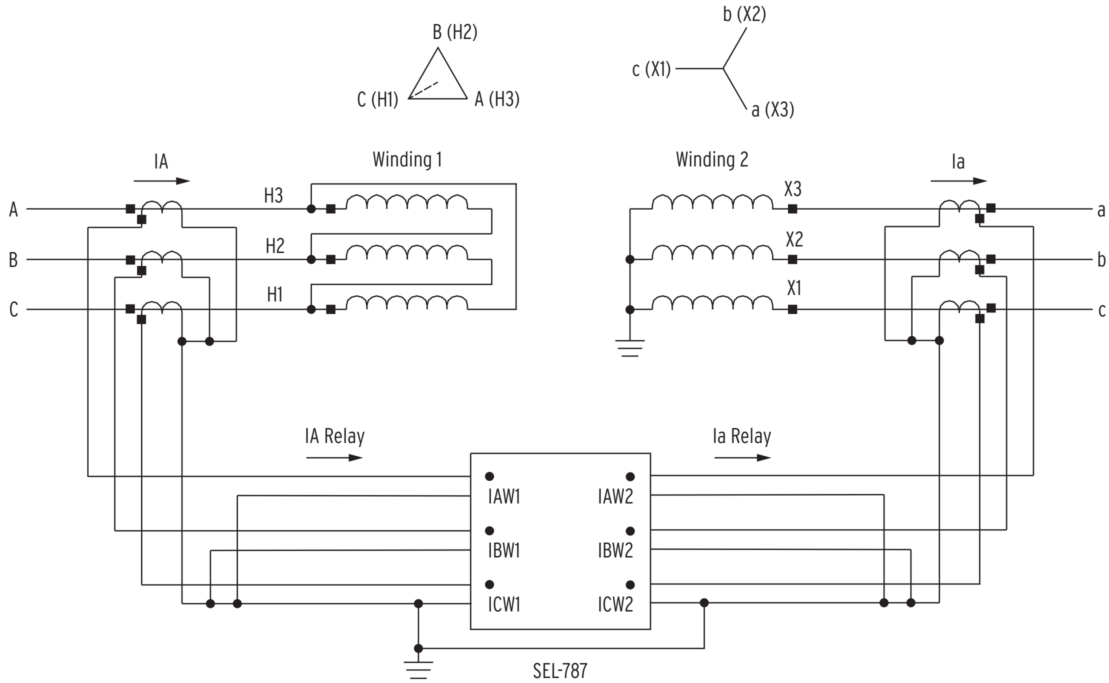

Figure L.18 Delta-Wye Transformer With Non-Standard Phase-to-Bushing Connections

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-787 Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2, so W2CTC must be determined.

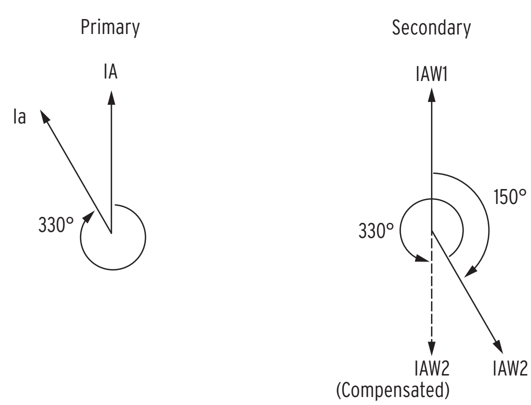

Figure L.19 Primary Currents and Secondary Currents as Measured by the Relay

IAW2 must be rotated 330 degrees (11 multiples of 30 degrees) in the counter-clockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 11. The resulting compensation settings are W1CTC = 0 and W2CTC = 11. Although the same transformer is used in Example L.1 and Example L.2, notice that the non-standard phase-to-bushing connections affect the compensation settings in both examples.

EXAMPLE L.3 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, X-Side Non-Standard CT Connections, and an ABC System Phase Rotation

This example uses standard phase-to-bushing connections as shown in Figure L.20. Notice the X-side CT connections are non-standard. This example differs from the previous examples because the wye winding is now on the high side. The method to solve for the compensation settings is the same.

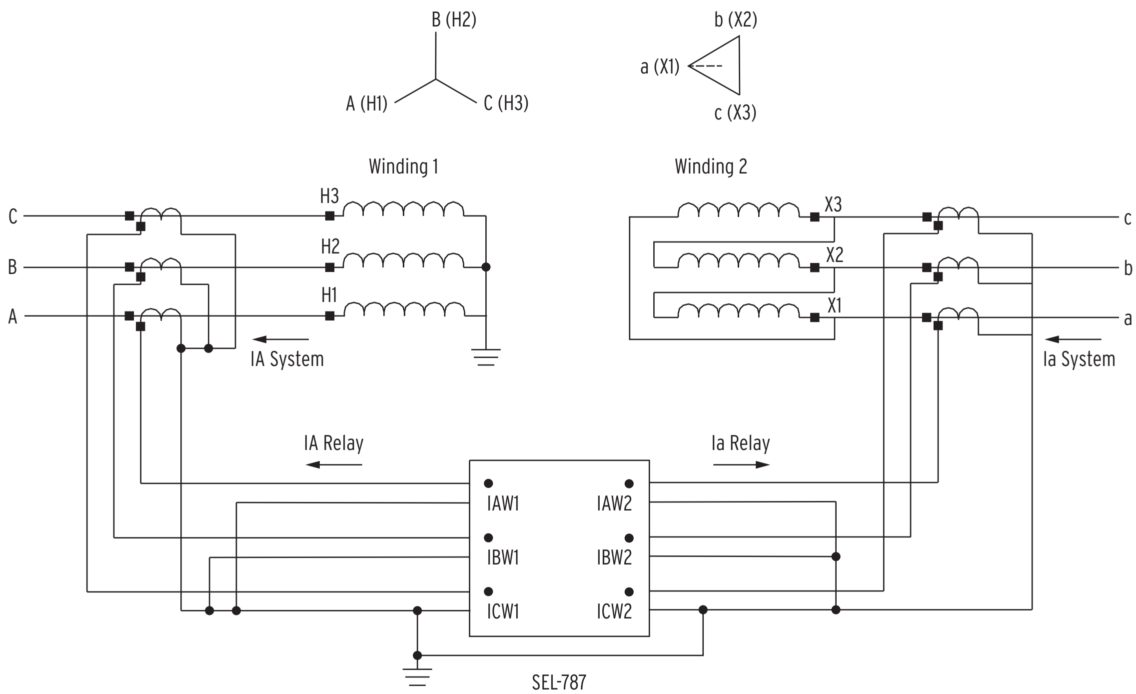

Figure L.20 Wye-Delta Transformer With Non-Standard CT Connections on the X-Side

Assume balanced three-phase currents on the wye side of the transformer. In this example, the wye side is associated with the H-side of the transformer. The phase currents on the X-side are:

Ia = IA – IC
Ib = IB – IA
Ic = IC – IB

In Figure L.21, IA on the wye side of the transformer is chosen as the reference to derive the phasor diagram of the delta-side currents. The system primary current Ia (X-side) lags IA (H-side) by 30 degrees or leads IA by 330 degrees.

