SEL-421 Relay

Protection and Automation System

Instruction Manual

User's Guide

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SCHWEITZER ENGINEERING LABORATORIES, INC.

PM421-01

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Preface

This manual provides information and instructions for installing and operating the SEL-421 Relay. The three volumes that comprise this manual are for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples. While this manual gives reasonable examples and illustrations of relay uses, you must exercise sound judgment at all times when applying the SEL-421 in a power system.

SEL-421 Versions and Supported Features on page U.1.7 shows the relay features supported by versions SEL-421-0, SEL-421-1, SEL-421-2, and SEL-421-3. Throughout the manual, we provide margin notes next to the text explaining a feature to specify the availability of that feature in different versions of the relay.

Manual Overview

The SEL-421 Relay Manual consists of three volumes:

- User's Guide
- Applications Handbook
- Reference Manual

In addition, the SEL-421 Relay Manual contains a comprehensive Index that encompasses the entire manual. The index appears at the end of each printed volume. In the electronic version of the manual, the index appears once; hyperlinks take you to material referenced in the index. Also included is a glossary that lists and defines technical terms used throughout the manual.

The SEL-421 Relay Manual is a comprehensive work covering all aspects of relay application and use. Read the sections that pertain to your application to gain valuable information about using the SEL-421. For example, to learn about relay protection functions, read the protection sections of this manual and skim the automation sections, then concentrate on the operation sections or on the automation sections of this manual as your job needs and responsibilities dictate. An overview of each manual section and section topics follows.

User's Guide

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

Section 1: Introduction and Specifications. Introduces SEL-421 features; summarizes relay functions and applications; lists relay specifications, type tests, and ratings.

Section 2: Installation. Discusses the ordering configurations and interface features (control inputs, control outputs, and analog inputs, for example); provides information about how to design a new physical installation and secure the relay in a panel or rack; details how to set relay board jumpers and make proper rear-panel connections (including wiring to CTs, PTs, and a GPS receiver); explains basic connections for the relay communications ports.

Section 3: PC Software. Explains how to use the ACSELERATOR QuickSet® SEL-5030 software program.

Section 4: Basic Relay Operations. Describes how to perform fundamental operations such as applying power and communicating with the relay, setting and viewing passwords, checking relay status, viewing metering data, reading event reports and SER (Sequential Events Recorder) records, operating relay control outputs and control inputs, and using relay features to make relay commissioning easier.

Section 5: Front-Panel Operations. Describes the LCD display messages and menu screens; shows you how to use front-panel pushbuttons and read targets; provides information about local substation control and how to make relay settings via the front panel.

Section 6: Testing and Troubleshooting. Describes techniques for testing, troubleshooting, and maintaining the SEL-421; includes the list of status notification messages and a troubleshooting chart.

Appendix A: Firmware and Manual Versions. Lists the current firmware versions and details differences between the current and previous versions.

Applications Handbook

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

- Overhead single 230 kV transmission line
- Overhead parallel 500 kV transmission lines with zero-sequence mutual coupling
- Overhead tapped 345 kV transmission line
- Parallel 230 kV underground cables

This section also provides separate application examples for out-of-step blocking and tripping, circuit breaker failure protection, and automatic reclose and synchronism checking.

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

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

Section 4: Time-Synchronized Measurements. Explains synchronized phasor measurements and estimation of power system states using the SEL-421 high-accuracy time-stamping capability; presents real-time load flow/power flow application ideas.

Section 5: Substation Automatic Restoration. Describes an example of automatic substation restoration; gives a real-world example of the programming ease and flexibility of free-form expanded SELOGIC® control equations.

Section 6: SEL Communications Processor Applications. Provides examples of how to use the SEL-421 with the SEL-2032, SEL-2030, and SEL-2020 Communications Processors for total substation automation solutions.

Section 7: Direct Network Communication. Explains how to use DNP3 (serial and LAN/WAN) and other Ethernet protocols such as Telnet, FTP, and IEC 61850.

Reference Manual

Section 1: Protection Functions. Describes the function of various relay protection elements; describes how the relay processes these elements; gives detailed specifics on protection scheme logic for POTT, DCB, DCUB, and DTT; provides trip logic diagrams, and current and voltage source selection details.

Section 2: Auto-Reclosing and Synchronism Check. Explains how to operate the SEL-421 two-circuit breaker multi-shot recloser; describes how to set the SEL-421 for single-pole reclosing, three-pole reclosing, or both; shows selection of the lead and follow circuit breakers; explains how to set and apply synchronism-check elements for automatic and manual closing.

Section 3: SELOGIC Control Equation Programming. Describes multiple setting groups and SELOGIC control equations and how to apply these equations; discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers; provides a tutorial for converting older format SELOGIC control equations to new free-form equations.

Section 4: Communications Interfaces. Explains the physical connection of the SEL-421 to various communications network topologies.

Section 5: SEL Communications Protocols. Describes the various SEL software protocols and how to apply these protocols to substation integration and automation; includes details about SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS® communications.

Section 6: DNP3 Communications. Describes the DNP3 communications protocol and how to apply this protocol to substation integration and automation; provides a Job Done® example for implementing DNP3 in a substation.

Section 7: Synchrophasors. Describes the Phasor Measurement Unit (PMU) functions of the SEL-421; provides details on synchrophasor measurement; describes the IEEE C37.118 synchrophasor protocol settings; describes the SEL Fast Message synchrophasor protocol settings.

Section 8: IEC 61850 Communications. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

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

Section 10: Settings. Provides a list of all SEL-421 settings and defaults. The organization of the settings is similar to the settings organization in the relay and in the ACSELERATOR QuickSet software.

Appendix A: Relay Word Bits. Contains a summary of Relay Word bits.

Appendix B: Analog Quantities. Contains a summary of analog quantities.

CD-ROM

The CD-ROM contains the SEL-421 Relay Manual in an electronic form that you can search easily.

Conventions

Typographic Conventions

There are three ways to communicate with the SEL-421:

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

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

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
{CLOSE}	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
RELAY RESPONSE MAIN > METER	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.
U.3.1 A.3.1 R.3.1	Page numbers include a reference to the volume, section, and page number. U stands for User's Guide A stands for Applications Handbook R stands for Reference Manual.
SELOGIC control equations	SEL trademarks and registered trademarks contain the appropriate symbol on first reference in a section. In the SEL-421 Instruction Manual, certain SEL trademarks appear in small caps. These include SELOGIC control equations, MIRRORED BITS communications, and the ACSELERATOR QuickSet software program.
Modbus®	Registered trademarks of other companies include the registered trademark symbol with the first occurrence of the term in a section.

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-421. 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-421.

Notes

Margin notes serve two purposes in the SEL-421 Relay Manual. Notes present valuable or important points about relay features or functions. Use these notes as tips to easier and more efficient operation of the relay. Also in this manual, notes specify differences between the SEL-421-0, SEL-421-1, SEL-421-2, and SEL-421-3 models when these differences affect relay functions or operations.

Commands

You can simplify the task of entering commands by shortening any ASCII command to the first three characters (upper- or lowercase); for example, **ACCESS** becomes **ACC**.

Always send a carriage return **<CR>** character, or a carriage return character followed by a line feed character **<CR><LF>**, to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a **<CR>**. For example, to send the **ACCESS** command, type the following:

ACC <Enter>

Numbers

This manual displays numbers as decimal values. Hexadecimal numbers include the letter h appended to the number. Alternatively, the prefix 0X can also indicate a hexadecimal number. For instance, 11 is the decimal number eleven, but 11h and 0X11 are hexadecimal representations of the decimal value seventeen.

Safety Information

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

⚠CAUTION

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

⚠WARNING

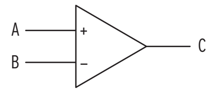
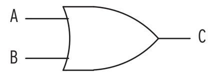
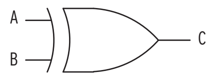
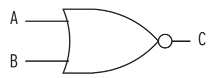
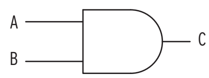
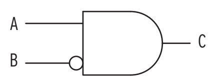
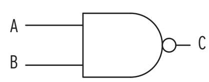
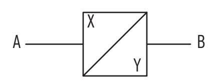
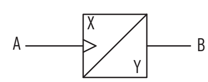
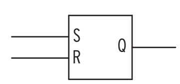
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠DANGER

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

Logic Diagrams

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

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

SEL-421 Cautions, Warnings, and Dangers

The following hazard statements appear in the body of this manual in English. See the following table for the English and French translation of these statements.

English	French
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.	⚠ATTENTION Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.
⚠CAUTION Equipment damage can result from connecting ac circuits to Hybrid (high-current-interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.	⚠ATTENTION Des dommages à l'appareil pourraient survenir si un circuit CA était raccordé aux contacts de sortie à haut pouvoir de coupure de type "Hybrid." Ne pas raccorder de circuit CA aux contacts de sortie de type "Hybrid." Utiliser uniquement du CC avec les contacts de sortie de type "Hybrid."
⚠CAUTION Substation battery systems that have either a high resistance to ground (greater than 10 kΩ) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.	⚠ATTENTION Les circuits de batterie de postes qui présentent une haute résistance à la terre (plus grande que 10 kΩ) ou sont isolés peuvent présenter un biais de tension CC entre les deux polarités de la batterie quand utilisés avec plusieurs entrées à couplage direct. Des conditions similaires peuvent exister pour des systèmes de surveillance de batterie qui utilisent des circuits d'équilibrage à haute résistance ou des masses flottantes. Pour ce type d'applications, SEL peut fournir en option des contacts d'entrée isolés (par couplage optoélectronique). De surcroît, SEL a publié des recommandations relativement à cette application. Contacter l'usine pour plus d'informations.
⚠CAUTION If you are planning to install an INT4 I/O Interface Board in your relay (see Table 2.3 and Table 2.4 for board descriptions), first check the firmware version of the relay—see Firmware Version Number on page U.6.39. If the firmware version is R111 or lower, you must first upgrade the relay firmware to the newest version and verify that the firmware upgrade was successful before installing the new board. Failure to install the new firmware first will cause the I/O Interface Board to fail, and it may require factory service. Complete firmware upgrade instructions are provided when new firmware is ordered.	⚠ATTENTION Si vous avez l'intention d'installer une Carte d'Interface INT4 I/O dans votre relais (voit Table 2.3 et Table 2.4 pour la description de la carte), vérifiez en premier la version du logiciel du relais (voir l'indentification de la Version du logiciel [Firmware Version Number on page U.6.39]). Si la version est R111 ou antérieure, vous devez mettre à jour le logiciel du relais avec la version la plus récente et vérifier que la mise à jour a été correctement installée sur la nouvelle carte. Les instructions complètes de mise à jour sont fournies quand le nouveau logiciel est commandé.
⚠CAUTION Field replacement of I/O boards INT1, INT2, INT5, INT6, INT7, or INT8 with INT4 can cause I/O contact failure. The INT4 board has a pickup and dropout delay setting range of 0–1 cycle. For all other I/O boards, pickup and dropout delay settings (IN201PU–IN224PU, IN201DO–IN224DO, IN301PU–IN324PU, and IN301DO–IN324DO) have a range of 0–5 cycles. Upon replacing any I/O board with an INT4 board, manually confirm reset of pickup and dropout delays to within the expected range of 0–1 cycle.	⚠ATTENTION Le remplacement en chantier des cartes d'entrées/sorties INT1, INT2, INT5, INT6, INT7 ou INT8 par une carte INT4 peut causer la défaillance du contact d'entrée/sortie. La carte INT4 présente un intervalle d'ajustement pour les délais de montée et de retombée de 0 à 1 cycle. Pour toutes les autres cartes, l'intervalle de réglage du délai de montée et retombée (IN201PU–IN224PU, IN201DO– IN224DO, IN301PU–IN324PU, et IN301DO–IN324DO) est de 0 à 5 cycles. Quand une carte d'entrées/sorties est remplacée par une carte INT4, vérifier manuellement que les délais de montée et retombée sont dans l'intervalle de 0 à 1 cycle.

English	French
⚠CAUTION Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.	**⚠ATTENTION** Ne pas installer de cavalier sur les positions A ou D sur le connecteur J18 de la carte principale. Une opération intempestive du relais pourrait résulter suite à l'installation d'un cavalier entre les positions J18A et J18D.
⚠CAUTION Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.	**⚠ATTENTION** Un niveau d'isolation insuffisant peut entraîner une détérioration sous des conditions anormales et causer des dommages à l'équipement. Pour les circuits externes, utiliser des conducteurs avec une isolation suffisante de façon à éviter les claquages durant les conditions anormales d'opération.
⚠CAUTION Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.	**⚠ATTENTION** Une opération intempestive du relais peut résulter par le branchement de tensions et courants secondaires non conformes aux spécifications. Avant de brancher un circuit secondaire, vérifier la tension ou le courant nominal sur la plaque signalétique à l'arrière.
⚠CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.	**⚠ATTENTION** Des problèmes graves d'alimentation et de terre peuvent survenir sur les ports de communication de cet appareil si des câbles d'origine autre que SEL sont utilisés. Ne jamais utiliser de câble de modem nul avec cet équipement.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	**⚠ATTENTION** Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	**⚠ATTENTION** L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	**⚠AVERTISSEMENT** L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	**⚠AVERTISSEMENT** Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	**⚠AVERTISSEMENT** Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING Do not look into the fiber (laser) ports/connectors.	**⚠AVERTISSEMENT** Ne pas regarder vers l'extremité des ports ou connecteurs de fibres pour laser.
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	**⚠AVERTISSEMENT** Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.

English	French
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠WARNING Incorporated components, such as LEDs, transceivers, and laser emitters, are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes), émetteurs-récepteurs ou émetteurs pour rayon laser ne peuvent pas être entretenus par l'usager. Retourner ces unités à SEL pour toute réparation ou remplacement.
⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.

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Section 1

Introduction and Specifications

The SEL-421 Relay is a high-speed transmission line protection relay featuring single-pole and three-pole tripping and reclosing with synchronism check, circuit breaker monitoring, circuit breaker failure protection, and series-compensated line protection logic. The relay features extensive metering and data recording including high-resolution data capture and reporting.

NOTE: Not all features mentioned on this page are available in the SEL-421-1 and the SEL-421-2. See SEL-421 Versions and Supported Features on page U.1.7 for more details about the different versions of the relay and about differences among the SEL-421-0, SEL-421-1, SEL-421-2, and SEL-421-3.

The SEL-421 features expanded SELOGIC® control equation programming for easy and flexible implementation of custom protection and control schemes. The relay has separate protection and automation SELOGIC control equation programming areas with extensive protection programming capability and 1000 lines of automation programming capability. You can organize automation of SELOGIC control equation programming into 10 blocks of 100 program lines each.

The SEL-421 provides extensive communications interfaces from standard SEL ASCII and enhanced MIRRORED BITS® communications protocols to Ethernet connectivity with the optional Ethernet card. With the Ethernet card, you can employ the latest industry communications tools, including Telnet, FTP, IEC 61850, and DNP3 (serial and LAN/WAN) protocols.

Purchase of an SEL-421 includes the ACSELERATOR QuickSet® SEL-5030 Software program. ACSELERATOR QuickSet assists you in setting, controlling, and acquiring data from the relays, both locally and remotely. ACSELERATOR Architect® SEL-5032 Software is included with purchase of the optional Ethernet card with IEC 61850 protocol support. ACSELERATOR Architect enables you to view and configure IEC 61850 settings via a GUI interface, tightly integrated with ACSELERATOR QuickSet.

Synchrophasor measurements are available when a high-accuracy time source is connected to the relay. The SEL-421 supports the IEEE C37.118, Standard for Synchrophasors for Power Systems.

A simple and robust hardware design features efficient digital signal processing. Combined with extensive self-testing, these features provide relay reliability and enhance relay availability.

This section introduces the SEL-421 and provides information on the following topics:

Features

The SEL-421 contains many protection, automation, and control features. *Figure 1.1* presents a simplified functional overview of the relay.