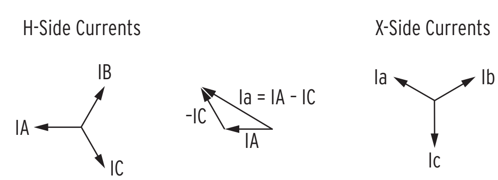

Figure L.21 X- and H-Side Current Phasors for Figure L.20

With the reversed CT polarity on the X-side, the current is leaving Terminal W2 at the polarity mark instead of entering the polarity mark, which makes the current seen by the relay 180 degrees out-of-phase compared to a standard CT connection. In Non-Standard CT Connections: Reversed CT Polarity and Reversed Connections, two methods are proposed to correct the phase shift for reverse polarity CTs. The first method is to rewire the current inputs on the relay so that they match the standard connections. The second method is to use the compensation settings; by adding or subtracting 6 from the setting. This example explores the latter method.

Following the settings guidelines, select the delta side as the reference. The delta side of the transformer is connected to relay Terminal W2, therefore, W2CTC = 0 and is used as the reference. Figure L.22 compares the current phasors if the X-side CT connections use standard connections rather than non-standard connections. On the left side of Figure L.22, standard CT connections and an ABC phase rotation require IAW1 to be rotated by 330 degrees (11 multiples of 30 degrees) counterclockwise in order to be 180 degrees out-of-phase with IAW2. Therefore, if the X-side CTs have standard connections, set W1CTC = 11. The resulting compensation settings with standard CT connections are W2CTC = 0 and W1CTC = 11.

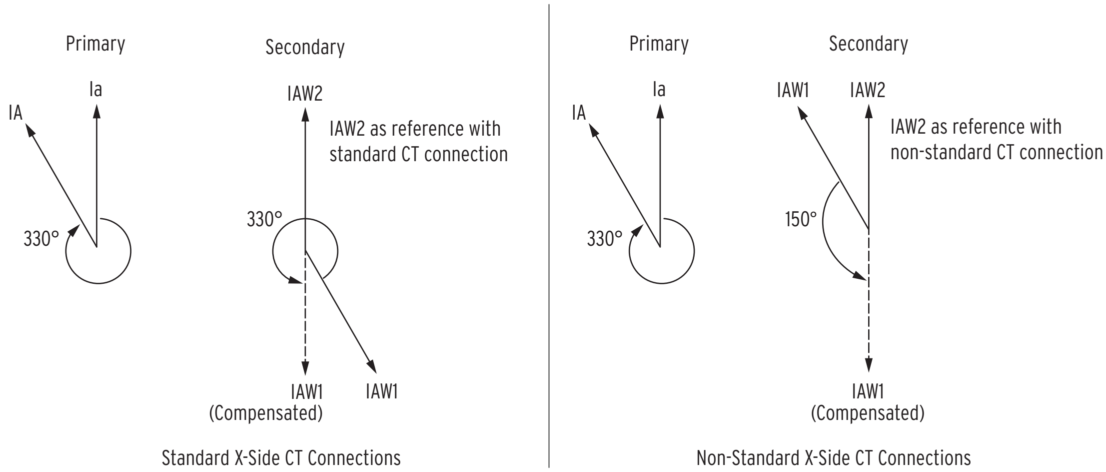

Figure L.22 Comparison of Standard and Non-Standard CT Connections on the X-Side of the Transformer

However, in this example, non-standard CT connections are used on the delta winding, which results in IAW1 leading IAW2 by 30 degrees. IAW1 needs to rotate 150 degrees (5 multiples of 30 degrees) counterclockwise for a system with an ABC phase rotation in order to be 180 degrees out-of-phase with IAW2. Therefore, set W1CTC = 5. The resulting compensation settings with non-standard CT connections on the X-side are W2CTC = 0 and W1CTC = 5.

EXAMPLE L.4 Autotransformer, Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

Consider the autotransformer shown in Figure L.23. The delta tertiary exists, but is buried and not brought out to the relay. The primary current phase shift for these connections is shown in Figure L.24. The system primary current Ia (X-side) is in phase with the system primary current IA (H-side). The CT connections are standard, which results in IAW2 180 degrees out-of-phase with IAW1.

Per the guidelines, since there is no delta winding connected to the relay, choose any one of the wye windings, say H-side, as the reference winding and choose matrix CTC(11) for the compensation. The H-side currents are connected to Terminal W1 of the SEL-787 Relay. Therefore, set W1CTC = 11. The X-side currents are connected to Terminal W2, so W2CTC must be determined. Figure L.24 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay. Since Matrix 11 is applied to Winding 1, this will shift IAW1 11 multiples of 30 degrees in the counterclockwise direction. In order to keep Winding 2 current, IAW2 180 degrees out-of-phase with IAW1, you must also shift IAW2 by 11 multiples of 30 degrees in the counterclockwise direction. The resulting compensation settings are W1CTC = 11 and W2CTC = 11.

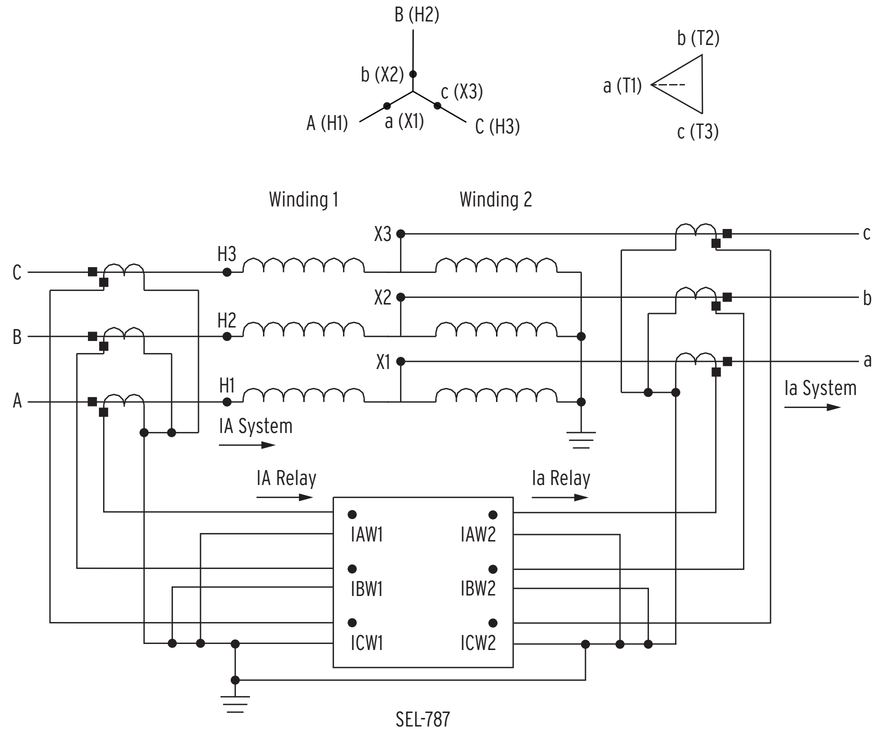

Figure L.23 Autotransformer With Standard Phase-to-Bushing Connections

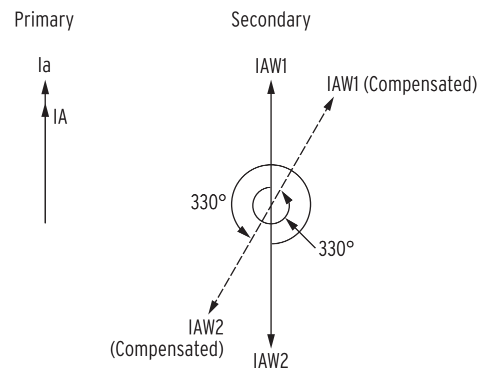

Figure L.24 Primary Currents and Secondary Currents as Measured by the Relay

Special Cases

EXAMPLE L.5 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ACB System Phase Rotation

Consider the application in Figure L.25 with standard phase-to-bushing connections, standard CT connections, and an ACB system phase rotation.