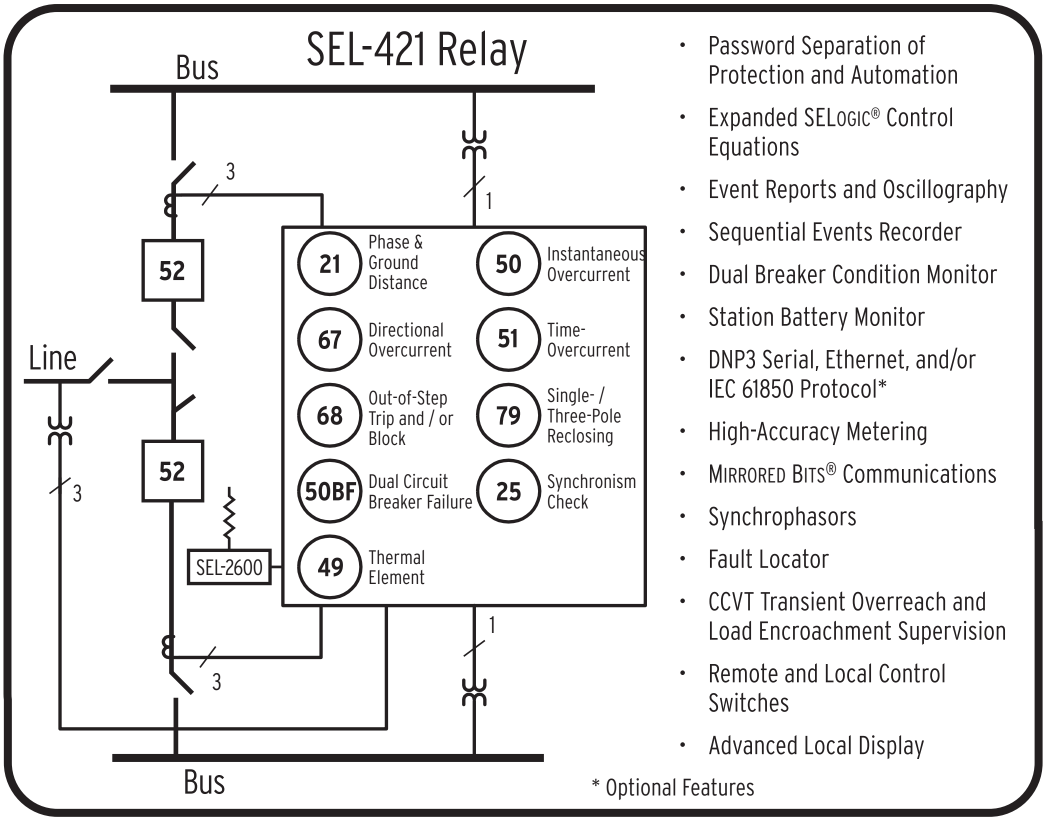


Figure 1.1 SEL-421 Functional Overview

SEL-421 features include the following:

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

Superior Protection. Combine five zones of phase distance and ground distance elements with directional overcurrent elements. Patented Coupling Capacitor Voltage Transformer (CCVT) transient overreach logic enhances Zone 1 distance element security. The Best Choice Ground Directional Element™ optimizes directional element performance and eliminates many settings. Additional logic prevents Zone 1 overreach on series-compensated lines.

NOTE: The SEL-421-1 and the SEL-421-2 do not provide high-speed directional elements and high-speed distance elements.

High-Speed Tripping. The SEL-421 uses the HSDPS (High-Speed Directional and Phase Selection) element and high-speed distance elements for subcycle detection of power system faults.

Reclosing. Incorporate programmable single-pole and three-pole tripping and reclosing of one and two circuit breakers into an integrated substation control system. Synchronism and voltage checks from multiple sources provide complete bay control.

Breaker Failure. The SEL-421 incorporates CT subsidence detection to produce element dropout in 5/8 cycle. Apply the SEL-421 to supply three-pole breaker failure for one or two breakers. Included is the necessary logic for single-pole and three-pole breaker failure retrip and initiation of transfer tripping.

Out-of-Step Blocking and Tripping. Select out-of-step blocking of distance elements or out-of-step tripping during power swings. The SEL-421 includes multizone elements and logic for detection of an out-of-step condition.

Switch-Onto-Fault. Relay switch-onto-fault (SOTF) logic permits specific protection elements to quickly trip after the circuit breaker closes, protecting maintenance personnel and substation equipment.

Fault Locator. Efficiently dispatch line crews to quickly repair line problems.

Primary Potential Redundancy. Multiple voltage inputs to the SEL-421 provide primary input redundancy. At loss-of-potential (LOP) detection, configure the relay to use inputs from an electrically equivalent source. Protection remains in service without compromising security.

Dual CT Input. Apply with ring bus, breaker-and-a-half, or other two-breaker schemes. Combine currents within the relay from two sets of CTs for protection functions, but keep them separately available for monitoring and station integration applications.

NOTE: The SEL-421-1 and the SEL-421-2 have only one 100-line automation programming block.

Automation. Take advantage of enhanced automation features that include 32 programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large format front-panel Liquid Crystal Display (LCD) eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, Sequential Events Recorder (SER) reports, breaker monitor, relay summary event reports, and time synchronization. Use expanded SELOGIC control equations with math and comparison functions in control applications. Incorporate up to 1000 lines of automation logic to speed and improve control actions.

Monitoring. Schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole of two circuit breakers) indicates possible excess contact wear. Electrical and mechanical operating times are recorded for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems (two independent battery monitors) even if voltage is low only during trip or close operations.

Comprehensive Metering. View metering information for Line, Circuit Breaker 1, and Circuit Breaker 2. SEL-421 metering includes fundamental and rms metering, as well as energy import/export, demand, and peak demand metering data. Synchrophasor data can be used for time-synchronized state measurements across the system.

Oscillography and Event Reporting. Record voltages, currents, and internal logic points at up to 8 kHz sampling rate. Phasor and harmonic analysis features allow investigation of relay and system performance.

Sequential Events Recorder (SER). Record the last 1000 entries, including setting changes, power-ups, and selectable logic elements.

High-Accuracy Time Stamping. Time-tag binary COMTRADE event reports with real-time accuracy of better than 10 µs. View system state information to an accuracy of better than 1/4 of an electrical degree.

Digital Relay-to-Relay Communication. Enhanced MIRRORED BITS communications to monitor internal element conditions between relays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.

Ethernet Access. Access all relay functions with the optional Ethernet card. Interconnect with automation systems using IEC 61850 or DNP3 LAN/WAN protocols directly or DNP3 through an SEL-2032 Communications Processor. Use file transfer protocol (FTP) for high-speed data collection.

Increased Security. The SEL-421 divides control and settings into seven relay access levels; the relay has separate breaker, protection, automation, and output access levels, among others. Set unique passwords for each access level.

Rules-Based Settings Editor. Communicate with and set the relay using an ASCII terminal, or use the PC-based ACSELERATOR QuickSet SEL-5030 Software to configure the SEL-421 and analyze fault records with relay element response. View real-time phasors.

Settings Reduction. Internal relay programming shows only the settings for the functions and elements you have enabled.

Thermal Overload Modeling. Use the SEL-421 with the SEL-2600A RTD Module for dynamic overload protection using SELOGIC control equations. For more information, see SEL Application Guide *AG2003-06, Implementation of the* SEL-*49 Relay Line Thermal Protection Using the* SEL-421 *Relay SELOGIC Equations*.

Alias Settings. Use as many as 200 aliases to rename any digital or analog quantity in the relay. The aliases are now available for use in customized programming, making the initial programming and maintenance much easier.

Auxiliary {TRIP}/{CLOSE} Pushbuttons. The part number indicates whether the relay has auxiliary **{TRIP}** and **{CLOSE}** pushbuttons. These pushbuttons are shown in *Figure 5.2*. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

Part numbers 0421*xxxxxxxxxx*3A*xxxxx*, 0421*xxxxxxxxxx*7A*xxxxx*, 0421*xxxxxxxxxx*3B*xxxxx*, and 0421*xxxxxxxxxx*7B*xxxxx* designate relays *with* the auxiliary **{TRIP}** and **{CLOSE}** pushbuttons.

The lowercase *x*s in the above part numbers represent fields that contain other values that are not important in determining the operator controls of the relay. Refer to the SEL-421 Model Option Table for complete part number details. These tables are available on the SEL website or from the factory.

Models and Options

Consider the following options when ordering and configuring the SEL-421.

- Chassis size
  - 3U, 4U, and 5U
    (U is one rack unit—1.75 inches or 44.45 mm)
- Main board I/O

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B.

  - Main Board A:

    Contact inputs: 5 independent and 2 common inputs (programmable pickup threshold);
    Contact outputs: 2 standard Form A, 3 standard Form C, and 3 High-Current Interrupting Form A outputs
  - Main Board B:

    Contact inputs: 5 independent and 2 common inputs (level sensitive and optoisolated);
    Contact outputs: 2 standard Form A, 3 standard Form C, and 3 High-Current Interrupting Form A outputs
- Additional I/O board (for 4U and 5U chassis)

NOTE: The SEL-421-0 and the SEL-421-1 do not support I/O boards INT2, INT3, INT7, and INT8.

  - INT1:

    Contact inputs: 8 independent inputs (programmable pickup threshold);
    Contact outputs: 13 standard Form A and 2 standard Form C outputs
  - INT2:

    Contact inputs: 8 independent inputs (level sensitive and optoisolated);
    Contact outputs: 13 standard Form A and 2 standard Form C outputs
  - INT3:

    Contact inputs: 18 common (2 groups of 9) and 6 independent inputs (level sensitive and optoisolated);
    Contact outputs: 4 high-current interrupting Form A outputs
  - INT4:

    Contact inputs: 18 common (2 groups of 9) and 6 independent inputs (level sensitive and optoisolated);
    Contact outputs: 6 Fast High-Current Interrupting Form A and 2 standard Form A outputs
  - INT5:

    Contact inputs: 8 independent inputs (programmable pickup threshold);
    Contact outputs: 8 Fast High-Current Interrupting Form A outputs

- INT6:

  Contact inputs: 8 independent inputs (programmable pickup threshold);
  Contact outputs: 13 High-Current Interrupting Form A and 2 standard Form C outputs

- INT7:

  Contact inputs: 8 independent inputs (level sensitive and optoisolated);
  Contact outputs: 13 High-Current Interrupting Form A and 2 standard Form C outputs

- INT8:

  Contact inputs: 8 independent inputs (level sensitive and optoisolated);
  Contact outputs: 8 Fast High-Current Interrupting Form A outputs

- Chassis orientation and type
  - Horizontal rack mount
  - Horizontal panel mount
  - Vertical rack mount
  - Vertical panel mount
- Power supply
  - 24/48 Vdc
  - 48/125 Vdc or 120 Vac
  - 125/250 Vdc or 120/230 Vac
- Secondary inputs
  - 1 A nominal or 5 A nominal CT inputs.
    300 V phase-to-neutral wye configuration PT inputs
- Communications card options
  - Ethernet card with combinations of 10/100BASE-T and 100BASE-FX media connections on each of two ports
- Communications protocols
  - Complete group of SEL protocols
    (SEL ASCII, SEL Compressed ASCII, SEL Settings File Transfer, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, RTDs, Enhanced MIRRORED BITS Communications), and Synchrophasors (SEL Fast Message and IEEE C37.118 format).
  - Complete group of SEL protocols, Synchrophasors (SEL Fast Message and IEEE C37.118 format), plus DNP3
  - Complete group of SEL protocols, Synchrophasors (SEL Fast Message and IEEE C37.118 format), plus IEC 61850

- Connector type
  - Fixed PT and CT terminal block inputs
  - Plug-in/plug-out PT and shorting CT Connectorized® versions

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Factory Assistance on page U.6.45*). You can also view the latest part number and ordering information on the SEL website at www.selinc.com.

SEL-421 Versions and Supported Features

SEL-421 Features	-0	-1	-2	-3
Protection				
21G Mho Ground Distance and 21P Mho Phase Distance	standard	standard	standard	standard
High-Speed Distance and High-Speed Directional	standard			standard
50N/G Ground, 50P Phase, and 50Q Negative-Sequence—O/C	standard	standard	standard	standard
51N/G Ground, 51P Phase, and 51Q Negative-Sequence Time—O/C	standard	standard	standard	standard
67N/G Ground, 67P Phase, and 67Q Neg.-Seq. Directional—O/C	standard	standard	standard	standard
Programmable Analog Math	standard	standard	standard	standard
Out-of-Step Trip and Block	standard	standard	standard	standard
Load-Encroachment Supervision	standard	standard	standard	standard
Switch-Onto-Fault	standard	standard	standard	standard
Single-Pole Trip	standard	standard	standard	standard
MIRRORED BITS Communications	standard	standard	standard	standard
Zone/Level Timers	standard	standard	standard	standard
Pilot Protection Logic	standard	standard	standard	standard
Series-Compensated Line Logic	standard			standard
Instrumentation and Control				
79 Automatic Reclosing, Voltage Check on Closing, 25 Synchronism Check	standard	standard	standard	standard
Fault Locating	standard	standard	standard	standard
SELOGIC Control Equations	standard	standard	standard	standard
Maximum Automation SELOGIC Control Equations	1000	100	100	1000
Substation Battery Monitor	standard	standard	standard	standard
Breaker Wear Monitor	standard	standard	standard	standard
Event Report (Multicycle Data) and Sequential Events Recorder	standard	standard	standard	standard
Instantaneous, RMS, and Demand Meter	standard	standard	standard	standard
DNP3 Level 2 Slave	standard	optional	optional	optional
Synchrophasors (IEEE C37.118 and SEL-Fast Message)[a]	standard	standard	standard	standard
Remote Synchrophasor Measurement[b]			standard	standard

SEL-421 Features	-0	-1	-2	-3
Contact Input Option				
Main Board A—User-Settable Level-Sensitive Contact Inputs	standard	standard	optional	optional
Main Board B—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional
INT1 Interface Board—User-Settable Level-Sensitive Contact Inputs	optional	optional	optional	optional
INT2 Interface Board—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional
INT3 Interface Board—Optoisolated Level-Sensitive Contact Inputs[d]			optional	optional
INT4 Interface Board—Optoisolated Level-Sensitive Contact Inputs[e]	optional	optional	optional	optional
INT5 Interface Board—User-Settable Level-Sensitive Contact Inputs	optional	optional	optional	optional
INT6 Interface Board—User-Settable Level-Sensitive Contact Inputs	optional	optional	optional	optional
INT7 Interface Board—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional
INT8 Interface Board—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional

[a] Firmware versions R102–R112 provide synchrophasors using the SEL Fast Message protocol in the SEL-421-0.
[b] Firmware versions R123 and older do not provide this feature.
[c] Firmware versions R115 and older do not provide support for Main Board B, INT2, INT7, and INT8 interface boards.
[d] Firmware versions R121 and older do not provide support for the INT3 interface board.
[e] Firmware versions R112 and older do not provide support for the INT4 interface board.

Applications

Use the SEL-421 in a variety of transmission line protection applications. For information on connecting the relay, see *Installation on page U.2.1*. See the *Applications Handbook* for thorough discussions of protection and automation applications using the SEL-421.

The figures in this subsection illustrate common relay application configurations. *Figure 1.3*, *Figure 1.4*, *Figure 1.5*, *Figure 1.6*, and *Figure 1.7* demonstrate relay versatility with Global setting ESS (Current and Voltage Source Selection). These figures show the power and simplicity of the four preprogrammed ESS options. For more information on setting ESS, see *Current and Voltage Source Selection on page R.1.2*.

The SEL-421 has two sets of three-phase analog current inputs, IW and IX, and two sets of three-phase analog voltage inputs, VY and VZ. The drawings that follow use a two-letter acronym to represent all three phases of a relay analog input. For example, IW represents IAW, IBW, and ICW for A-, B-, and C-phase current inputs on terminal W, respectively. The drawings list a separate phase designator if you need only one or two phases of the analog input set (VAZ for the A-phase voltage of the VZ input set, for example).

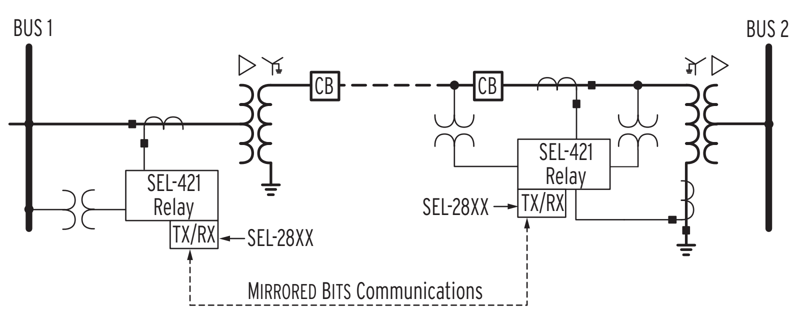
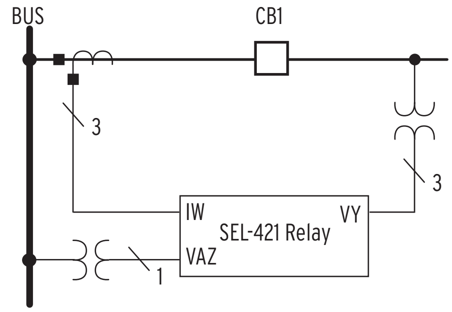
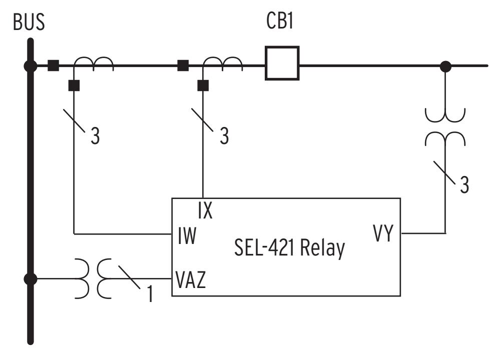


Figure 1.2 Protecting a Line Segment With MIRRORED BITS Communications on a Fiber Channel



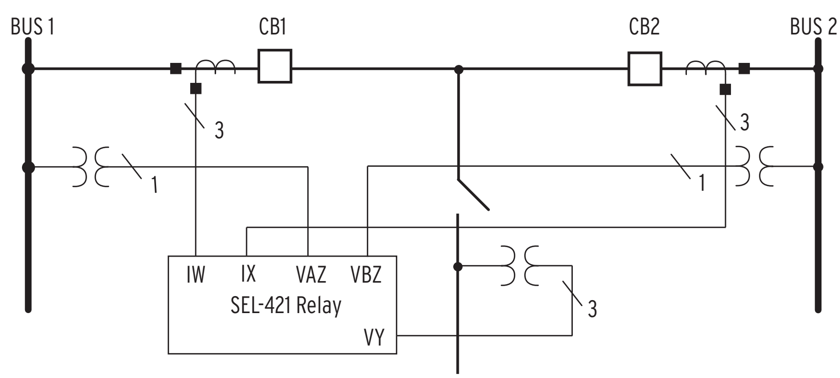
Analog Input	Function
IW	CB1 protection, line protection
VY	Line protection
VAZ	Synchronism check

Figure 1.3 Single Circuit Breaker Configuration (ESS := 1)



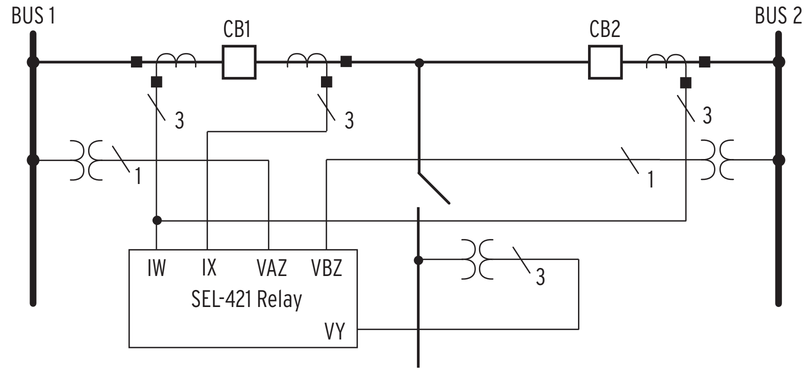
Analog Input	Function
IW	CB1 protection, line protection
IX	CB1 breaker failure
VY	Line protection
VAZ	Synchronism check

Figure 1.4 Single Circuit Breaker Configuration With Line Breaker CTs (ESS := 2)



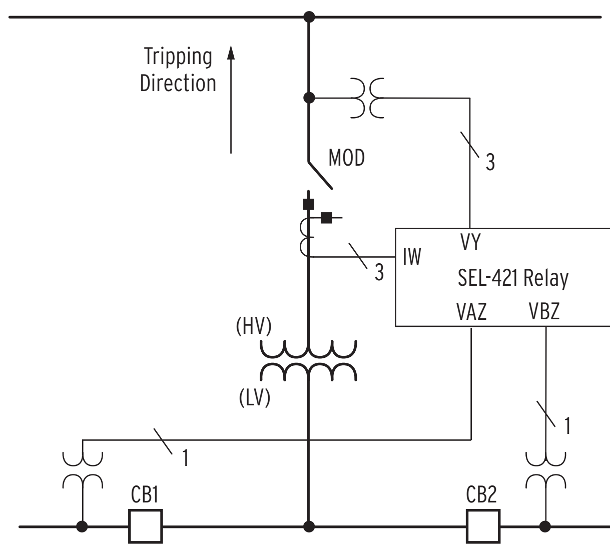
Analog Input	Function
IW+IX	Line Protection
IW	CB1 protection
IX	CB2 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.5 Double Circuit Breaker Configuration (ESS := 3)



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

Figure 1.6 Double Circuit Breaker Configuration With Bus Protection (ESS := 4)



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

Figure 1.7 Tapped Line (ESS := Y)

Application Highlights

NOTE: The SEL-421-1 and the SEL-421-2 do not provide high-speed directional elements and high-speed distance elements.

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

Apply the SEL-421 in power system protection and control situations. *Table 1.1* lists applications and key features of the relay.

Table 1.1 Application Highlights (Sheet 1 of 2)

Application	Key Features
Single-pole and three-pole tripping	High-speed distance elements Best Choice Ground Directional element Secure protection during open-pole interval Pole-discordance logic trips three-pole for excessive single-pole-open conditions
Multiple-breaker tripping	SPT one; 3PT other SPT both; 3PT both Breaker failure protection
Reclosing and synchronism check	2 shots SPT; 4 shots 3PT Leader/follower breaker arrangements Two-circuit-breaker universal synchronism check
Coupling-Capacitor Voltage Transformer (CCVT) transient detection logic	Detect CCVT transients to provide correct operation of the direct tripping (Zone 1) distance elements
Long lines	Load-encroachment elements prevent unwanted trips on load Voltage elements detect local bus overvoltages Sensitive negative-sequence and residual overcurrent elements provide sensitive backup protection
Tapped and three-terminal lines	Five zones Three zero-sequence compensation factors for more accurate ground-distance reach on either side of tap Independent reach settings for phase, ground mho, and ground quadrilateral elements Multiple settings groups cover any switching configurations
Bus-tie or transfer circuit breakers	Multiple setting groups Match relay settings group to each line substitution Eliminate current reversing switches Local or remote operator switches the setting groups
Subtransmission lines	Time-step distance protection Ground directional overcurrent protection Torque-controlled time-overcurrent elements
Lines with capacitors	Series-compensated line logic
Lines with transformers	Negative-sequence overcurrent protection
Short transmission lines	Directional overcurrent elements and communications-assisted tripping schemes
Permissive Overreaching Transfer Tripping (POTT) schemes	Current reversal guard logic Open breaker echo keying logic Weak-infeed and zero-infeed logic Time-step distance backup protection
Directional Comparison Unblocking Tripping (DCUB) schemes	Includes all POTT logic All loss-of-channel logic is inside the relay Time-step distance backup protection
Permissive Underreaching Transfer Tripping (PUTT) schemes	Supported by POTT logic Time-step distance backup protection

Table 1.1 Application Highlights (Sheet 2 of 2)

Application	Key Features
Directional Comparison Blocking Trip (DCB) schemes	Current reversal guard logic Carrier coordinating timers Carrier send and receive extend logic Zone 3 latch eliminates the need for offset three-phase distance elements Time-step distance backup protection
Direct Transfer Tripping (DTT) schemes	SELOGIC control equations program the elements that key direct tripping
SCADA applications	Analog and digital data acquisition for station wide functions
Communications capability	SEL ASCII Enhanced MIRRORED BITS communications SEL Fast Meter, SEL Fast Operate, SEL Fast SER SEL Compressed ASCII Phasor Measurement Unit (PMU) protocols RTD Optional Serial DNP3 Optional protocols: Ethernet, IEC 61850, DNP3 (Ethernet), FTP, Telnet
Customized protection and automation schemes	Separate protection and automation SELOGIC control equation programming areas Use timers and counters in expanded SELOGIC control equations for complete flexibility
Synchrophasors	The SEL-421 can function as a phasor measurement unit (PMU) at the same time as it provides best-in-class protective relay functions. C37.118 message format allows up to eight current and four voltage synchronized measurements, up to 60 messages per second (on a 60 Hz nominal power system). Two choices of filter response, settable angle correction, and choice of numeric representation makes the data usable for a variety of synchrophasor applications. SEL Fast Operate commands are available on the synchrophasor communications ports, allowing control actions initiated by the synchrophasor processor. SEL Fast Message Synchrophasor format is also available, with up to four current and four voltage synchronized measurements.

NOTE: Starting with SEL-421 firmware version R112, synchrophasors are available in the SEL-421-1.

Specifications

Important: Do not use the following specification information to order an SEL-421. Refer to the actual ordering information sheets.

General

AC Current Inputs (Secondary Circuits)

Note: Current transformers are Measurement Category II.

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

AC Voltage Inputs

300 V_{L-N} continuous (connect any voltage up to 300 Vac)

600 Vac for 10 seconds

Burden:	0.03 VA at 67 V 0.06 VA at 120 V 0.8 VA at 300 V

Power Supply

125/250 Vdc or 120/230 Vac

Range:	85–300 Vdc <35 W or 85–264 Vac
Nominal Frequency:	50/60 Hz
Range:	30–120 Hz
Burden:	<120 VA

48/125 Vdc or 120 Vac

Range:	38–140 Vdc <35 W or 85–140 Vac
Nominal Frequency:	50/60 Hz
Range:	30–120 Hz
Burden:	<120 VA

24/48 Vdc

Range:	18–60 Vdc
Burden:	<35 W

Control Outputs

Standard

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1s Rating:	50 A
MOV Protection (maximum voltage):	250 Vac/330 Vdc
Pickup/Dropout Time:	6 ms, resistive load
Update Rate:	1/8 cycle

Break Capacity (10000 operations):

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 Capacity (2.5 cycle/second):

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

Note: EA certified relays do not have MOV protected standard output contacts.

Hybrid (high current interrupting):

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1s Rating:	50 A
MOV Protection (maximum voltage):	330 Vdc
Pickup/Dropout Time:	6 ms, resistive load
Update Rate:	1/8 cycle

Break Capacity (10000 operations):

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):

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

Note: Do not use hybrid control outputs to switch ac control signals. These outputs are polarity dependent.

Fast Hybrid (high-speed high current interrupting):

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (maximum voltage):	250 Vac/330 Vdc
Pickup Time:	10 µs, resistive load
Dropout Time:	8 ms, resistive load
Update Rate:	1/8 cycle

Break Capacity (10000 operations):

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):

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

Note: Per IEC 60255-23:1994, using the simplified method of assessment.
Note: Make rating per IEEE C37.90-1989.

Auxiliary Trip/Close Pushbuttons (Select Models Only)

Resistive DC or AC Outputs with Arc Suppression Disabled:

Make:	30 A
Carry:	6 A continuous carry

1 s Rating:	50 A
MOV Protection:	250 Vac/330 Vdc/130 J

Breaking Capacity (1000 operations):

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

Note: Make per IEEE C37.90-1989.

High Interrupt DC Outputs with Arc Suppression Enabled:

Make:	30 A
Carry:	6 A continuous carry
1 s Rating:	50 A
MOV Protection:	330 Vdc/130 J

Breaking Capacity (10000 operations):

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

Note: Make per IEEE C37.90-1989.

Breaker Open/Closed LEDs:

250 Vdc:	on for 150–300 Vdc; 192–288 Vac
125 Vdc:	on for 80–150 Vdc; 96–144 Vac
48 Vdc:	on for 30–60 Vdc;
24 Vdc:	on for 15–30 Vdc

Note: With nominal control voltage applied, each LED draws 8 mA (max.). Jumpers may be set to 125 Vdc for 110 Vdc input and set to 250 Vdc for 220 Vdc input.

Control Inputs

Direct Coupled (for use with dc signals)

Main Board A:	5 inputs with no shared terminals 2 inputs with shared terminals
INT1, INT5, and INT6 interface boards:	8 inputs with no shared terminals
Range:	15–265 Vdc, independently adjustable
Accuracy:	±5% plus ±3 Vdc
Maximum Voltage:	300 Vdc
Sampling Rate:	1/16 cycle
Typical Burden:	0.24 W at 125 Vdc

Optoisolated (use with ac or dc signals)

Main Board B:	5 inputs with no shared terminals 2 inputs with shared terminals
INT2, INT7, and INT8 interface boards:	8 inputs with no shared terminals
INT3 and INT4 interface board:	6 inputs with no shared terminals 18 inputs with shared terminals (2 groups of 9 inputs with each group sharing one terminal)
Voltage Options:	24 V standard 48, 110, 125, 220, 250 V level sensitive

DC Thresholds
(Dropout thresholds indicate level-sensitive option):

24 Vdc:	Pickup 15.0–30.0 Vdc rms
48 Vdc:	Pickup 38.4–60.0 Vdc; Dropout <28.8 Vdc
110 Vdc:	Pickup 88.0–132.0 Vdc; Dropout <66.0 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout <75 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout <132 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout <150 Vdc

AC Thresholds (Ratings met only when recommended control input settings are used—see *Table 2.2 on page U.2.7*.):

24 Vac:	Pickup 12.8–30.0 Vac rms
48 Vac:	Pickup 32.8–60.0 Vac rms; Dropout <20.3 Vac rms
110 Vac:	Pickup 75.1–132.0 Vac rms; Dropout <46.6 Vac rms
125 Vac:	Pickup 89.6–150.0 Vac rms; Dropout <53.0 Vac rms
220 Vac:	Pickup 150–264 Vac rms; Dropout <93.2 Vac rms
250 Vac:	Pickup 170.6–300 Vac rms; Dropout <106 Vac rms
Current Drawn:	5 mA at nominal voltage 8 mA for 110 V option
Sampling Rate:	1/16 cycle

Frequency and Rotation

System Frequency:	50/60 Hz
Phase Rotation:	ABC or ACB
Frequency Tracking Range:	40–65 Hz

Communications Ports

EIA-232:	1 Front and 3 Rear
Serial Data Speed:	300–57600 bps

Communications Card Slot for optional Ethernet Processor

Fiber Optic (Optional)

Ordering Options:

Mode:	Multi	Multi
Wavelength (nm):	820	1300
Source:	LED	LED
Connector type:	ST	ST
Min. TX Pwr. (dBm):	–15.8	–19
Max. TX Pwr. (dBm):	12	–14
RX Sens. (dBm):	–34.4	–32
Sys. Gain (dB):	5	13

Time Inputs

IRIG-B Input—Serial Port 1

Input:	Demodulated IRIG-B
Nominal Voltage:	5 Vdc +10%
Maximum Voltage:	8 Vdc
Input Impedance:	333 ohms
Isolation:	500 Vdc

IRIG-B Input—BNC Connector

Input:	Demodulated IRIG-B
Nominal Voltage:	5 Vdc +10%
Maximum Voltage:	8 Vdc
Input Impedance:	2500 ohms

Operating Temperature

Without Ethernet: –40° to +85°C (–40° to +185°F)

With Ethernet: –40° to +75°C (–40° to +167°F)

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

Humidity

5% to 95% without condensation

Weight (Maximum)

3U Rack Unit: 8.0 kg (17.5 lbs)
4U Rack Unit: 9.8 kg (21.5 lbs)
5U Rack Unit: 11.6 kg (25.5 lbs)

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum: 1.0 Nm (9 in-lb)
Maximum: 2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Sizes and Insulation

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:

Connection Type	Minimum Wire Size	Maximum Wire Size
Grounding (Earthing) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Current Connection	16 AWG (1.5 mm^2)	12 AWG (4 mm^2)
Potential (Voltage) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Other Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)

Use wire with 0.4 mm-thick insulation for high-voltage connections to allow for contact between adjacent wires. If possible, use 0.4 mm insulated wires for all connections.

Routine Dielectric Strength Tests (Performed on Each Manufactured Relay)

AC Current Inputs, optoisolated inputs, and output contacts: 2500 Vac for 10 s

Power Supply: 3100 Vdc for 10 s

Type Tests

Electromagnetic Compatibility Emissions

Emissions: IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity: IEC 60255-22-6:2001
Severity Level: 10 Vrms
IEC 61000-4-6:2008
Severity Level: 10 Vrms

Electrostatic Discharge Immunity: IEC 60255-22-2:2008
Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEC 61000-4-2:2008
Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEEE C37.90.3-2001
Severity Level: 2, 4, 8 kV contact; 4, 8, 15 kV air

Fast Transient/Burst Immunity: IEC 60255-22-4:2008
Severity Level: Calss A: 4 kV, 5 kHz; 2 kV, 5 kHz on communication ports
IEC 61000-4-4:2011
Severity Level: 4 kV, 5 kHz

Magnetic Field Immunity: IEC 61000-4-8:2009
Severity Level: 900 A/m for 3 seconds, 100 A/m for 1 minute
IEC 61000-4-9:2001
Severity Level: 1000 A/m

Power Supply Immunity: IEC 60255-11:2008
IEC 61000-4-11:2004
IEC 61000-4-29:2000

Radiated Digital Radio Telephone RF Immunity: ENV 50204:1995
Severity Level: 10 V/m at 900 MHz and 1.89 GHz

Radiated Radio Frequency Immunity: IEC 60255-22-3:2007
Severity Level: 10 V/m
IEC 61000-4-3:2010
Severity Level: 10 V/m
IEEE C37.90.2-2004
Severity Level: 35 V/m

Surge Immunity: IEC 60255-22-5:2008
Severity Level: 1 kV Line-to-Line, 2 kV Line-to-Earth
IEC 61000-4-5:2005
Severity Level: 1 kV Line-to-Line, 2 kV Line-to-Earth

Surge Withstand Capability Immunity: IEC 60255-22-1:2007
Severity Level: 2.5 kV peak common mode, 1.0 kV peak differential mode
IEEE C37.90.1-2002
Severity Level: 2.5 kV oscillatory, 4 kV fast transient waveform

Environmental

Cold: IEC 60068-2-1:2007
Severity Level: 16 hours at –40°C

Damp Heat, Cyclic: IEC 60068-2-30:2005
Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity: 95%

Dry Heat: IEC 60068-2-2:2007
Severity Level: 16 hours at +85°C

Vibration: IEC 60255-21-1:1988
Severity Level: Class 1 Endurance, Class 2 Response
IEC 60255-21-2:1988
Severity Level: Class 1–Shock withstand, Bump, and Class 2–Shock Response
IEC 60255-21-3:1993
Severity Level: Class 2 (Quake Response)

Safety

Dielectric Strength: IEC 60255-5:2000
Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.
IEEE C37.90-2005
Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.