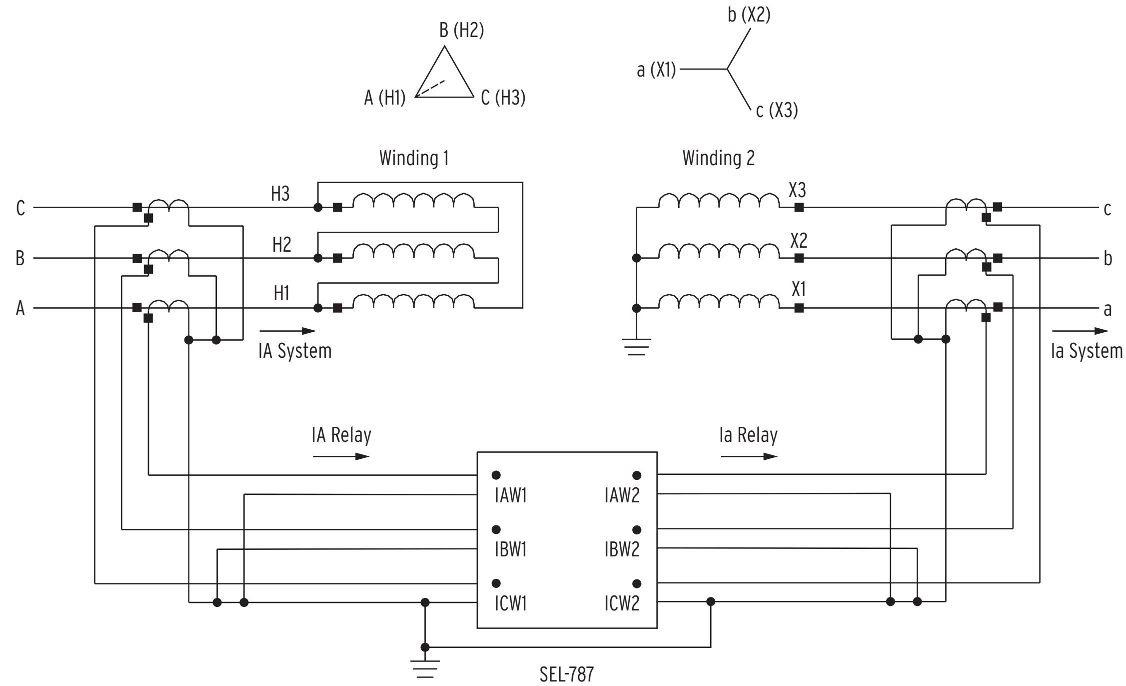

Figure L.25 Delta-Wye Transformer With Standard Phase-to-Bushing Connections With an ACB Phase Rotation

The H-side currents are:

IA = Ia – Ib

IB = Ib – Ic

IC = Ic – Ia

Figure L.26 uses a balanced set of three-phase currents with an ACB phase sequence on the wye winding as a reference to derive the delta winding (H-side) currents. When compared to Example L.1, even with the same transformer and the same connections, Figure L.26 shows that Ia (X-side) now leads IA (H-side) by 30 degrees because of the system phase rotation. Note that in Example L.1, Ia (X-side) lags IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 lagging IAW1 by 150 degrees. Figure L.28 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

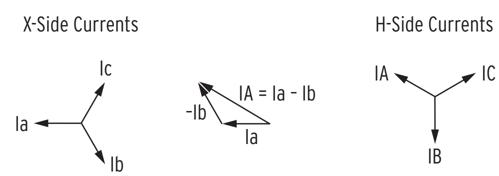

Figure L.26 X- and H-Side Current Phasors for Figure L.25

A common misconception is that a different compensation setting pair is required depending on the system phase rotation. However, closer inspection of the compensation matrices and the direction of correction in Table L.1 (also shown in Figure L.27) indicate that the matrix causes the compensated currents to rotate in the opposite direction depending on the system phase rotation.

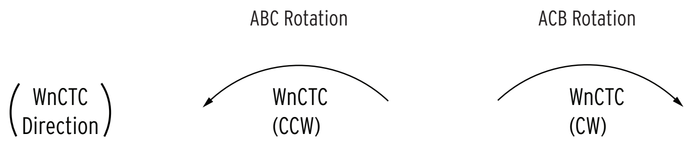

Figure L.27 Direction of Compensation Based on System Phase Rotation

Thus, the compensation settings required for Example L.1 and Example L.5 are the same. Following the settings guideline, the delta side of the transformer is selected as the reference, so W1CTC = 0. Figure L.28 shows IAW2 needs to be rotated 30 degrees (1 multiple of 30 degrees) clockwise for a system with an ACB phase rotation in order to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 1. The resulting compensation settings are W1CTC = 0 and W2CTC = 1.

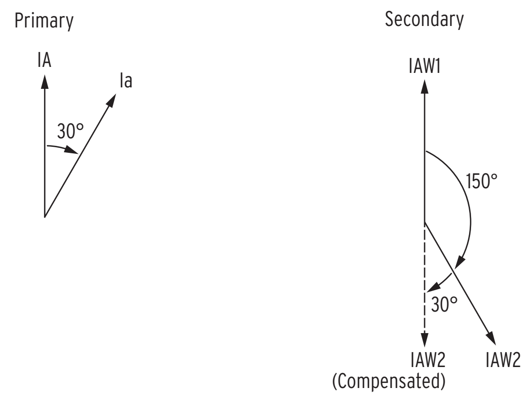

Figure L.28 Primary Currents and Secondary Currents as Measured by the Relay

If the relay is set assuming an ABC phase rotation, but the actual system phase sequence is ACB, the relay compensation settings do not need to be changed. However, the calculated positive- and negative-sequence currents will be incorrect unless the Global setting for phase rotation, PHROT, matches the system phase sequence. PHROT does not affect the compensation settings or the differential protection.

EXAMPLE L.6 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation With a Zig-Zag Grounding Transformer Within the Differential Zone on the Delta Side

This example uses the same transformer and CT connections as in Example L.1, except that it includes a zig-zag grounding transformer within the differential zone on the delta side of the transformer. Zig-zag transformers are typically used for grounding purposes and act as a source of zero-sequence current. If the zig-zag transformer is located outside of the differential zone on the delta side, it can be ignored, and the compensation settings will remain the same as in Example L.1. The same is true if the zig-zag transformer is present on the wye side, be it inside or outside the differential zone. If the zig-zag grounding transformer is within the differential zone on the delta side, then it has to be accounted for when determining the compensation settings.