Impulse: IEC 60255-5:2000
Severity Level: 0.5 Joule, 5 kV
IEEE C37.90-2005
Severity Level: 0.5 Joule, 5 kV

Safety Agency Certifications

Product Safety: C22.2 No. 14
cUL Listed Protective Relay, Product Category NRGU7
UL 508
UL Listed Protective Relay, Product Category NRGU

Certifications

ISO: Relay is designed and manufactured using ISO 9001:2000 certified quality program.

Product Safety: IEC 60255-6:1988

Reporting Functions

High-Resolution Data

Rate: 8000 samples/second
4000 samples/second
2000 samples/second
1000 samples/second

Output Format: Binary COMTRADE

Note: Per *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999*

Event Reports

Storage: 35 quarter-second events or 24 half-second events

Maximum Duration: Record events as long as 5 seconds

Resolution: 8- or 4-samples/cycle

Event Summary

Storage: 100 summaries

Breaker History

Storage: 128 histories

Sequential Events Recorder

Storage: 1000 entries

Trigger Elements: 250 relay elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency of 3000 Hz.

Digital Filtering

Full-cycle cosine and half-cycle Fourier filters after low-pass analog and digital filtering.

Protection and Control Processing

8 times per power system cycle

Synchrophasors

Maximum data rate in messages per second

IEEE C37.118 protocol: 60 (nominal 60 Hz system)
50 (nominal 50 Hz system)

SEL Fast Message protocol: 20 (nominal 60 Hz system)
10 (nominal 50 Hz system)

Control Points

32 remote bits
32 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

Relay Element Pickup Ranges and Accuracies

Mho Phase Distance Elements

Zones 1–5 Impedance Reach

Setting Range

5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps

1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model: 0.5 A_{P-P} secondary

1 A Model: 0.1 A_{P-P} secondary
(Minimum sensitivity is controlled by the pickup of the supervising phase-to-phase overcurrent elements for each zone.)

Accuracy (Steady State): ±3% of setting at line angle for SIR (source-to-line impedance ratio) < 30
±5% of setting at line angle for 30 ≤ SIR ≤ 60

Zone 1 Transient Overreach: <5% of setting plus steady-state accuracy

SEL-421-0 and SEL-421-3 Maximum Operating Time: 0.8 cycle at 70% of reach and SIR = 1

SEL-421-1 and SEL-421-2 Maximum Operating Time: 1.5 cycle at 70% of reach and SIR = 1

Mho Ground Distance Elements

Zones 1–5 Impedance Reach

Mho Element Reach

5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps

1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model: 0.5 A secondary

1 A Model: 0.1 A secondary
(Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)

Accuracy (Steady State): ±3% of setting at line angle for SIR < 30
±5% of setting at line angle for 30 ≤ SIR ≤ 60

Zone 1 Transient Overreach: <5% of setting *plus* steady-state accuracy

SEL-421-0 and SEL-421-3 Maximum Operating Time: 0.8 cycle at 70% of reach and SIR = 1

SEL-421-1 and SEL-421-2 Maximum Operating Time: 1.5 cycle at 70% of reach and SIR = 1

Quadrilateral Ground Distance Elements

Zones 1–5 Impedance Reach

Quadrilateral Reactance Reach

5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Quadrilateral Resistance Reach

5 A Model:	OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary (Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)

Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting plus steady-state accuracy

Instantaneous/Definite-Time Overcurrent Elements

Phase, Residual Ground, and Negative-Sequence

Pickup Range

5 A Model:	OFF, 0.25–100.00 A secondary, 0.01 A steps
1 A Model:	OFF, 0.05–20.00 A secondary, 0.01 A steps

Accuracy (Steady State)

5 A Model:	±0.05 A plus ±3% of setting
1 A Model:	±0.01 A plus ±3% of setting
Transient Overreach:	<5% of pickup
Time Delay:	0.000–16000.000 cycles, 0.125 cycle steps
Timer Accuracy:	±0.125 cycle plus ±0.1% of setting
Maximum Operating Time:	1.5 cycles

Time-Overcurrent Elements

Pickup Range

5 A Model:	0.25–16.00 A secondary, 0.01 A steps
1 A Model:	0.05–3.20 A secondary, 0.01 A steps

Accuracy (Steady State)

5 A Model:	±0.05 A plus ±3% of setting
1 A Model:	±0.01 A plus ±3% of setting

Time Dial Range

US:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles plus ±4% of curve time (for current between 2 and 30 multiples of pickup)
Reset:	1 power cycle or Electromechanical Reset Emulation time

Ground Directional Elements

Neg.-Seq. Directional Impedance Threshold (Z2F, Z2R)

5 A Model:	–64 to 64 Ω
1 A Model:	–320 to 320 Ω

Zero-Seq. Directional Impedance Threshold (Z0F, Z0R)

5 A Model:	–64 to 64 Ω
1 A Model:	–320 to 320 Ω

Supervisory Overcurrent Pickup 50FP, 50RP

5 A Model:	0.25 to 5.00 A 3I0 secondary 0.25 to 5.00 A 3I2 secondary
1 A Model:	0.05 to 1.00 A 3I0 secondary 0.05 to 1.00 A 3I2 secondary

Undervoltage and Overvoltage Elements

Pickup Ranges:	Phase elements: 1–200 V secondary, 1 V steps
Phase-to-Phase Elements:	1.0–300.0 V secondary, 0.1 V steps
Accuracy (Steady State):	±1 V plus ±5% of setting
Transient Overreach:	<5% of pickup

Optional RTD Elements (Models Compatible With SEL-2600A RTD Module)

12 RTD Inputs via SEL-2600 RTD Module and SEL-2800 Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

PT 100, NI 100, NI 120, and CU 10 RTD-Types Supported, Field Selectable

Up to 500 m Fiber-Optic Cable to SEL-2600 RTD Module

Breaker Failure Instantaneous Overcurrent

Setting Range

5 A Model:	0.50–50.0 A, 0.01 A steps
1 A Model:	0.10–10.0 A, 0.01 A steps

Accuracy

5 A Model:	±0.05 A plus ±3% of setting
1 A Model:	±0.01 A plus ±3% of setting
Transient Overreach:	<5% of setting
Maximum Pickup Time:	1.5 cycles
Maximum Reset Time:	1 cycle
Timers Setting Range:	0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*) 0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)
Time Delay Accuracy:	0.125 cycle plus ±0.1% of setting

Synchronism-Check Elements

Slip Frequency Pickup Range:	0.005–0.500 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.0025 Hz plus ±2% of setting
Close Angle Range:	3–80°, 1° steps
Close Angle Accuracy:	±3°

Load-Encroachment Detection

Setting Range	
5 A Model:	0.05–64 Ω secondary, 0.01 Ω steps
1 A Model:	0.25–320 Ω secondary, 0.01 Ω steps
Forward Load Angle:	–90° to +90°
Reverse Load Angle:	+90° to +270°
Accuracy	
Impedance Measurement:	±3%
Angle Measurement:	±2°

Out-of-Step Elements

Blinders (R1) Parallel to the Line Angle	
5 A Model:	0.05 to 70 Ω secondary –0.05 to –70 Ω secondary
1 A Model:	0.25 to 350 Ω secondary –0.25 to –350 Ω secondary
Blinders (X1) Perpendicular to the Line Angle	
5 A Model:	0.05 to 96 Ω secondary –0.05 to –96 Ω secondary
1 A Model:	0.25 to 480 Ω secondary –0.25 to –480 Ω secondary
Accuracy (Steady State)	
5 A Model:	±5% of setting plus ±0.01 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.01 A for 30 ≤ SIR ≤ 60
1 A Model:	±5% of setting plus ±0.05 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.05 A for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting *plus* steady-state accuracy
Positive-Sequence Overcurrent Supervision	
Setting Range	
5 A Model:	1.0–100.0 A, 0.01 A steps
1 A Model:	0.2–20.0 A, 0.01 A steps
Accuracy	
5 A Model:	±3% of setting plus ±0.05 A
1 A Model:	±3% of setting plus ±0.01 A
Transient Overreach:	< 5% of setting

Timer Specifications

Setting Ranges

Breaker Failure:	0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*) 0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)
Communications-Assisted Tripping Schemes:	0.000–16000 cycles, 0.125 cycle steps
Out-of-Step Timers	
OSBD, OSTD:	0.500–8000 cycles, 0.125 cycle steps
UBD:	0.500–120 cycles, 0.125 cycle steps
Pole Open Timer:	0.000–60 cycles, 0.125 cycle steps
Recloser:	1–99999 cycles, 1 cycle steps
Switch-Onto-Fault	
CLOEND, 52AEND:	OFF, 0.000–16000 cycles, 0.125 cycle steps
SOTFD:	0.50–16000 cycles, 0.125 cycle steps
Synchronism Check Timers	
TCLSBK1, TCLSBK2:	1.00–30.00 cycles, 0.25 cycle steps
Zone Time Delay:	0.000–16000 cycles, 0.125 cycle steps

Station DC Battery System Monitor Specifications

Operating Range:	0–350 Vdc
Input Sampling Rate:	2 kHz
Processing Rate:	1/8 cycle
Maximum Operating Time:	≤1.5 cycles
Setting Range	
DC settings:	15–300 Vdc, 1 Vdc steps
AC ripple setting:	1–300 Vac, 1 Vac steps
Accuracy	
Pickup Accuracy:	±3% plus ±2 Vdc (all elements but DC1RP and DC2RP) ±10% plus ±2 Vac (DC1RP and DC2RP)

Metering Accuracy

All metering accuracy is at 20°C, and nominal frequency unless otherwise noted.

Currents

Phase Current Magnitude	
5 A Model:	±0.2% plus ±4 mA (2.5–15 A sec)
1 A Model:	±0.2% plus ±0.8 mA (0.5–3 A sec)
Phase Current Angle	
All Models:	±0.2° in the current range 0.5 • I_{nom} to 3.0 • I_{nom}
Sequence Currents Magnitude	
5 A Model:	±0.3% plus ±4 mA (2.5–15 A sec)
1 A Model:	±0.3% plus ±0.8 mA (0.5–3 A sec)
Sequence Current Angle	
All Models:	±0.3° in the current range 0.5 • I_{nom} to 3.0 • I_{nom}

Voltages

Phase and Phase-to-Phase Voltage Magnitude:	± 0.1% (33.5–200 V_{L-N})
Phase and Phase-to-Phase Angle:	±0.05° (33.5–200 V_{L-N})
Sequence Voltage Magnitude:	±0.15% (33.5–200 V_{L-N})
Sequence Voltage Angle:	±0.1° (33.5–200 V_{L-N})

Frequency (Input 40–65 Hz)

Accuracy:	±0.01 Hz

Power and Energy

Real Power, P (MW), Three Phase

At 0.1 • I_{nom}

Power factor unity:	±0.4%
Power factor 0.5 lag, 0.5 lead:	±0.7%

At 1.0 • I_{nom}

Power factor unity:	±0.4%
Power factor 0.5 lag, 0.5 lead:	±0.4%

Reactive Power, Q (MVAR), Three Phase

At 0.1 • I_{nom}

Power factor 0.5 lag, 0.5 lead:	±0.5%

At 1.0 • I_{nom}

Power factor 0.5 lag, 0.5 lead:	±0.4%

Energy (MWh), Three Phase

At 0.1 • I_{nom}

Power factor unity:	±0.5%
Power factor 0.5 lag, 0.5 lead:	±0.7%

At 1.0 • I_{nom}

Power factor unity:	±0.4%
Power factor 0.5 lag, 0.5 lead:	±0.4%

Synchrophasors

See *Accuracy on page R.7.9* for test exclusions and details.

TVE (total vector error):	£1%
Frequency Range:	±5 Hz of nominal (50 or 60 Hz)
Voltage Range:	30 V–150 V
Current Range:	(0.1–2) • I_{nom} (I_{nom} = 1 A or 5 A)
Phase Angle Range:	–179.99° to 180°

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Section 2
Installation

The first steps in applying the SEL-421 Relay are installing and connecting the relay. This section describes common installation features and particular installation requirements for the many physical configurations of the SEL-421. You can order the relay in horizontal and vertical orientations, and in panel-mount and rack-mount versions. SEL also provides various expansion I/O (input/output) interface boards to tailor the relay to your specific needs.

To install and connect the relay safely and effectively, you must be familiar with relay configuration features and options and relay jumper configuration. You should carefully plan relay placement, cable connection, and relay communication. Consider the following when installing the SEL-421:

- ➤ *Shared Configuration Attributes on page U.2.1*
- ➤ *Plug-In Boards on page U.2.12*
- ➤ *Jumpers on page U.2.18*
- ➤ *Relay Placement on page U.2.30*
- ➤ *Connection on page U.2.31*
- ➤ *AC/DC Connection Diagrams on page U.2.50*

It is also very important to limit access to the SEL-421 settings and control functions by using passwords. For information on relay access levels and passwords, see *Changing the Default Passwords: Terminal on page U.4.9*.

Shared Configuration Attributes

There are common or shared attributes among the many possible configurations of SEL-421 relays. This section discusses the main shared features of the relay.

Relay Sizes

SEL produces the SEL-421 in horizontal and vertical rack-mount versions and horizontal and vertical panel-mount versions. Relay sizes correspond to height in rack units, U, where U is approximately 1.75 inches or 44.45 mm. The SEL-421 is available in 3U, 4U, and 5U sizes.

Front-Panel Templates

The horizontal front-panel template shown in *Figure 2.1* is the same for all 3U, 4U, and 5U horizontal versions of the relay. The vertical front-panel template (shown in *Figure 2.1*) is the same for all 3U, 4U, and 5U vertical versions of the relay.

The SEL-421 front panel has three pockets for slide-in labels: one pocket for the target LED label, and two pockets for the operator control labels. *Figure 2.1* shows the front-panel pocket areas and openings for typical horizontal and vertical relay orientations; dashed lines denote the pocket areas. Refer to the instructions included in the Configurable Label kit for information on reconfiguring front-panel LED and pushbutton labels.

Rear Panels

Rear panels are identical for the horizontal and the vertical configurations of the relay. *Figure 2.2* is an example of a rear panel for a 3U relay with fixed terminal block analog inputs. *Figure 2.3* shows a rear panel for a 3U relay with Connectorized® analog inputs. See *Rear-Panel Layout on page U.2.32* for representative 3U, 4U, and 5U relay rear panels (large drawings are in *Figure 2.28*, *Figure 2.29*, *Figure 2.30*, and *Figure 2.33*).

Connector Types

Screw Terminal Connectors—I/O and Monitor/Power

Connect to the relay I/O and Monitor/Power terminals on the rear panel through screw terminal connectors. You can remove the entire screw terminal connector from the back of the relay to disconnect relay I/O, dc battery monitor, and power without removing each wire connection. The screw terminal connectors are keyed (see *Figure 2.37*), so you can replace the screw terminal connector on the rear panel only at the location from which you removed the screw terminal connector. In addition, the receptacle key prevents you from inverting the screw terminal connector, making removal and replacement easier.

Secondary Circuit Connectors

Fixed Terminal Blocks

Connect PT and CT inputs to the fixed terminal blocks in the bottom row of the relay rear panel.

You cannot remove these terminal blocks from the relay rear panel. These terminals offer a secure high-reliability connection for PT and CT secondaries.

Connectorized

The Connectorized SEL-421 features receptacles that accept plug-in/plug-out connectors for terminating PT and CT inputs; this requires ordering a wiring harness (SEL-WA0421) with mating plugs and wire leads. *Figure 2.3* shows the relay 3U chassis with Connectorized CT and PT analog inputs (see *Connectorized on page U.2.42* for more information).