The compensation settings in Example L.1 are W1CTC = 0 for the delta winding (reference winding) and W2CTC = 1 for the wye winding. When a ground current source is within the differential zone on the delta side, the recommended compensation setting of W1CTC = 0 cannot be used. The zero-sequence current needs to be filtered to avoid an operation of the differential element for external ground faults. Therefore, set W1CTC = 12. Matrix CTC(12) has no phase shift, but CTC(12) removes zero-sequence current from the differential calculation.

Quick Settings Guide for Standard Connections

Figure L.29 shows examples of common transformer connections. *Table L.4* is a quick reference guide to be used when all standard phase-to-bushing, CT, and relay connections are present. *Table L.4* is applicable to both ABC and ACB system phase rotations.

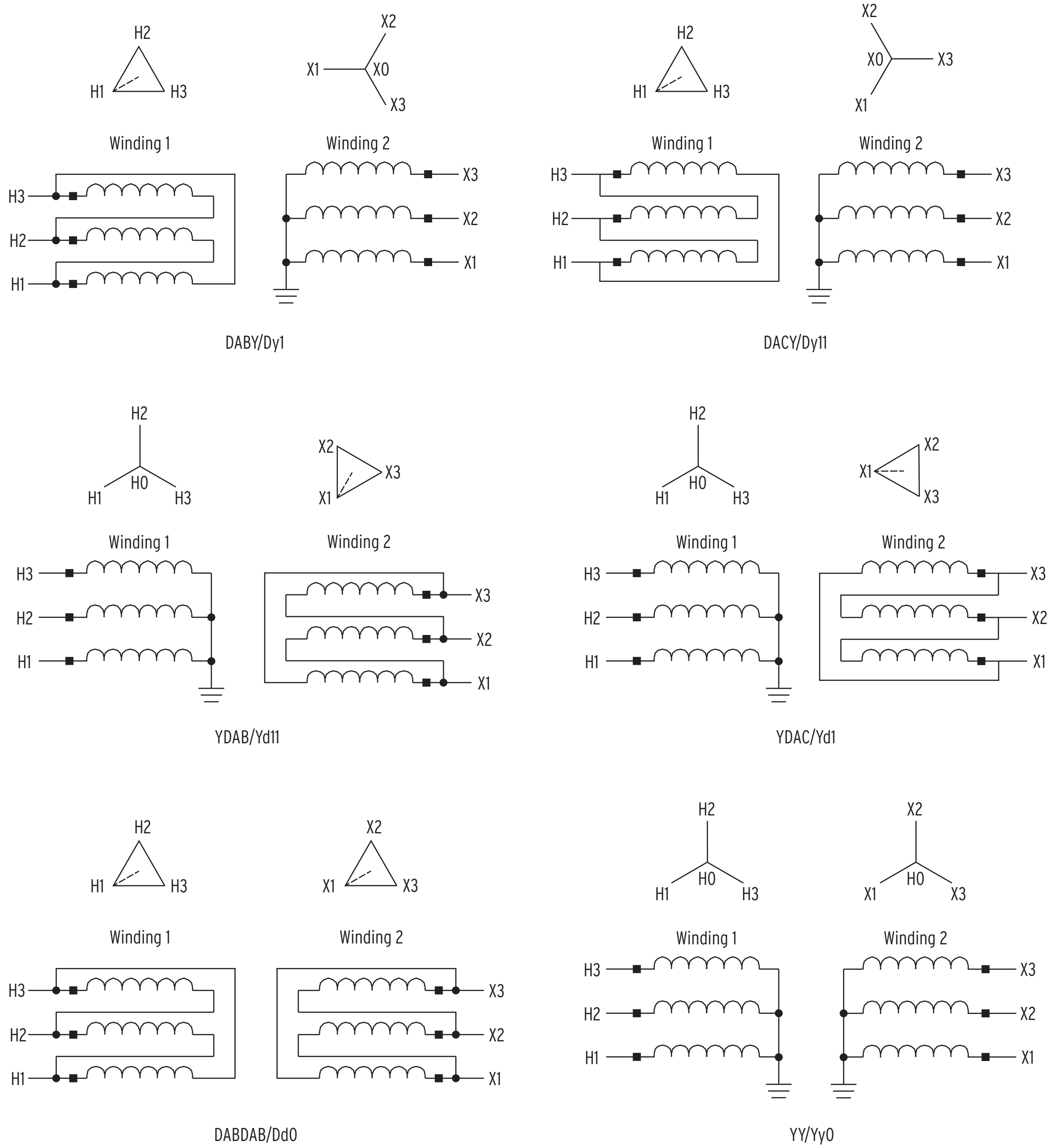

Figure L.29 Common Transformer Connections

Table L.4 Quick Settings Guide for Common Transformer Configurations and Standard Connections

XFMR Connection	W1CTC (Winding 1)	W2CTC (Winding 2)
DABY/Dy1	0	1
DACY/Dy11	0	11
YDAC/Yd1	11	0
YDAB/Yd11	1	0
DABDAB/Dd0 DACDAC/Dd0	0	0
YY/Yy0	11	11

The compensation settings of *Table L.4* assume that the Winding 1 side of the transformer is connected to relay Terminal W1 and the Winding 2 side of the transformer is connected to relay Terminal W2. These settings apply for all standard phase-to-bushing connections shown in *Table L.2*. In each of these phase-to-bushing connections, the order of the phase connections (A, B, C) matches the order of the bushings (H1, H2, H3).

References

Further discussion on selecting transformer compensations settings can be found in the technical paper, *Beyond the Nameplate – Selecting Transformer Compensation Settings for Secure Differential Protection* by Barker Edwards, David G. Williams, Ariana Hargrave, Matthew Watkins, and Vinod K. Yedidi, available at selinc.com.

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Glossary

A Abbreviation for amps or amperes; units of electrical current magnitude.

acSELerator QuickSet SEL-5030 Software A Windows-based program that simplifies settings and provides analysis support.

acSELerator Architect SEL-5032 Software Design and commissioning tool for IEC61850 communications.

Ambient Temperature Temperature of the ambient air adjacent to the transformer. Measured by an RTD whose location setting is AMB.

Analog In this instruction manual, Analog is synonymous with Transducer.

ANSI Standard Device Numbers A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include:

24 Volts/Hz Element (Overexcitation)
27 Undervoltage Element
32 Directional Power
50 Instantaneous Overcurrent Element
51 Inverse Time-Overcurrent Element
52 AC Circuit Breaker
55 Power Factor Element
59 Overvoltage Element
81 Frequency Element
87 Differential Element

These numbers are frequently used within a suffix letter to further designate application. The suffix letters used in this instruction manual include:

P Phase Element
G Residual/Ground Element
N Neutral/Ground Element
Q Negative-Sequence (3I2) Element

Apparent Power, S Complex power expressed in units of volt-amps (VA), kilovolt-amps (kVA), or megavolt-amps (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: S = P + jQ.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard way to communicate text characters between two electronic devices. The SEL-787 Transformer Protection Relay uses ASCII text characters to communicate using the relay front- and rear-panel EIA-232 serial ports.

Assert To activate; to fulfill the logic or electrical requirements needed to operate a device. To apply a short-circuit or closed contact to an SEL-787 input. To set a logic condition to the true state (logical 1). To close a normally-open output contact. To open a normally-closed output contact.

Breaker Auxiliary Contact
A spare electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A form-a breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed, opens when the breaker is open. A form-b breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Checksum
A numeric identifier of the firmware in the relay. Calculated by the result of a mathematic sum of the relay code.

CID
Abbreviation for Checksum Identifier. The checksum of the specific firmware installed in the relay.

Contiguous
Items in sequence; the second immediately following the first.

CR_RAM
Abbreviation for Critical RAM. Refers to the area of relay Random Access Memory (RAM) where the relay stores mission-critical data.

CRC-16
Abbreviation for Cyclical Redundancy Check-16. A mathematical algorithm applied to a block of digital information to produce a unique, identifying number. Used to ensure that the information was received without data corruption.

CT
Abbreviation for current transformer.

Current Differential Element
A protection element that measures the difference current between the two windings to detect internal faults.

Deassert
To deactivate; to remove the logic or electrical requirements needed to operate a device. To remove a short-circuit or closed contact from an SEL-787 input. To clear a logic condition to the false state (logical 0). To open a normally-open output contact. To close a normally-closed output contact.

Delta
A phase-to-phase connection of voltage transformers for electrical measuring purposes. Typically, two voltage transformers are used with one primary lead of the first transformer connected to A-phase and the other lead connected to B-phase. The second voltage transformer is connected to measure the voltage from B-phase to C-phase. When two transformers are used, this connection is frequently called "Open-Delta."

Dropout Time
The time measured from the removal of an input signal until the output signal deasserts. The time can be settable, as in the case of a logic variable timer, or can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

EEPROM
Abbreviation for Electrically Erasable Programmable Read-Only Memory. Nonvolatile memory where relay settings, event reports, SER records, and other nonvolatile data are stored.

Event History
A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; maximum fault phase current; and targets.

Event Report
A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, fault voltages, currents, etc. The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

Fail-Safe Refers to an output contact that is energized during normal relay operation and de-energized when relay power is removed or if the relay fails.

Fast Meter, Fast Operate Binary serial port commands that the relay recognizes at the relay front-and rear-panel EIA-232 serial ports. These commands and the responses from the relay make relay data collection by a communications processor faster and more efficient than transfer of the same data through use of formatted ASCII text commands and responses.

FID Relay firmware identification string. Lists the relay model, firmware version and date code, and other information that uniquely identifies the firmware installed in a particular relay.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash A type of nonvolatile relay memory used for storing large blocks of nonvolatile data, such as load profile records.

Fundamental Frequency The component of the measured electrical signal for which frequency is equal to the normal electrical system frequency, usually 50 or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Fundamental Meter Type of meter data presented by the SEL-787 that includes the present values measured at the relay ac inputs. The word “Fundamental” is used to indicate that the values are Fundamental Frequency values and do not include harmonics.

IA, IB, IC Measured A-, B-, and C-phase currents.

IEC 61850 Standard protocol for real-time exchange of data between databases in multi-vendor devices.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero. When a ground fault occurs, this current can be large.

IN Neutral current measured by the relay IN input. The IN input is typically connected to the secondary winding of a window-CT for ground fault detection on resistance-grounded systems.

LCD Abbreviation for Liquid Crystal Display. Used as the relay front-panel alphanumeric display.

LED Abbreviation for Light-Emitting Diode. Used as indicator lamps on the relay front panel.

MIRRORED BITS Communications Protocol for direct relay-to-relay communications.

NEMA Abbreviation for National Electrical Manufacturers Association.

Neutral Overcurrent Element
A protection element that causes the relay to trip when the neutral current magnitude (measured by the IN input) exceeds a user settable value. Used to detect and trip in response to ground faults.

Nominal Frequency
Normal electrical system frequency, usually 50 or 60 Hz.

Nonfail-Safe
Refers to an output contact that is not energized during normal relay operation. When referred to a trip output contact, the protected equipment remains in operation unprotected when relay power is removed or if the relay fails.

Nonvolatile Memory
Relay memory that is able to correctly maintain data it is storing even when the relay is de-energized.

Overfrequency Element
A protection element that causes the relay to trip when the measured electrical system frequency exceeds a settable frequency.

Phase Rotation
The sequence of voltage or current phasors in a multi-phase electrical system. In an ABC phase rotation system, the B-phase voltage lags the A-phase voltage by 120 degrees, and the C-phase voltage lags B-phase voltage by 120 degrees. In an ACB phase rotation system, the C-phase voltage lags the A-phase voltage by 120°, and the B-phase voltage lags the C-phase voltage by 120 degrees.

Pickup Time
The time measured from the application of an input signal until the output signal asserts. The time can be settable, as in the case of a logic variable timer, or can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout
The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

Power, P
Real part of the complex power (S) expressed in units of Watts (W), kilovolt-watts (kW), or megawatts (MW).

Power Factor
The cosine of the angle by which phase current lags phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a resistive load.

Power, Q
Reactive part of the complex power (S) expressed in units of Vars (W), kilovars (kVar), or megavars (MVar).

PT
Abbreviation for potential transformer. Also referred to as a voltage transformer or VT.

RAM
Abbreviation for Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data that are updated every processing interval.

Relay Word
The collection of relay element and logic results. Each element or result is represented by a unique identifier, known as a Relay Word bit.

Relay Word Bit
A single relay element or logic result that the relay updates once each processing interval. A Relay Word bit can be equal to either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted contact input or contact output. Logical 0 represents a false logic condition, dropped out element, or deasserted contact input or contact output. You can use Relay Word bits in SELOGIC control equations to control relay tripping, event triggering, and output contacts, as well as other functions.

Remote Bit A Relay Word bit for which state is controlled by serial port commands, including the **CONTROL** command, binary Fast Operate command, or Modbus® command.

Residual Current The sum of the measured phase currents. In normal, balanced operation, this current is very small or zero. When a ground fault occurs, this current can be large.

Restricted Earth Fault Element (REF) Provides sensitive protection against ground faults in wye-connected transformer windings. The element is "restricted" to ground faults within a zone defined by neutral and line CT placement.

RMS Abbreviation for Root-Mean-Square. Refers to the effective value of the sinusoidal current and voltage measured by the relay, accounting for the fundamental frequency and higher order harmonics in the signal.

ROM Abbreviation for Read-Only Memory. Nonvolatile memory where the relay firmware is stored.

RTD Abbreviation for Resistance Temperature Device. An RTD is made of a metal having a precisely known resistance and temperature coefficient of resistance. The SEL-787 (and the SEL-2600 RTD Module RTD modules) can measure the resistance of the RTD, and thus, determine the temperature at the RTD location, typically embedded in the transformer and oil tank.

Transducer Device that converts the input to the device to an analog output quantity of either current (±1, 2.5, 5, 10 and 20 mA, or 4–20 ma), or voltage (±1, 2.5, 5, or 10 V).