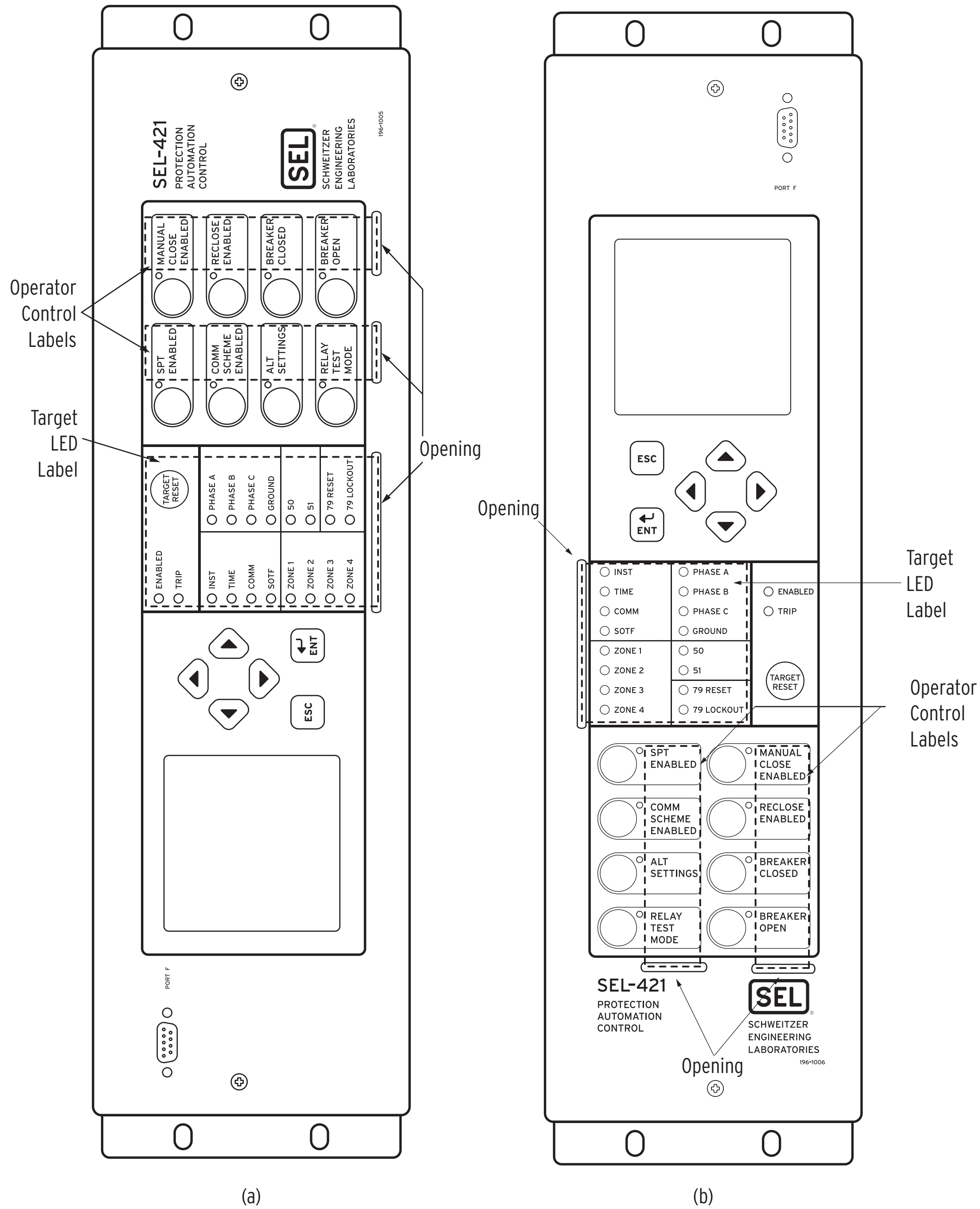

Figure 2.1 Horizontal Front-Panel Template (a); Vertical Front-Panel Template (b)

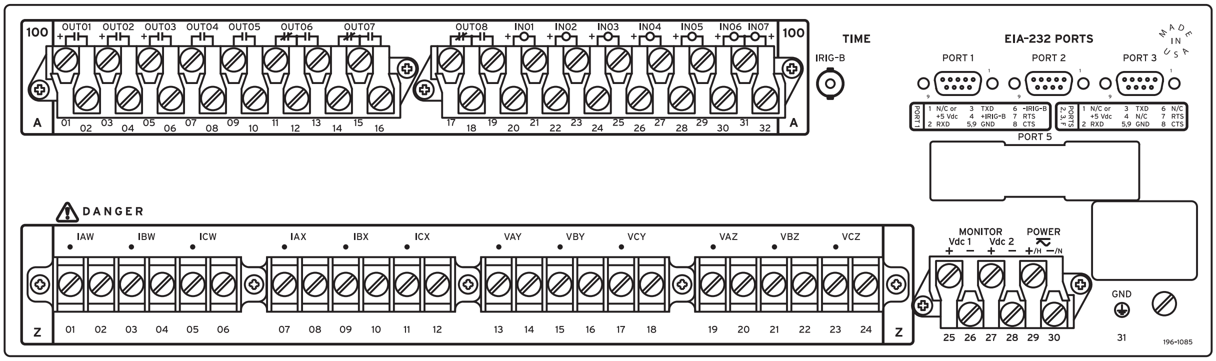

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Figure 2.2 Rear 3U Template, Fixed Terminal Block Analog Inputs

(In a vertical-mount relay, the right rear side is at the top.)

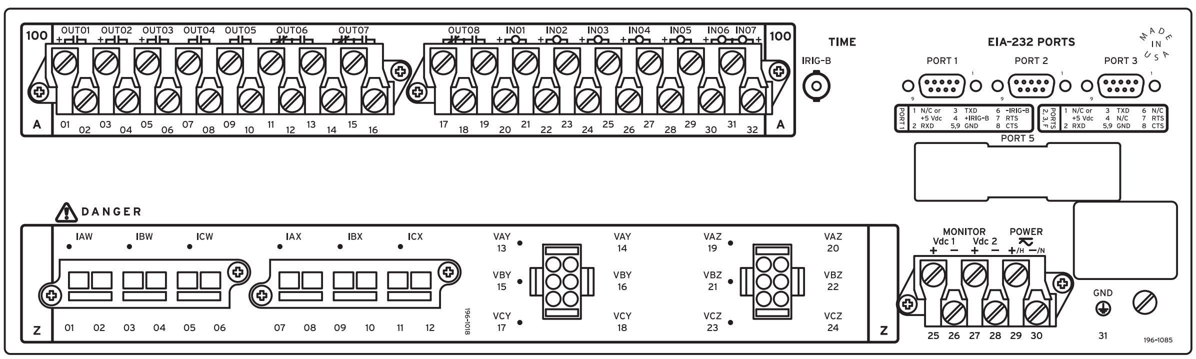

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Figure 2.3 Rear 3U Template, Connectorized Analog Inputs

(In a vertical-mount relay, the right rear side is at the top.)

Secondary Circuits

The SEL-421 is a very low burden load on the CT secondaries and PT secondaries. For both the CT and PT inputs, the frequency range is 40–65 Hz.

The relay accepts two sets of three-phase currents from power system CT inputs:

- ➤ IAW, IBW, and ICW
- ➤ IAX, IBX, and ICX

For 5 A relays, the rated nominal input current, I_{nom}, is 5 A. For 1 A relays, the rated nominal input current, I_{nom}, is 1 A.

Input current for both relay types can range to 20 • I_{nom}. The CT burden for each relay is the following:

- ➤ 5 A relay: 0.27 VA @ 5A and 2.51 VA @ 15 A
- ➤ 1 A relay: 0.13 VA @ 1 A and 1.31 VA @ 3A

See the *AC Current Inputs (Secondary Circuits) on page U.1.13* for complete CT input specifications.

The relay also accepts two sets of three-phase, four-wire (wye) potentials from power system PT or CCVT (coupling-capacitor voltage transformer) secondaries:

- VAY, VBY, and VCY
- VAZ, VBZ, and VCZ

The nominal line-to-neutral input voltage for the PT inputs is 67 volts with a range of 0–300 volts. The PT burden is less than 0.5 VA at 67 volts, L-N. See *AC Voltage Inputs on page U.1.13* for complete PT input specifications.

Some applications do not use all three phases of a source; for example, voltage synchronization sources can be single phase. See *Section 1: Protection Application Examples in the Applications Handbook* for examples of connections to the potential inputs.

See *Secondary Circuit Connections on page U.2.41* for information on connecting power system secondary circuits to these inputs.

Control Inputs

Direct Coupled

NOTE: The SEL-421 Main Board A and the INT1, INT5, and INT6 I/O interface boards have polarity-sensitive inputs, and the terminals are identified with a polarity mark.

The SEL-421 Main Board A inputs, and the inputs on the optional I/O interface boards (INT1, INT5, or INT6 I /O boards—see *Models and Options on page U.1.5*), are direct-coupled, high-impedance control inputs. Use these inputs for monitoring on/off and logical change-of-state conditions of power system equipment. These high-isolation control inputs are polarity-sensitive circuits. You cannot damage these inputs with a reverse polarity connection, although the relay will not detect input changes with a reverse-polarity input. For more information on control input specifications, see *Control Inputs on page U.1.14*.

Inputs can be independent or common. Independent inputs have two separate ground-isolated connections to a high-isolation ADC (analog to digital converter). There are no internal connections among independent inputs. Common inputs share one input leg in common; all input legs of common inputs are ground-isolated. Each pair of common inputs is isolated from all other pairs.

Nominal current draw for these inputs is very low (4 mA or less) with an input voltage range of 15 Vdc to 265 Vdc. You can adjust the level at which these inputs assert (and deassert) and can also debounce the control inputs. See *Global Settings on page R.10.4* for the default settings and more information.

To ensure secure performance of the control inputs, set the control input pickup level according to the battery voltage level. *Table 2.1* lists some of the common DC voltage levels and appropriate settings.

Table 2.1 Recommended Control Input Pickup Settings (Sheet 1 of 2)

Substation DC Voltage Level	Recommended Settings	
	Pickup: GINP[a]	Dropout: GINDF
24	18 Vdc	85%
48	36 Vdc	85%
110	88 Vdc	80%
125	100 Vdc	80%

Table 2.1 Recommended Control Input Pickup Settings (Sheet 2 of 2)

Substation DC Voltage Level	Recommended Settings	
	Pickup: GINP[a]	Dropout: GINDF
220	176 Vdc	80%
250	200 Vdc	80%

[a] Applies to IN1nnP, IN2nnP, IN3nnP when global setting EICIS := Y.

The control input accuracy is ±5 percent of the applied signal plus ±3 Vdc. The maximum voltage input is 300 Vdc, and the relay samples the control inputs 16 times per cycle. See *Raw and Filtered Data on page A.3.2*.

Optoisolated

The SEL-421 Main Board B inputs, and the inputs on the optional I/O interface boards (INT2, INT3, INT4, INT7, or INT8 I/O boards—see *Models and Options on page U.1.5*), are fixed pickup threshold, optoisolated, control inputs. The pickup voltage level is determined for each board at ordering time.

NOTE: The SEL-421 Main Board B and the INT2, INT3, INT4, INT7, and INT8 I/O interface boards have optoisolated contact inputs that can be used in either polarity.

Use these inputs for monitoring change-of-state conditions of power system equipment. These high-isolation control inputs are ground-isolated circuits and are not polarity sensitive. In other words, the relay will detect input changes with voltage applied at either polarity.

Inputs can be independent or common. Independent inputs have two separate ground-isolated connections, with no internal connections among inputs. Common inputs share one input leg in common; all input legs of common inputs are ground isolated. Each group of common inputs is isolated from all other groups.

Nominal current drawn by these inputs is 8 mA or less with 6 voltage options covering a wide range of voltages, as listed in *Control Inputs on page U.1.14*. You can debounce the control input pickup delay and dropout delay separately for each input, or you can use a single debounce setting that applies to all the contact input pickup and dropout times—see *Global Settings on page R.10.4*.

AC Control Signals

Optoisolated control inputs can be used with ac control signals, within the ratings shown in *Control Inputs on page U.1.14*. Specific pickup and dropout time-delay settings are required to achieve the specified ac thresholds, as shown in *Table 2.2*.

NOTE: Only the optoisolated control inputs can be used to detect ac control signals. Direct-coupled control inputs can only be used with dc control signals.

It is possible to mix ac and dc control signal detection on the same interface board with optoisolated contact inputs, provided that the two signal types are not present on the same set of combined inputs. Use standard debounce time settings (usually the same value in both the pickup and dropout settings) for the inputs being used with dc control voltages.

Table 2.2 Required Settings for Use with AC Control Signals[a]

Global Settings	Description	Entry[b]	Relay Recognition Time for AC Control Signal state change
IN*nmm*PU[c]	Pickup Delay	0.1250 cycles	0.625 cycles maximum (assertion)
IN*nmm*DO[c]	Dropout Delay	1.0000 cycle	1.1875 cycles maximum (deassertion)

[a] First set Global setting EICIS := Y to gain access to the individual input pickup and dropout timer settings.
[b] These are the only setting values that SEL recommends for detecting ac control signals. Other values may result in inconsistent operation.
[c] Where n is 1 for Main Board, 2 for Interface Board 1, and 3 for Interface Board 2; mm is number of available contact inputs depending on the type of board.

The recognition times listed in *Table 2.2* are only valid when:

- The ac signal applied is at the same frequency as the power system.
- The signal is within the ac threshold pickup ranges defined in *Optoisolated (use with ac or dc signals) on page U.1.14*.
- The signal contains no dc offset.

The SEL-421 samples the optoisolated inputs 16 times per cycle—see *Raw and Filtered Data on page A.3.2*.

Control Outputs

NOTE: EA certified relays do not have MOV protected standard output contacts.

I/O control outputs from the relay include Standard outputs, Hybrid (high-current-interrupting) outputs, and Fast Hybrid (fast high-current-interrupting) outputs. Fast Hybrid outputs are available only on the optional INT4, INT5, or INT8 I/O interface boards. An MOV (metal-oxide varistor) protects against excess voltage transients for each contact. Each output is individually isolated, except Form C outputs, which share a common connection between the NC (normally closed) and NO (normally open) contacts.

The relay updates control outputs eight times per cycle. Updating of relay control outputs does not occur when the relay is disabled. When the relay is reenabled, the control outputs assume the state that reflects the present protection processing.

Standard Control Outputs

NOTE: You can use ac or dc circuits with Standard control outputs.

The Standard control outputs are “dry” Form A contacts rated for tripping duty. Ratings for Standard outputs are 30 A make, 6 A continuous, and 0.5 A or less break (depending on circuit voltage). Standard contact outputs have a maximum voltage rating of 250 Vac/330 Vdc. Maximum break time is 6 ms (milliseconds) with a resistive load. The maximum pickup time for the Standard control outputs is 6 ms. *Figure 2.4* shows a representative connection for a Form A Standard control output on the main board I/O terminals.

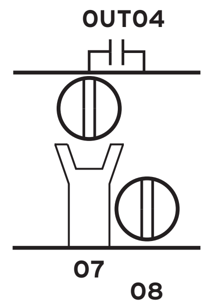


Figure 2.4 Standard Control Output Connection

See *Control Outputs on page U.1.13* for complete standard control output specifications.

Hybrid (High-Current-Interrupting) Control Outputs

⚠CAUTION
Equipment damage can result from connecting ac circuits to Hybrid (high-current-interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.

The Hybrid (high-current-interrupting) control outputs are polarity dependent and are capable of interrupting high-current, inductive loads. Hybrid control outputs use an IGBT (Insulated Gate Bipolar Junction Transistor) in parallel with a mechanical contact to interrupt (break) highly inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients.

With any hybrid output, break time varies according to the L/R (circuit inductive/resistive) ratio. As the L/R ratio increases, the time needed to interrupt the circuit fully increases also. The reason for this increased interruption delay is that circuit current continues to flow through the output MOV after the output deasserts, until all of the inductive energy dissipates. Maximum dropout (break) time is 6 ms with a resistive load, the same as for the Standard control outputs. The other ratings of these control outputs are similar to the Standard control outputs, except that the Hybrid outputs can break current as great as 10 A. Hybrid contact outputs have a maximum voltage rating of 330 Vdc.

The maximum pickup time for the Hybrid control outputs is 6 ms. *Figure 2.5* shows a representative connection for a Form A Hybrid control output on the main board I/O terminals.

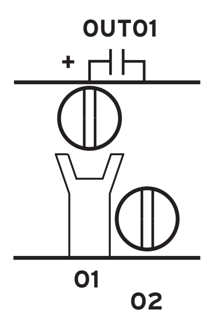


Figure 2.5 Hybrid Control Output Connection

See *Section 1: Introduction and Specifications*, for complete Hybrid control output specifications.

Fast Hybrid (Fast High-Current-Interrupting) Control Outputs

NOTE: You can use ac or dc circuits with Fast Hybrid (fast high-current-interrupting) outputs.

In addition to the Standard control outputs and the Hybrid control outputs, the INT4, INT5, and INT8 I/O interface boards offer Fast Hybrid (fast high-current-interrupting) control outputs. These control outputs have a resistive load pickup time of 10 µs (microseconds), which is much faster than the 6 ms pickup time of the Standard and Hybrid control outputs. The Fast Hybrid control outputs drop out at a maximum time of 8 ms. The maximum voltage rating is 250 Vac/330 Vdc. See *Control Outputs on page U.1.13*, for complete Fast Hybrid control output specifications.

Figure 2.6 shows a representative connection for a Form A Fast Hybrid control output on the INT5 (INT8) I/O interface terminals.

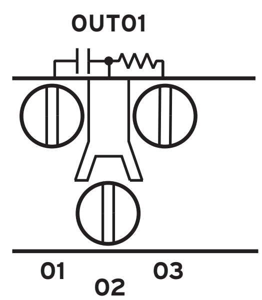


Figure 2.6 Fast Hybrid Control Output Connection, INT5 (INT8)

Figure 2.7 shows a representative connection for a Form A Fast Hybrid control output on the INT4 I/O interface terminals. The HS marks are included to indicate that this is a high-speed control output.

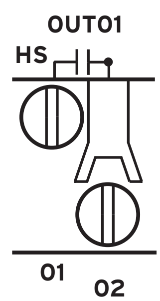


Figure 2.7 Fast Hybrid Control Output Connection, INT4

The INT5 (INT8) Fast Hybrid control output uses three terminal positions, while the INT4 Fast Hybrid uses two. The third terminal of each INT5 (INT8) Fast Hybrid control output is connected to precharge resistors that can be used to mitigate transient inrush current conditions, as explained below. A similar technique can be used with INT4 board Fast Hybrid control outputs using external resistors.