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates if an out-of-tolerance condition is detected. The SEL-787 is equipped with self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC® Control Equation A relay setting that allows you to control a relay function (such as an output contact) by using a logical combination of relay element outputs and fixed logic outputs. Logical AND, OR, INVERT, rising edge [/], and falling edge [\] operators, plus a single level of parentheses are available to use in each control equation setting.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a settable list. Provides a useful way to determine the order and timing of events following a relay operation.

SER Abbreviation for Sequential Events Recorder or the relay serial port command to request a report of the latest 1024 sequential events.

Synchrophasors The word synchrophasor is derived from two words: synchronized phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

TFE A Through-Fault Event (TFE) monitor is designed to capture cumulative mechanical stresses caused by faults that occur outside the transformer unit protection zone.

Terminal Emulation Software Personal computer (PC) software that can be used to send and receive ASCII text messages via the PC serial port.

Underfrequency Element A protection element that causes the relay to trip when the measured electrical system frequency is less than a settable frequency.

VA, VB, VC Measured A-, B-, and C-phase-to-neutral voltages.

VAB, VBC, VCA Measured or calculated phase-to-phase voltages.

VG Residual voltage calculated from the sum of the three phase-to-neutral voltages, if connected.

VT Abbreviation for voltage transformer. Also referred to as a potential transformer or PT.

Volts/Hz The ratio of voltage to frequency is a measure of transformer excitation and the Volts/Hz element protects against overexcitation.

Wye As used in this instruction manual, a phase-to-neutral connection of voltage transformers for electrical measuring purposes. Three voltage transformers are used with one primary lead of the first transformer connected to A-phase and the other lead connected to ground. The second and third voltage transformers are connected to measure the voltage from B-phase and C-phase-to-ground, respectively. This connection is frequently called "four-wire wye," alluding to the three phase leads plus the neutral lead.

Z-Number That portion of the relay RID string that identifies the proper QuickSet relay driver version when creating or editing relay settings files.

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Page numbers appearing in bold mark the location of the topic's primary discussion.

SEL-787 Relay Command Summary

The table below lists the front serial port ASCII commands associated with particular activities. The commands are shown in uppercase letters, but they can also be entered using lowercase letters. Commands can be initiated with the three initial letters of the command. Refer to *SEL ASCII Protocol and Commands* for additional details and capabilities of each command.

Serial Port Command	Command Description
Access Level 0 Commands	
ACC	Goes to Access Level 1. If the main board access jumper is not in place, the relay prompts for the entry of the Access Level 1 password.
ID	Relay identification code.
QUI	Goes to Access Level 0.
Access Level 1 Commands	
2AC	Goes to Access Level 2. If the main board access jumper is not in place, the relay prompts for the entry of the Access Level 2 password.
CEV *n*	Shows compressed event report number *n*, at 1/4-cycle resolution. Attach **DIF** for compressed differential element report, at 1/4-cycle resolution. Attach **R** for compressed raw report, at 1/16-cycle resolution.
COM A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM B	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.
COM C	Clears all communications records. If both MIRRORED BITS channels are enabled, omitting the channel specifier (A or B) clears both channels.
COM C A	Clears all communications records for Channel A.
COM C B	Clears all communications records for Channel B.
COM L	Appends a long report to the summary report of the last 255 records in the MIRRORED BITS communications buffer.
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM L B	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.
COM S	Returns a summary report of the last 255 records in the MIRRORED BITS communications buffer.
COU *n*	Shows the current state of the device counters. *n* = repeat the report *n* times, with a 1/2 second delay between each report.
DATE	View the date.
DATE *dd/mm/yyyy*	Sets the date in DMY format if DATE_F setting is DMY.
DATE *mm/dd/yyyy*	Sets the date in MDY format if DATE_F setting is MDY.
DATE *yyyy/mm/dd*	Sets the date in YMD format if DATE_F setting is YMD.
ETH	Shows the Ethernet port status.
EVE *n*	Shows standard analog event report *n* with 4 samples per cycle. If *n* is omitted, most recent report is displayed.

Serial Port Command	Command Description
EVE *n*R	Shows standard analog event report *n* with raw (unfiltered) 16 samples per cycle data.
EVE D *n*	Shows digital data event report number *n*, with 1/4-cycle resolution.
EVE D *n*R	Shows digital data event report number *n*, with 1/16-cycle resolution.
EVE DIF1 *n*	Show Differential Element 1 event report number *n*, with 1/4-cycle resolution.
EVE DIF2 *n*	Show Differential Element 2 event report number *n*, with 1/4-cycle resolution.
EVE DIF3 *n*	Show Differential Element 3 event report number *n*, with 1/4-cycle resolution.
EVE R *n*	Shows raw analog data event report number *n*, with 1/16-cycle resolution, same as **EVE *n* R**.
FIL DIR	Returns a list of files.
FIL READ *filename*	Transfers the settings file *filename* from the relay to the PC.
FIL SHOW *filename*	Displays contents of the file *filename*.
GOOSE *k*	Displays the transmit and receive GOOSE messaging information. Enter number *k* to scroll the GOOSE data *k* times on the screen.
GROUP	Displays the active group setting.
HELP	Displays a short description of selected commands.
HIS *n*	Shows a summary of *n* latest event reports, where *n* = 1 is the most recent entry. If *n* is not specified, all event report summaries are displayed.
HIS C or **R**	Clears or resets the history buffer.
IRIG	Forces the synchronization of internal control clock to IRIG-B time-code input.
LDP	Displays the signal profile data.
LDP C	Clears the signal profile data.
MAC	Displays the MAC address of the Ethernet port (PORT 1).
MET or **MET F**	Displays the fundamental metering data.
MET *k*	Displays the fundamental metering data *k* times, where *k* is between 1 and 32767.
MET AI	Displays the analog input (transducer) data.
MET DEM *k*	Displays the demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on the screen.
MET DIF *k*	Displays the differential metering data. Enter number *k* to scroll metering *k* times on the screen.
MET E	Displays the energy metering data.
MET H	Generates a harmonic report for all input currents and voltages, showing first- to fifth-harmonic levels and %THD (total harmonic distortion).
MET M	Displays the minimum and maximum metering data.
MET MV	Displays the SELOGIC math variable data.
MET PEA *k*	Displays the peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on the screen.
MET PM	Displays the synchrophasor metering data.
MET RD	Resets the demand metering values.
MET RE	Resets the energy metering data.
MET RM	Resets the minimum and maximum metering data.