Short transient inrush current can flow at the closing of an external switch in series with open Fast Hybrid contacts. This transient will not energize the circuits in typical relay-coil control applications (trip coils and close coils), and standard auxiliary relays will not pick up. However, an extremely sensitive digital input or light-duty, high-speed auxiliary relay can pick up for this condition. This false pick-up transient occurs when the capacitance of the Fast Hybrid output circuitry charges (creating a momentary short circuit that a fast, sensitive device sees as a contact closure). A third terminal (03 in *Figure 2.8*) provides an internal path for precharging the Fast Hybrid output circuit capacitance when the circuit is open.

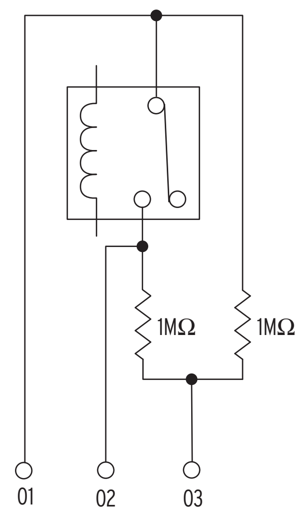


Figure 2.8 Fast Hybrid Control Output Typical Terminals, INT5 (INT8)

Figure 2.9 shows some possible connections for this third terminal that will eliminate the false pick-up transients when closing an external switch. In general, you must connect the third terminal to the dc rail (positive or negative) that is on the same side as the open external switch condition. If an open switch exists on either side of the output contact, then you can accommodate only one condition because two open switches (one on each side of the contact) defeat the precharge circuit.

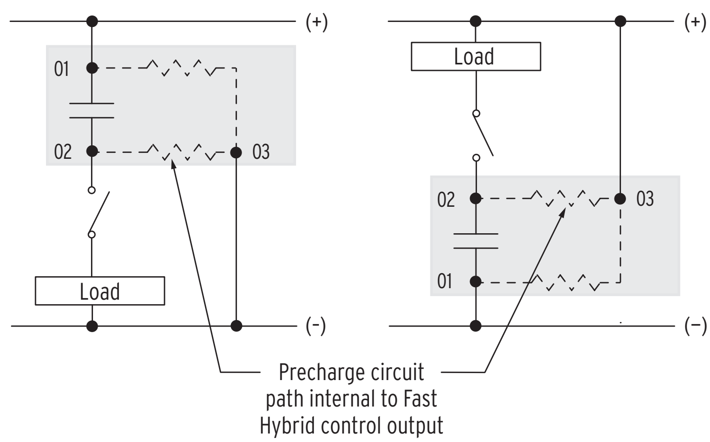


Figure 2.9 Precharging Internal Capacitance of Fast Hybrid Output Contacts, INT5 (INT8)

For wiring convenience, on the INT5 (INT8) I/O Interface Board, the precharge resistors shown in *Figure 2.8* are built-in to the I/O board, and connected to a third terminal. On the INT4 I/O Interface Board, there are no built-in precharge resistors, and each Fast Hybrid control output has only two terminal connections.

Main Board I/O

The SEL-421 base model is a 3U chassis with I/O interface on the main board (the top board). See *Figure 2.27* and *Figure 2.28* for representative rear-panel views of the 3U chassis rear panel. There are two options for the main board depending on the type of contact inputs. The Main Board A I/O interface has direct coupled contact inputs. The Main Board B I/O interface has optoisolated contact inputs.

Every SEL-421 configuration includes the main board I/O and features these connections:

- Three Hybrid (high-current-interrupting) Form A outputs
- Two Standard Form A outputs
- Three Standard Form C outputs
- Seven high-isolation control inputs (five independent and two with a common leg)

TIME Inputs

The SEL-421 has a regular IRIG timekeeping mode, and a high-accuracy IRIG (HIRIG) timekeeping mode, as described in *Configuring High-Accuracy Timekeeping on page U.4.71*.

The IRIG-B serial data format consists of a 1-second frame containing 100 pulses divided into fields. The relay decodes the second, minute, hour, and day fields and sets the internal time clock upon detecting valid time data in the IRIG time mode.

There are two IRIG-B inputs on the SEL-421 rear panel, but only one is capable of supporting the HIRIG mode. For input specifications, see *Time Inputs on page U.1.14*.

IRIG-B Pins of Serial Port 1

This IRIG-B input is capable of regular IRIG mode timekeeping only. Timing accuracy for the IRIG time mode is 500 µs.

IRIG-B BNC Connector

This IRIG-B input is capable of both modes of timekeeping. If the connected timekeeping source is qualified as high-accuracy (see *Table 4.9 on page U.4.71*), the relay enters the HIRIG mode, which has a timing accuracy of 1 µs.

If both inputs are connected, the SEL-421 will use the IRIG-B BNC connector signal if a signal is detected.

SEL-421 Time Inputs Changed

If you are upgrading the firmware in an existing SEL-421 relay, you may need to remove or reconnect your time-source cables. Beginning with the release of SEL-421 firmware version R112, the rear-panel TIME inputs have been changed. There is no longer a 1k PPS time input—see *1k PPS Connection Not Required on page U.4.72* for details.

Battery-Backed Clock

If relay input power is lost or removed, a lithium battery powers the relay clock, providing date and time backup. The battery is a 3 V lithium coin cell, Ray-O-Vac® No. BR2335 or equivalent. If power is lost or disconnected, the battery discharges to power the clock. At room temperature (25°C), the battery will operate for approximately 10 years at rated load.

When the SEL-421 is operating with power from an external source, the self-discharge rate of the battery only is very small. Thus, battery life can extend well beyond the nominal 10-year period because the battery rarely discharges after the relay is installed. The battery cannot be recharged. *Figure 2.19* shows the clock battery location (at the front of the main board).

If the relay does not maintain the date and time after power loss, replace the battery (see *Replacing the Lithium Battery on page U.2.46*).

Communications Interfaces

The SEL-421 has several communications interfaces you can use to communicate with other IEDs (intelligent electronic devices) via EIA-232 ports: **PORT 1**, **PORT 2**, **PORT 3**, and **PORT F**. See *Section 4: Communications Interfaces in the Reference Manual* for more information and options for connecting your relay to the communications interfaces.

An optional communications card provides Ethernet capability for the SEL-421. A communications card gives the relay access to popular Ethernet networking standards including TCP/IP, FTP, Telnet, DNP3, and IEC 61850 over local area and wide area networks. The Ethernet card with IEC 61850 support is only available at purchase as a factory-installed option. For information on DNP3 applications, see *Section 6: DNP3 Communications in the Reference Manual*. For more information on IEC 61850 applications, see *Section 8: IEC 61850 Communications in the Reference Manual*.

Other Shared Configuration Attributes

All versions of the SEL-421 also feature ground, power, and battery monitor connections. See *Connection on page U.2.31* for information on these relay interface features.

Plug-In Boards

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

NOTE: Ordering the 4U and 5U relay with partial or no extra I/O allows for future system expansion and future use of additional relay features.

The SEL-421 is available in many input/output configuration options. The relay base model is a 3U chassis with Main Board A or Main Board B I/O and screw terminal connector connections (see *Figure 2.2*). Other ordering options include versions of the relay in larger enclosures (4U or 5U) with all, partial, or no extra I/O boards installed.

Plug-in communications cards are also available for the SEL-421. The optional Ethernet card allows you to use TCP/IP, FTP, Telnet, DNP3 LAN/WAN, and IEC 61850 applications on an Ethernet network. This card is only available at the time of purchase of a new SEL-421 as a factory-installed option or as a factory-installed conversion to an existing relay.

I/O Interface Boards

You can choose among seven input/output interface boards for the I/O slots of the 4U and 5U chassis. These I/O interface boards are in addition to the main board I/O described in *Shared Configuration Attributes on page U.2.1*. The I/O interface boards are INT1, INT2, INT3, INT4, INT5, INT6, INT7, and INT8. *Figure 2.10*. *Figure 2.11*, *Figure 2.12*, *Figure 2.13*, *Figure 2.14*, *Figure 2.15*, *Figure 2.16*, and *Figure 2.17* show the rear screw terminal connectors associated with these interface boards.

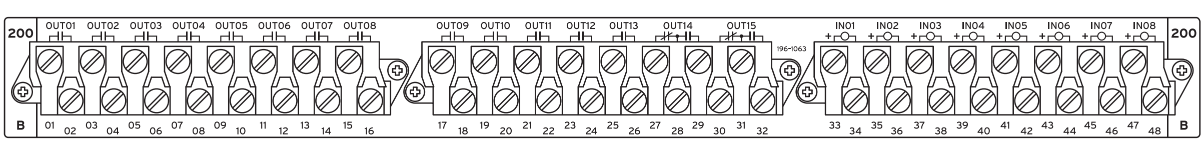


Figure 2.10 INT1 I/O Interface Board

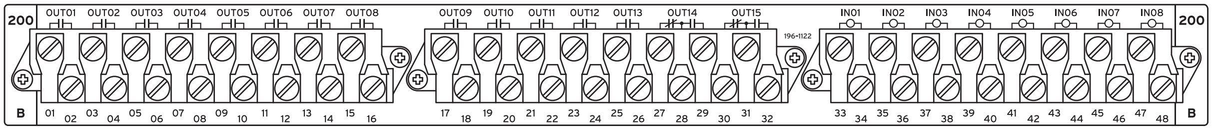


Figure 2.11 INT2 I/O Interface Board

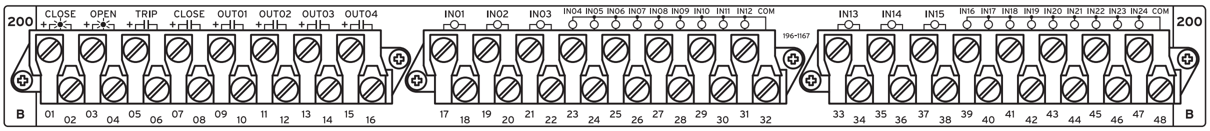


Figure 2.12 INT3 I/O Interface Board

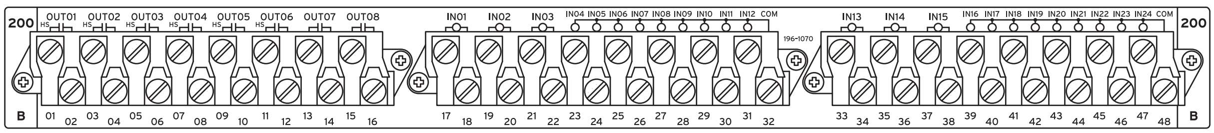


Figure 2.13 INT4 I/O Interface Board

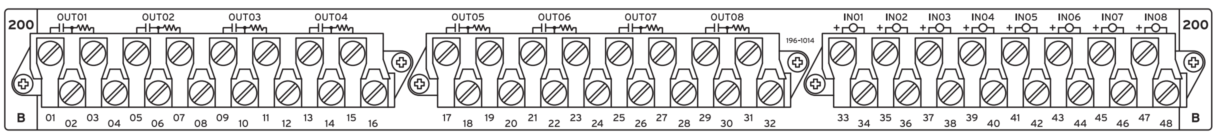


Figure 2.14 INT5 I/O Interface Board

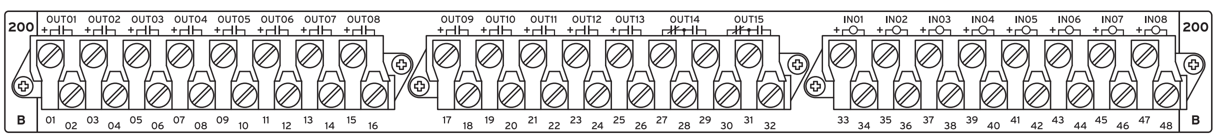


Figure 2.15 INT6 I/O Interface Board

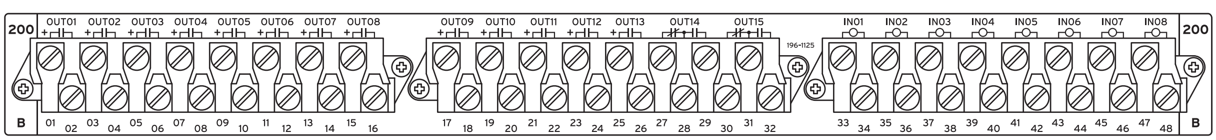


Figure 2.16 INT7 I/O Interface Board

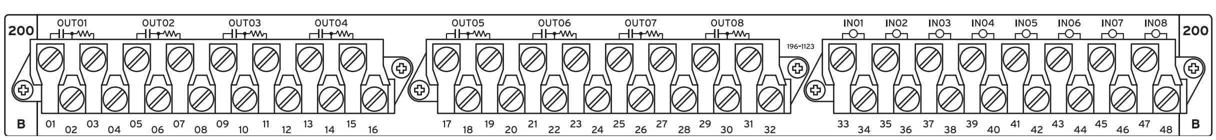


Figure 2.17 INT8 I/O Interface Board

The I/O interface boards carry jumpers that identify the board location (see *Jumpers on page U.2.18*).

I/O Interface Board Inputs

⚠CAUTION
Substation battery systems that have either a high resistance to ground (greater than 10 kΩ) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.

The INT1, INT5, and INT6 I/O interface boards have eight independent control inputs. All independent inputs are isolated from other inputs. These high-isolation control inputs are direct coupled and hence polarity-sensitive. You cannot damage these inputs with a reverse polarity connection; though, the relay will not detect input changes with a reverse-polarity input.

The INT3 and INT4 I/O interface board has two groups of nine (9) common contacts (18 total) and six (6) independent control inputs. The INT2, INT7, and INT8 I/O interface boards have eight independent control inputs. All independent inputs are isolated from other inputs. These control inputs are optoisolated and hence are not polarity sensitive, i.e., the relay will detect input changes with voltage applied at either polarity, or ac signals (when properly configured, see *Optoisolated on page U.2.6*).

Table 2.3 is a comparison of the I/O board input capacities; the table also shows the I/O inputs on Main Board A or Main Board B. See *Control Inputs on page U.1.14* for complete control input specifications.

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

Table 2.3 I/O Interface Boards Control Inputs

Board Number	Independent Contact Pairs	Common Contacts
INT1[a]	8	
INT2[b]	8	
INT3[b]	6	Two sets of 9
INT4[b]	6	Two sets of 9
INT5[a]	8	
INT6[a]	8	
INT7[b]	8	
INT8[b]	8	
Main Board A[a]	5	2
Main Board B[b]	5	2

[a] Main Board A, INT1, INT5, and INT6 control inputs are direct coupled and are polarity sensitive.
[b] Main Board B, INT2, INT3, INT4, INT7, and INT8 control inputs are optoisolated and are not polarity sensitive.

I/O Interface Board Outputs

NOTE: Form A control outputs cannot be jumpered to Form B.

The I/O interface boards vary by the type and amount of output capabilities. *Table 2.4* lists the outputs of the additional I/O interface boards; the table also shows the I/O outputs on the main board. Information about the Standard and Hybrid (high-current interrupting) control outputs is in *Control Outputs on page U.2.7*.

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

Table 2.4 I/O Interface Boards Control Outputs

Board Number	Standard		Fast Hybrid[a]	Hybrid[b]
	Form A	Form C	Form A	Form A
INT1	13	2		
INT2	13	2		
INT3				4
INT4	2		6	
INT5			8	
INT6		2		13
INT7		2		13
INT8			8	
Main Board A	2	3		3
Main Board B	2	3		3

[a] High-Speed/High-Current Interrupting.
[b] High-Current Interrupting.

Installing Optional I/O Interface Boards

Perform the following steps to expand the capability of the SEL-421 with additional I/O interface boards:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-421.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

⚠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 6. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 7. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 8. Confirm proper installation of address jumpers on the interface board (see *Jumpers on page U.2.18*).

Step 9. Confirm drawout tray keying.

The relay chassis and the drawout trays for the 200-addresses slot and the 300-addresses slot are keyed (see *Figure 2.18*).

The keys are two round plug-in/plug-out discs on the bottom of the drawout tray.

The 200-addresses slot keys go to the left, and the 300-addresses slot keys go to the right (when viewed from the top and front of the drawout tray).

⚠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.

⚠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.

⚠CAUTION
If you are planning to install an INT4 I/O Interface Board in your relay (see Table 2.3 and Table 2.4 for board descriptions), first check the firmware version of the relay—see Firmware Version Number on page U.6.39. If the firmware version is R111 or lower, you must first upgrade the relay firmware to the newest version and verify that the firmware upgrade was successful before installing the new board. Failure to install the new firmware first will cause the I/O Interface Board to fail, and it may require factory service. Complete firmware upgrade instructions are provided when new firmware is ordered.

⚠CAUTION
Field replacement of I/O boards INT1, INT2, INT5, INT6, INT7, or INT8 with INT4 can cause I/O contact failure. The INT4 board has a pickup and dropout delay setting range of 0–1 cycle. For all other I/O boards, pickup and dropout delay settings (IN201PU–IN224PU, IN201DO–IN224DO, IN301PU–IN324PU, and IN301DO–IN324DO) have a range of 0–5 cycles. Upon replacing any I/O board with an INT4 board, manually confirm reset of pickup and dropout delays to within the expected range of 0–1 cycle.

Step 10. Move a key on the bottom of the drawout tray to the correct position by prying the key from the tray and reinserting the key in the proper position.

Do this for both keys.

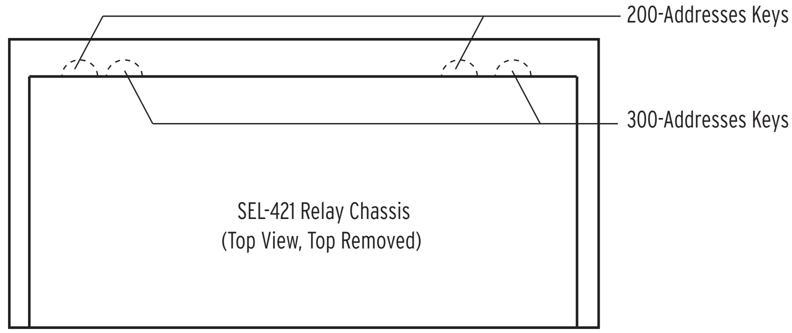


Figure 2.18 Chassis Key Positions for I/O Interface Boards

Step 11. Install the drawout tray with the I/O interface board, using the following precautions:

a. Position the drawout tray edges into the left-side and right-side internally mounted slots.

b. Slide the I/O interface board into the SEL-421 by pushing the front edge of the board drawout tray.

c. Apply firm pressure to fully seat the I/O interface board.

If you encounter resistance, stop, and withdraw the board.

Inspect the drawout tray edge guide slots for damage.

If you see no damage, take all of the precautions outlined above and try again to insert the board.

Step 12. If this is a new I/O interface board installation, remove the INTERFACE BOARD EXPANSION SLOT self-sticking label from the rear panel.

Lift a corner of the label with a sharp tool and peel away the label from the rear panel.

Step 13. Confirm screw terminal connector keying.

SEL supplies three new screw terminal connectors with new I/O interface boards.

a. Inspect the screw terminal connector receptacles on the rear of the I/O interface board.

b. Refer to *Figure 2.38* for the corresponding key positions inside the receptacle.

c. If the keys inside the I/O interface board receptacles are not in the positions indicated in *Figure 2.38*, grasp the key edge with long-nosed pliers to remove the key and reinsert the key in the correct position.

d. Break the webs of the screw terminal connectors in the position that matches the receptacle key (see *Figure 2.37*).

Step 14. Attach the screw terminal connector.

a. Mount the screw terminal connectors to the rear panel of the SEL-421.

Refer to *Figure 2.10* and *Figure 2.14* for screw terminal connector placement.

b. Tighten the screw terminal connector mounting screws to between 7 in-lb. and 12 in-lb. (0.8 Nm to 1.4 Nm).

Step 15. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

Step 16. Reconnect the cable removed in *Step 6* and reinstall the relay front-panel cover.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 18. Apply power.

Step 19. Enter Access Level 2 (see *Making Simple Settings Changes on page U.4.13*).

Step 20. Issue the **STA** command and answer **Y <Enter>** to accept the new hardware configuration (see *STATUS on page R.9.48*).

Step 21. Inspect the relay targets to confirm that the relay reads the added I/O interface board(s).

You can see the new control inputs in the target listings by using a terminal, the ACSELERATOR QuickSet® SEL-5030 software program, or the front panel.

Step 22. Use a communications terminal to issue the commands **TAR IN201 <Enter>** (for the 200-addresses slot) or **TAR IN301 <Enter>** (for the 300-addresses slot).

Alternatively, from the front panel `MAIN` menu, select `RELAY ELEMENTS`, and press the **{Down Arrow}** pushbutton to go to `ROW 101` (for the 200-addresses slot) or `ROW 104` (for the 300-addresses slot).

Step 23. Follow your company standard procedure to return the relay to service.

Communications Card

You can add communications protocols to the SEL-421 by purchasing the Ethernet card option. Factory-installed in the rear relay **PORT 5**, the Ethernet card provides Ethernet ports for industrial applications that process data traffic between the SEL-421 and a LAN (local area network).

Jumpers

The SEL-421 contains jumpers that configure the relay for certain operating modes. The jumpers are located on the main board (the top board) and the I/O interface boards (one or two boards located immediately below the main board).

Main Board Jumpers

The jumpers on the main board of the SEL-421 perform these functions:

- Temporary/emergency password disable
- Circuit breaker control enable
- Rear serial port +5 Vdc source enable

Figure 2.19 shows the positions of the main board jumpers. The main board jumpers are in two locations. The password disable jumper and circuit breaker control jumper are at the front of the main board. The serial port jumpers are near the rear-panel serial ports; each serial port jumper is directly in front of the serial port that it controls.

Password and Circuit Breaker Jumpers

⚠CAUTION
Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.

You can access the password disable jumper and circuit breaker control jumper without removing the main board from the relay cabinet. Remove the SEL-421 front cover to view these jumpers (use appropriate ESD precautions). The password and circuit breaker jumpers are on jumper header J18 on the front of the main board, located immediately left of power connector J17 (see *Figure 2.19*).

The J18 header is denoted A, B, C, and D from right to left (position A is on the right). Position B is the password disable jumper; position C is the circuit breaker control enable jumper. Positions A and D are not used. *Figure 2.20* shows the jumper header with the circuit breaker/control jumper in the ON position and the password jumper in the OFF position; these are the normal jumper positions for an in-service relay. *Table 2.5* lists the J18 jumper positions and functions.

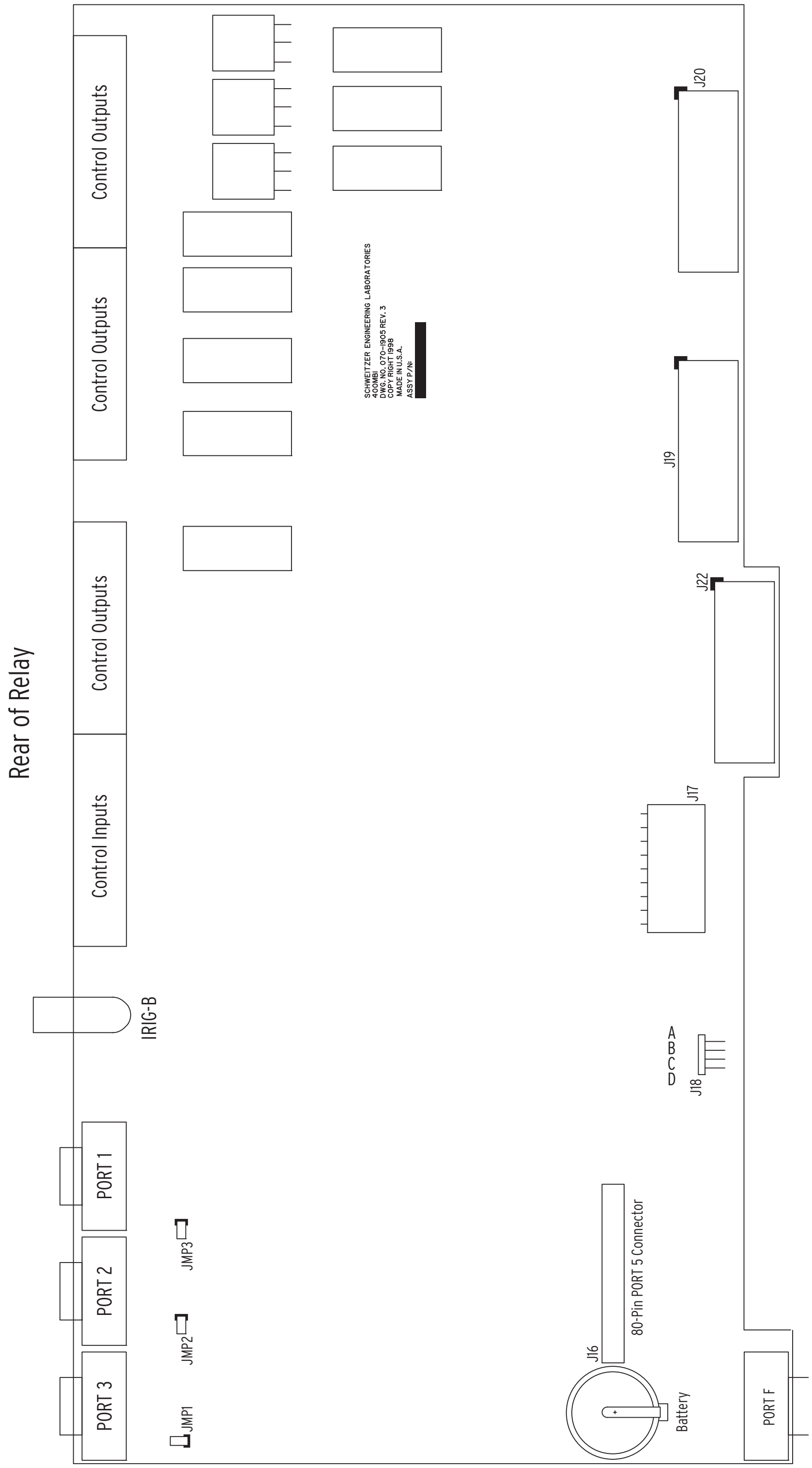


Figure 2.19 Major Component Locations on the SEL-421 Main Board A (or B)

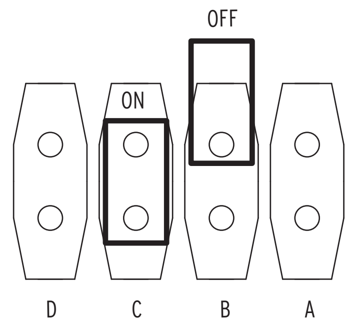


Figure 2.20 J18 Header—Password and Breaker Jumpers

Table 2.5 Main Board Jumpers[a]

Jumper	Jumper Location	Jumper Position	Function
J18A	Front	OFF	For SEL use only
J18B	Front	OFF	Enable password protection (normal and shipped position)
		ON	Disable password protection (temporary or emergency only)
J18C	Front	OFF	Disable circuit breaker commands (**OPEN** and **CLOSE**) and output **PULSE** commands[b] (shipped position)
		ON	Enable circuit breaker commands (**OPEN** and **CLOSE**) and output **PULSE** commands[b]
J18D	Front	OFF	For SEL use only

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.
[b] Also affects the availability of the Fast Operate Breaker Control Messages and the front-panel LOCAL CONTROL > BREAKER CONTROL, and front-panel LOCAL CONTROL > OUTPUT TESTING screens.

The password disable jumper, J18B, is for temporary or emergency suspension of the relay password protection mechanisms. Under no circumstance should you install J18B on a long-term basis. The SEL-421 ships with password disable jumper J18B OFF (passwords enabled).

For temporary unprotected access to a particular access level, use the **PAS *n* DISABLE** command (***n*** is the access level: ***n*** = **1**, **B**, **P**, **A**, **O**, **2**). For more information on this command and setting passwords, see *Passwords on page U.4.9*.

The circuit breaker control enable jumper, Jumper J18C, supervises the **CLOSE *n*** command, the **OPEN *n*** command, the **PULSE OUT*nnn*** command, and front-panel local bit control. To use these functions, you must install jumper J18C.

The relay checks the status of the circuit breaker control jumper when you issue **CLOSE *n***, **OPEN *n***, **PULSE OUT*nnn***, and when you use the front panel to close or open circuit breakers, control a local bit, or pulse an output.

The SEL-421 ships with circuit breaker jumper J18C OFF. For commissioning and testing of the SEL-421 contact outputs, it may be convenient to set J18C ON, so that the **PULSE OUT*nnn*** commands can be used to check output wiring. J18C must also be set ON if SCADA control of the circuit breaker via Fast Operate is required, or if the LOCAL CONTROL > BREAKER CONTROL screens are going to be used.

Serial Port Jumpers

Place jumpers on the main board to connect +5 Vdc to Pin 1 of each of the three rear-panel EIA-232 serial ports. The maximum current available from this Pin 1 source is 0.5 A. The Pin 1 source is useful for powering an external modem. *Table 2.6* describes the JMP1, JMP2, and JMP3 positions. Refer to *Figure 2.19* for the locations of these jumpers. The SEL-421 ships with JMP1, JMP2, and JMP3 OFF (no +5 Vdc on Pin 1).

Table 2.6 Main Board Jumpers—JMP1, JMP2, and JMP3[a]

Jumper	Jumper Location	Jumper Position	Function
JMP1	Rear	OFF	Serial PORT 3, Pin 1 = not connected
		ON	Serial PORT 3, Pin 1 = +5 Vdc
JMP2	Rear	OFF	Serial PORT 2, Pin 1 = not connected
		ON	Serial PORT 2, Pin 1 = +5 Vdc
JMP3	Rear	OFF	Serial PORT 1, Pin 1 = not connected
		ON	Serial PORT 1, Pin 1 = +5 Vdc

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.

Changing Serial Port Jumpers

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

⚠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.

⚠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.

You must remove the main board to access the serial port jumpers. Perform the following steps to change the JMP1, JMP2, and JMP3 jumpers in an SEL-421:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-421.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Remove the rear-panel **EIA-232 PORT** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 6. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 7. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 8. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 9. Remove the screw terminal connectors.

   a. Loosen the attachment screws at each end of the 100-addresses screw terminal connectors.

   b. Pull straight back to remove.

Step 10. Carefully pull out the drawout assembly containing the main board.

Step 11. Locate the jumper you want to change.

Jumpers JMP1, JMP2, and JMP3 are located at the rear of the main board, directly in front of **PORT 3**, **PORT 2**, and **PORT 1**, respectively (see *Figure 2.19*).

Step 12. Install or remove the jumper as needed (see *Table 2.6* for jumper position descriptions).

Step 13. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

Step 14. Reconnect the cable removed in *Step 7* and reinstall the relay front-panel cover.

Step 15. Reattach the rear-panel connections.

Step 16. Affix the screw terminal connectors to the appropriate 100-addresses locations on the rear panel.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 18. Follow your company standard procedure to return the relay to service.

I/O Interface Board Jumpers

Jumpers on the I/O interface boards identify the particular I/O board configuration and I/O board control address. Eight I/O interface boards are available: INT1, INT2, INT3, INT4, INT5, INT6, INT7, and INT8 (see *I/O Interface Boards on page U.2.12* for more information on these boards). The jumpers on these I/O interface boards are at the front of each board, as shown in *Figure 2.21*, *Figure 2.22*, *Figure 2.23*, *Figure 2.24*, and *Figure 2.25*.