Serial Port Command	Command Description
MET RMS	Displays the rms metering data.
MET RP	Resets the peak demand metering values.
MET T	Displays the RTD metering data.
SER	Displays the entire Sequential Events Recorder (SER) report.
SER *date1*	Displays all the rows in the SER report recorded on the specified date (see **DATE** command for date format).
SER *date1 date2*	Displays all the rows in the SER report recorded between dates *date1* and *date2*, inclusive.
SER *row1*	Displays the latest *row1* rows in the SER report (*row1* = 1–1024, where 1 is the most recent entry).
SER *row1 row2*	Displays rows *row1–row2* in the SER report.
SER C or **R**	Clears SER data.
SER D	Displays SER delete report, which shows deleted items (use when SER Auto Deletion is selected to remove chatter)
SHO *n*	Displays relay settings for Group *n* (*n* = 1, 2, 3, or 4). If *n* is not specified, the default is the active settings group.
SHO DNP *n*	Displays the DNP data map settings for Map *n* (*n* = 1, 2, or 3).
SHO F	Displays the front-panel settings.
SHO G	Displays the global settings.
SHO L	Displays the general logic settings.
SHO M	Displays the Modbus user map settings.
SHO P *n*	Displays the port settings, where *n* specifies the port (1, 2, 3, 4, or F); *n* defaults to the active port if not listed.
SHO R	Displays the report settings.
STA	Displays the relay self-test status.
STA S	Displays the SELOGIC usage status report.
SUM	Displays an event summary.
SUM R or **C**	Resets the event summary buffer.
TAR	Displays the default target row or the most recently viewed target row.
TAR *n*	Displays target Row *n*.
TAR *n k*	Display target Row *n*. Repeats the display of Row *n* for repeat count *k*.
TAR *name*	Display the target row with target *name* in the row.
TAR *name k*	Display the target row with target *name* in the row. Repeats the display of this row for repeat count *k*.
TAR R	Resets any latched targets and the most recently viewed target row.
TFE	Displays cumulative and individual through-fault event data. The twenty (20) most recent individual events are displayed.
TFE *n*	Displays cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 500.
TFE A	Displays cumulative and individual through-fault event data. The most recent individual events are displayed, as many as 500.
TIME	Displays the time.
TIME *hh*	Sets the time by entering **TIME** followed by hours, as shown (24-hour clock).

Serial Port Command	Command Description
TIME *hh:mm*	Sets the time by entering **TIME** followed by hours and minutes, as shown (24-hour clock).
TIME *hh:mm:ss*	Sets the time by entering **TIME** followed by hours, minutes, and seconds, as shown (24-hour clock).
TRI	Triggers an event report data capture.
Access Level 2 Commands	
ANA *c p t*	Tests the analog output channel where *c* is the channel name or number, *p* is a percentage of full scale or either letter “R” or “r” indicates ramp mode, and *t* is the duration of the test in decimal minutes.
CAL	Goes to Access Level C. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CLO *n*	Close Circuit Breaker *n*, where *n* = 1 or 2.
CON RB*nn k*	Select a remote bit to set, clear, or pulse where *nn* is a number from 01 to 32, representing RB01 through RB32. *k* is S, C, or P for Set, Clear, or Pulse.
COPY *m n*	Copy relay and logic settings from Group *m* to Group *n*.
DTO	Downloads the volts/hertz user curve from the SEL-5806 Curve Designer Software.
FIL WRITE *filename*	Transfers the settings file *filename* from the PC to the relay.
GRO *n*	Modify active group setting, where *n* = 1, 2, 3, or 4.
L_D	Loads new firmware.
LOO	Enables loopback testing of MIRRORED BITS channels.
LOO A	Enables loopback on MIRRORED BITS Channel A for the next 5 minutes.
LOO B	Enables loopback on MIRRORED BITS Channel B for the next 5 minutes.
OPE *n*	Open Circuit Breaker *n*, where *n* = 1 or 2.
PAS 1	Changes the Access Level 1 password.
PAS 2	Changes the Access Level 2 password.
PING *x.x.x.x t*	Determines if the Ethernet port is functioning and configured properly. *x.x.x.x* is the IP address and *t* is the PING interval settable from 2 to 255 seconds. Default *t* is 1 second. Press **Q** to stop.
PUL *n t*	Pulse Output Contact *n* (*n* = OUT101…) for *t* (1 to 30, default is 1) seconds.
SET	Modifies the relay settings.
SET *name*	For all the **SET** commands, jump ahead to a specific setting by entering the setting name, e.g., 50P1P.
SET DNP *n*	Modifies the DNP data map settings for Map *n*, where *n* = 1, 2, or 3.
SET F	Modifies the front-panel settings.
SET G	Modifies the global settings.
SET L	Modifies the SELOGIC variable and timer settings.
SET M	Modifies the Modbus user map settings.
SET P *n*	Modifies the Port *n* settings, where *n* = 1, 2, 3, 4, or F. If not specified, the default is the active port.
SET R	Modifies the report settings.
SET … TERSE	For all the **SET** commands, TERSE disables the automatic **SHO** command after the settings entry.
STA C or **R**	Clears the self-test status and restarts the relay.
TFE C or **R**	Clears/resets cumulative and individual through-fault event data.
TFE P	Preloads cumulative through-fault event data.

Serial Port Command	Command Description
Access Level C Commands	
PAS C	Changes the Access Level C password.

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SEL-787 Relay Command Summary

The table below lists the front serial port ASCII commands associated with particular activities. The commands are shown in uppercase letters, but they can also be entered using lowercase letters. Commands can be initiated with the three initial letters of the command. Refer to *SEL ASCII Protocol and Commands* for additional details and capabilities of each command.

Serial Port Command	Command Description
Access Level 0 Commands	
ACC	Goes to Access Level 1. If the main board access jumper is not in place, the relay prompts for the entry of the Access Level 1 password.
ID	Relay identification code.
QUI	Goes to Access Level 0.
Access Level 1 Commands	
2AC	Goes to Access Level 2. If the main board access jumper is not in place, the relay prompts for the entry of the Access Level 2 password.
CEV *n*	Shows compressed event report number *n*, at 1/4-cycle resolution. Attach **DIF** for compressed differential element report, at 1/4-cycle resolution. Attach **R** for compressed raw report, at 1/16-cycle resolution.
COM A	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM B	Returns a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.
COM C	Clears all communications records. If both MIRRORED BITS channels are enabled, omitting the channel specifier (A or B) clears both channels.
COM C A	Clears all communications records for Channel A.
COM C B	Clears all communications records for Channel B.
COM L	Appends a long report to the summary report of the last 255 records in the MIRRORED BITS communications buffer.
COM L A	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.
COM L B	Appends a long report to the summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.
COM S	Returns a summary report of the last 255 records in the MIRRORED BITS communications buffer.
COU *n*	Shows the current state of the device counters. *n* = repeat the report *n* times, with a 1/2 second delay between each report.
DATE	View the date.
DATE *dd/mm/yyyy*	Sets the date in DMY format if DATE_F setting is DMY.
DATE *mm/dd/yyyy*	Sets the date in MDY format if DATE_F setting is MDY.
DATE *yyyy/mm/dd*	Sets the date in YMD format if DATE_F setting is YMD.
ETH	Shows the Ethernet port status.
EVE *n*	Shows standard analog event report *n* with 4 samples per cycle. If *n* is omitted, most recent report is displayed.

Serial Port Command	Command Description
EVE *n*R	Shows standard analog event report *n* with raw (unfiltered) 16 samples per cycle data.
EVE D *n*	Shows digital data event report number *n*, with 1/4-cycle resolution.
EVE D *n*R	Shows digital data event report number *n*, with 1/16-cycle resolution.
EVE DIF1 *n*	Show Differential Element 1 event report number *n*, with 1/4-cycle resolution.
EVE DIF2 *n*	Show Differential Element 2 event report number *n*, with 1/4-cycle resolution.
EVE DIF3 *n*	Show Differential Element 3 event report number *n*, with 1/4-cycle resolution.
EVE R *n*	Shows raw analog data event report number *n*, with 1/16-cycle resolution, same as **EVE *n* R**.
FIL DIR	Returns a list of files.
FIL READ *filename*	Transfers the settings file *filename* from the relay to the PC.
FIL SHOW *filename*	Displays contents of the file *filename*.
GOOSE *k*	Displays the transmit and receive GOOSE messaging information. Enter number *k* to scroll the GOOSE data *k* times on the screen.
GROUP	Displays the active group setting.
HELP	Displays a short description of selected commands.
HIS *n*	Shows a summary of *n* latest event reports, where *n* = 1 is the most recent entry. If *n* is not specified, all event report summaries are displayed.
HIS C or **R**	Clears or resets the history buffer.
IRIG	Forces the synchronization of internal control clock to IRIG-B time-code input.
LDP	Displays the signal profile data.
LDP C	Clears the signal profile data.
MAC	Displays the MAC address of the Ethernet port (PORT 1).
MET or **MET F**	Displays the fundamental metering data.
MET *k*	Displays the fundamental metering data *k* times, where *k* is between 1 and 32767.
MET AI	Displays the analog input (transducer) data.
MET DEM *k*	Displays the demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on the screen.
MET DIF *k*	Displays the differential metering data. Enter number *k* to scroll metering *k* times on the screen.
MET E	Displays the energy metering data.
MET H	Generates a harmonic report for all input currents and voltages, showing first- to fifth-harmonic levels and %THD (total harmonic distortion).
MET M	Displays the minimum and maximum metering data.
MET MV	Displays the SELOGIC math variable data.
MET PEA *k*	Displays the peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on the screen.
MET PM	Displays the synchrophasor metering data.
MET RD	Resets the demand metering values.
MET RE	Resets the energy metering data.
MET RM	Resets the minimum and maximum metering data.

Serial Port Command	Command Description
MET RMS	Displays the rms metering data.
MET RP	Resets the peak demand metering values.
MET T	Displays the RTD metering data.
SER	Displays the entire Sequential Events Recorder (SER) report.
SER *date1*	Displays all the rows in the SER report recorded on the specified date (see **DATE** command for date format).
SER *date1 date2*	Displays all the rows in the SER report recorded between dates *date1* and *date2*, inclusive.
SER *row1*	Displays the latest *row1* rows in the SER report (*row1* = 1–1024, where 1 is the most recent entry).
SER *row1 row2*	Displays rows *row1–row2* in the SER report.
SER C or **R**	Clears SER data.
SER D	Displays SER delete report, which shows deleted items (use when SER Auto Deletion is selected to remove chatter)
SHO *n*	Displays relay settings for Group *n* (*n* = 1, 2, 3, or 4). If *n* is not specified, the default is the active settings group.
SHO DNP *n*	Displays the DNP data map settings for Map *n* (*n* = 1, 2, or 3).
SHO F	Displays the front-panel settings.
SHO G	Displays the global settings.
SHO L	Displays the general logic settings.
SHO M	Displays the Modbus user map settings.
SHO P *n*	Displays the port settings, where *n* specifies the port (1, 2, 3, 4, or F); *n* defaults to the active port if not listed.
SHO R	Displays the report settings.
STA	Displays the relay self-test status.
STA S	Displays the SELOGIC usage status report.
SUM	Displays an event summary.
SUM R or **C**	Resets the event summary buffer.
TAR	Displays the default target row or the most recently viewed target row.
TAR *n*	Displays target Row *n*.
TAR *n k*	Display target Row *n*. Repeats the display of Row *n* for repeat count *k*.
TAR *name*	Display the target row with target *name* in the row.
TAR *name k*	Display the target row with target *name* in the row. Repeats the display of this row for repeat count *k*.
TAR R	Resets any latched targets and the most recently viewed target row.
TFE	Displays cumulative and individual through-fault event data. The twenty (20) most recent individual events are displayed.
TFE *n*	Displays cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 500.
TFE A	Displays cumulative and individual through-fault event data. The most recent individual events are displayed, as many as 500.
TIME	Displays the time.
TIME *hh*	Sets the time by entering **TIME** followed by hours, as shown (24-hour clock).

Serial Port Command	Command Description
TIME *hh:mm*	Sets the time by entering **TIME** followed by hours and minutes, as shown (24-hour clock).
TIME *hh:mm:ss*	Sets the time by entering **TIME** followed by hours, minutes, and seconds, as shown (24-hour clock).
TRI	Triggers an event report data capture.
Access Level 2 Commands	
ANA *c p t*	Tests the analog output channel where *c* is the channel name or number, *p* is a percentage of full scale or either letter “R” or “r” indicates ramp mode, and *t* is the duration of the test in decimal minutes.
CAL	Goes to Access Level C. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CLO *n*	Close Circuit Breaker *n*, where *n* = 1 or 2.
CON RB*nn k*	Select a remote bit to set, clear, or pulse where *nn* is a number from 01 to 32, representing RB01 through RB32. *k* is S, C, or P for Set, Clear, or Pulse.
COPY *m n*	Copy relay and logic settings from Group *m* to Group *n*.
DTO	Downloads the volts/hertz user curve from the SEL-5806 Curve Designer Software.
FIL WRITE *filename*	Transfers the settings file *filename* from the PC to the relay.
GRO *n*	Modify active group setting, where *n* = 1, 2, 3, or 4.
L_D	Loads new firmware.
LOO	Enables loopback testing of MIRRORED BITS channels.
LOO A	Enables loopback on MIRRORED BITS Channel A for the next 5 minutes.
LOO B	Enables loopback on MIRRORED BITS Channel B for the next 5 minutes.
OPE *n*	Open Circuit Breaker *n*, where *n* = 1 or 2.
PAS 1	Changes the Access Level 1 password.
PAS 2	Changes the Access Level 2 password.
PING *x.x.x.x t*	Determines if the Ethernet port is functioning and configured properly. *x.x.x.x* is the IP address and *t* is the PING interval settable from 2 to 255 seconds. Default *t* is 1 second. Press **Q** to stop.
PUL *n t*	Pulse Output Contact *n* (*n* = OUT101…) for *t* (1 to 30, default is 1) seconds.
SET	Modifies the relay settings.
SET *name*	For all the **SET** commands, jump ahead to a specific setting by entering the setting name, e.g., 50P1P.
SET DNP *n*	Modifies the DNP data map settings for Map *n*, where *n* = 1, 2, or 3.
SET F	Modifies the front-panel settings.
SET G	Modifies the global settings.
SET L	Modifies the SELOGIC variable and timer settings.
SET M	Modifies the Modbus user map settings.
SET P *n*	Modifies the Port *n* settings, where *n* = 1, 2, 3, 4, or F. If not specified, the default is the active port.
SET R	Modifies the report settings.
SET … TERSE	For all the **SET** commands, TERSE disables the automatic **SHO** command after the settings entry.
STA C or **R**	Clears the self-test status and restarts the relay.
TFE C or **R**	Clears/resets cumulative and individual through-fault event data.
TFE P	Preloads cumulative through-fault event data.

Serial Port Command	Command Description
Access Level C Commands	
PAS C	Changes the Access Level C password.

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