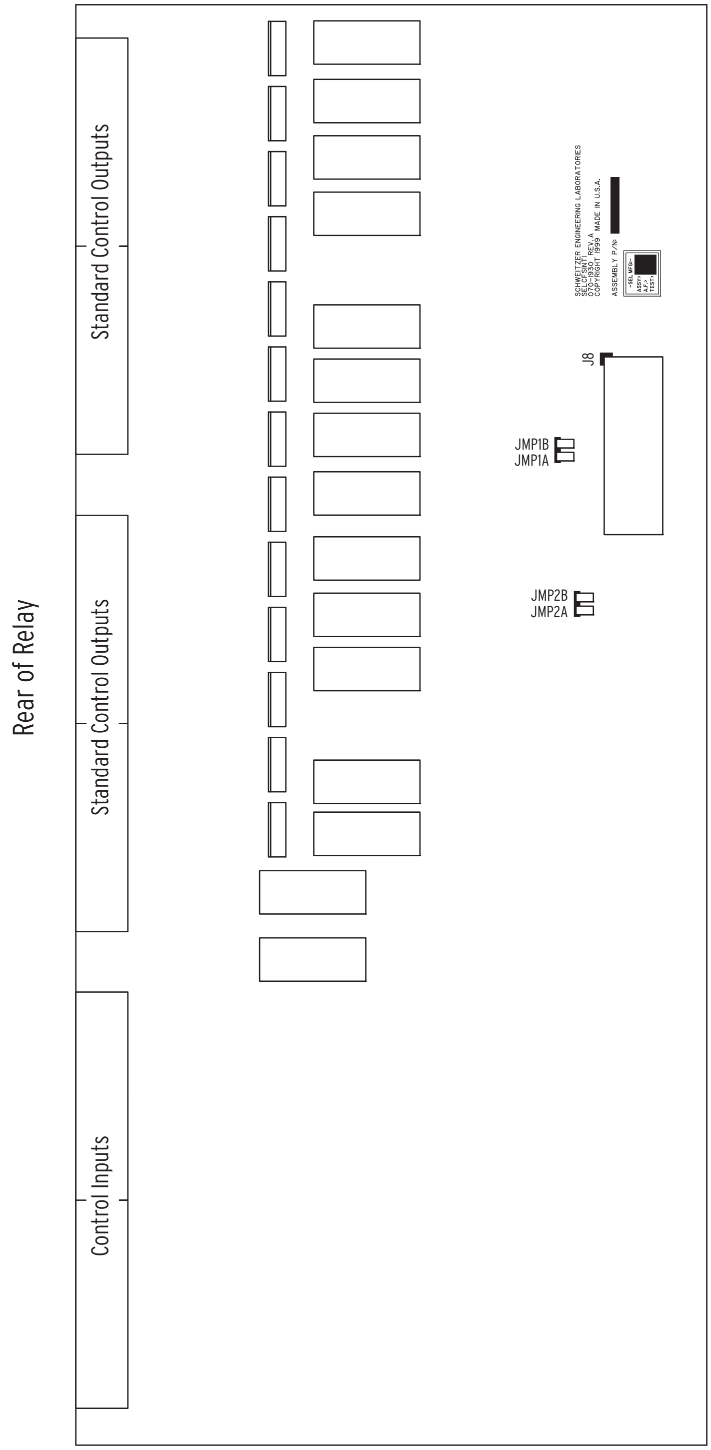


Figure 2.21 Major Component Locations on the SEL-421 INT1 (or INT2) I/O Board

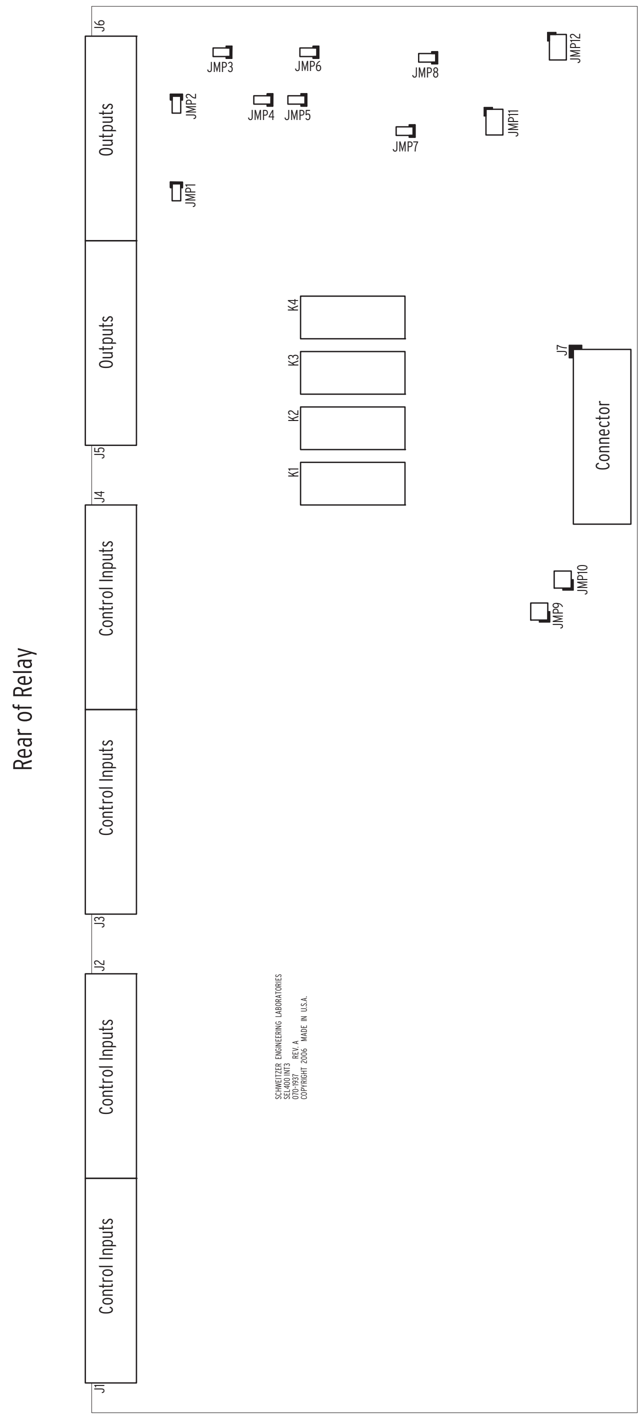


Figure 2.22 Major Component Locations on the SEL-421 INT3 I/O Board

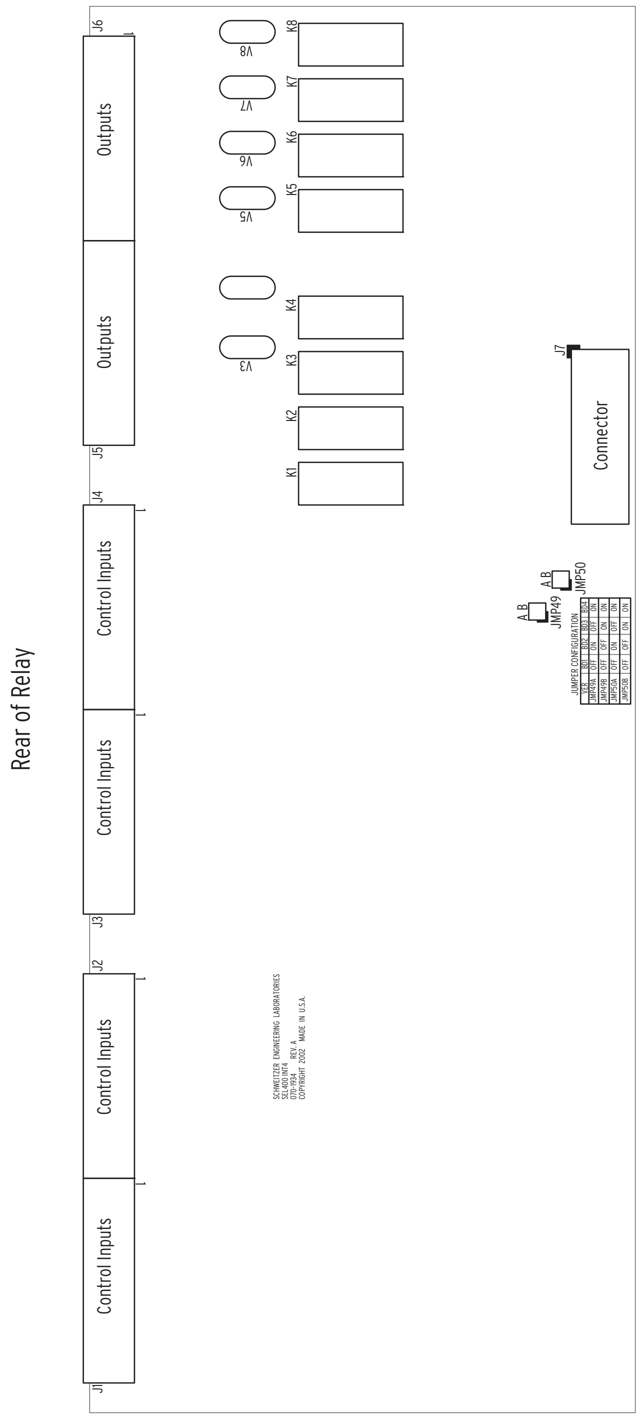


Figure 2.23 Major Component Locations on the SEL-421 INT4 I/O Board

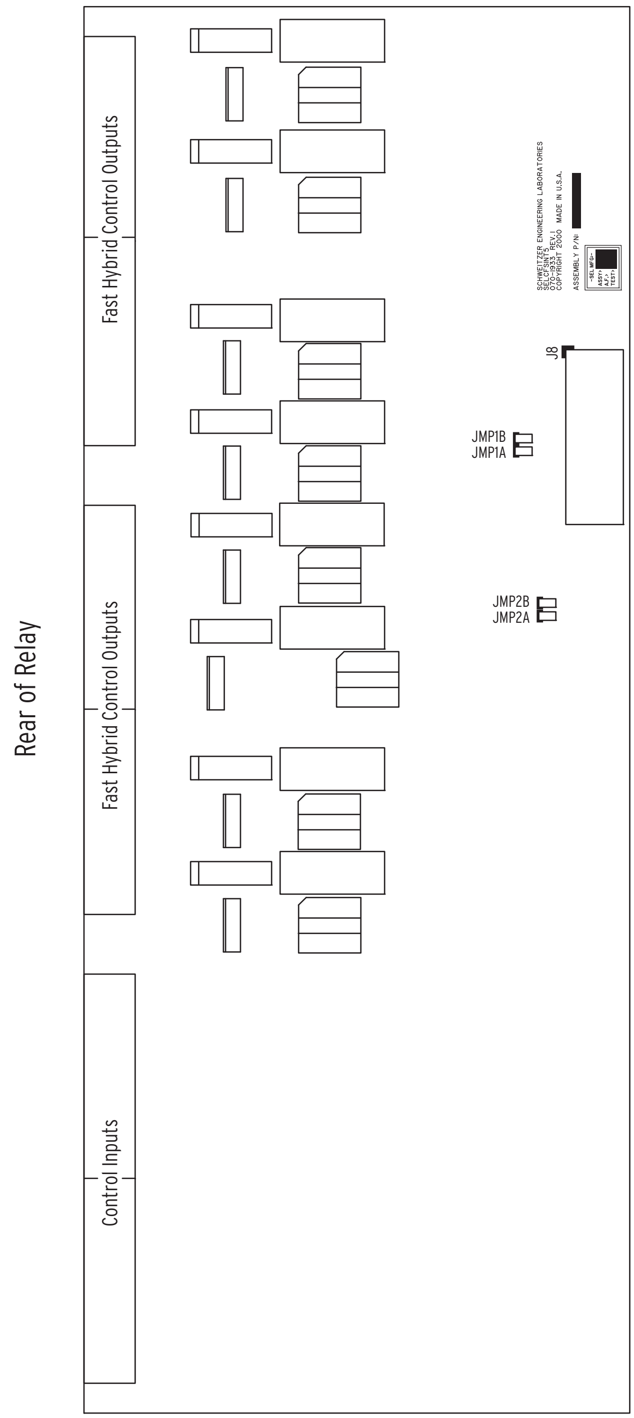


Figure 2.24 Major Component Locations on the SEL-421 INT5 (or INT8) I/O Board

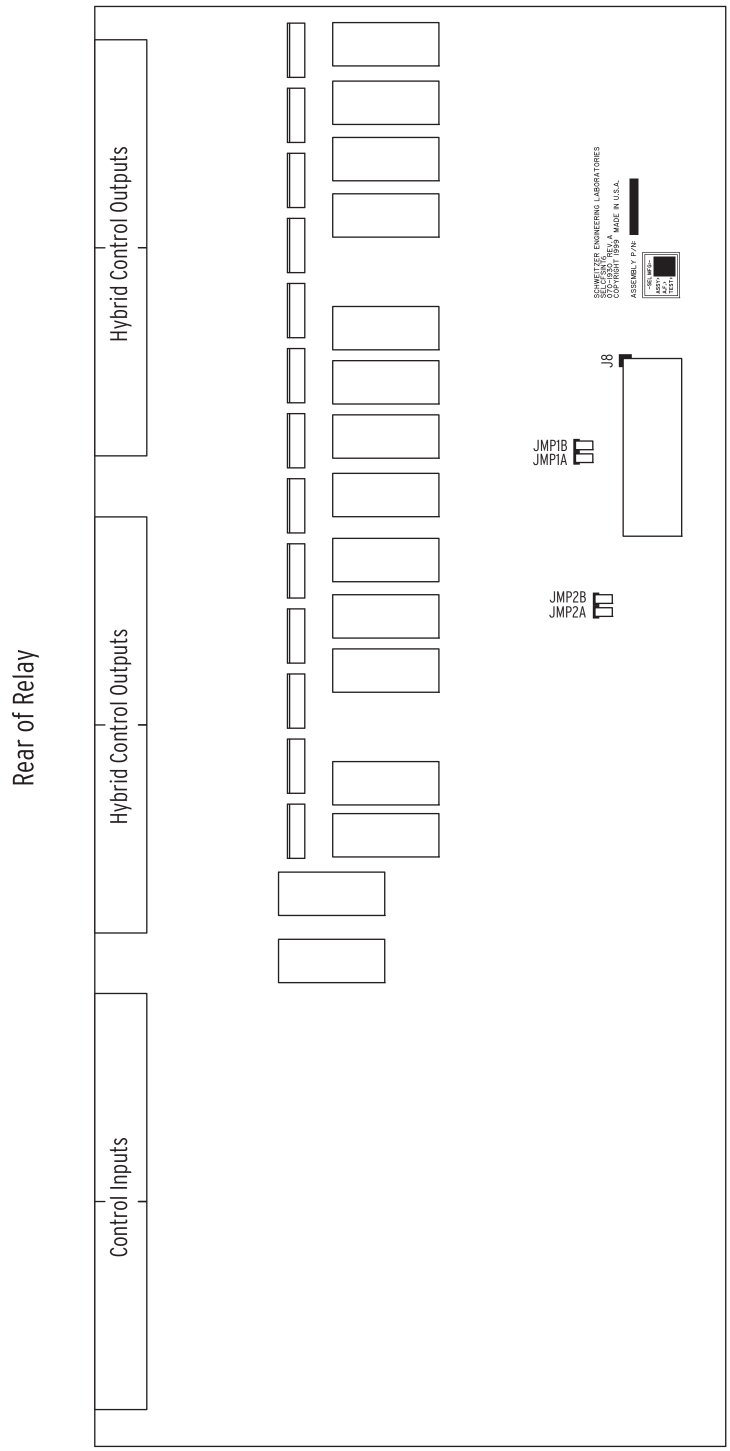


Figure 2.25 Major Component Locations on the SEL-421 INT6 (or INT7) I/O Board

To confirm the positions of your I/O board jumpers, remove the front panel and visually inspect the jumper placements. *Table 2.7* lists the four jumper positions for I/O interface boards. Refer to *Figure 2.21*, *Figure 2.23*, *Figure 2.24*, and *Figure 2.25* for the locations of these jumpers.

The I/O board control address has a hundreds-series prefix attached to the control inputs and control outputs for that particular I/O board chassis slot. A 4U chassis has a 200-addresses slot for inputs IN201, IN202, etc., and outputs OUT201, OUT202, etc. A 5U chassis has a 200-addresses slot and a 300-addresses slot.

The drawout tray on which each I/O board is mounted is keyed. See *Installing Optional I/O Interface Boards on page U.2.15* for information on the key positions for the 200-addresses slot trays and the 300-addresses slot trays.

Table 2.7 I/O Board Jumpers

I/O Board Control Address	JMP1A/ JMP49A[a]	JMP1B/ JMP49B[a]	JMP2A/ JMP50A[a]	JMP2B/ JMP50B[a]
2XX	OFF	OFF	OFF	OFF
3XX	ON	OFF	ON	OFF

[a] INT4 I/O Interface Board jumper numbering.

Changing I/O Interface Board Jumpers

Change the I/O interface board jumpers only when you move the slot position of an I/O board. You must remove the I/O interface boards to access the jumpers. Perform the following steps to change jumpers on an SEL-421 I/O interface board:

⚠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.

⚠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.

⚠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.

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-421.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 6. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 7. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 8. Pull out the drawout assembly containing the I/O interface board.

Step 9. Locate the jumper you want to change.

The I/O interface board jumpers are located near the front of each I/O board, and near the interface board connector, as shown for each type of interface board in *Figure 2.21* through *Figure 2.25*.

Step 10. Install or remove the jumper as needed (see *Table 2.7* for jumper position descriptions).

Step 11. Reinstall the interface board, and reconnect the power, the interface board, and the analog input board cables.

Step 12. Reconnect the cable removed in *Step 6* and reinstall the relay front-panel cover.

Step 13. Replace any cables previously removed from serial ports.

Step 14. Follow your company standard procedure to return the relay to service.

Step 15. At relay power-up, confirm that the relay does not display a status warning about I/O board addresses. For information on this status warning, see *Relay Self-Tests on page U.6.38*.

Auxiliary {TRIP}/{CLOSE} Pushbutton and Breaker Status LED Jumpers (select models only)

The jumpers listed in *Table 2.8* are used to select the proper control voltage for breaker open/closed indicating LEDs on the front panel of the relay. *Figure 2.22* shows the jumper locations on the magnetics/auxiliary pushbutton board. The jumpers come preset from the factory with the voltage range set the same as the control input voltage, as determined by the part number at order time.

The voltage setting can be different for each LED. To access these jumpers, the relay front cover, top cover, main board, and any additional I/O board (if present) must first be removed. See instructions and precautions in the subsection *Changing Serial Port Jumpers on page U.2.21*.

Table 2.8 Jumper Positions for Breaker OPEN/CLOSE Indication

	BREAKER OPEN LED			BREAKER CLOSED LED		
	JMP4	JMP5	JMP7	JMP3	JMP6	JMP8
24 V	Installed	Installed	Installed	Installed	Installed	Installed
48 V	Installed	Installed	Not Installed	Installed	Installed	Not Installed
110/125 V	Installed	Not Installed	Not Installed	Installed	Not Installed	Not Installed
220/250 V	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed

Table 2.9 shows how to enable or disable the arc suppression feature of the {TRIP} and {CLOSE} pushbuttons. If ac control power is used to operate the breaker, then the corresponding arc suppression jumper must be removed. If dc control power is used to operate the breaker, then the arc suppression is strongly recommended to break inductive loads. The arc suppression comes enabled from the factory. *Figure 2.22* shows the jumper locations on the magnetics/auxiliary pushbutton board.

NOTE: With arc suppression enabled, the corresponding output polarity marks must be followed when wiring the control.

Table 2.9 Jumper Positions for Arc Suppression

Option	{TRIP} pushbutton	{CLOSE} pushbutton
	JMP2	JMP1
Arc Suppression Enabled	Installed	Installed
Arc Suppression Disabled	Not Installed	Not Installed

Table 2.10 Front-Panel LED Option

JMP11, JMP12[a]	LED Color
BRIDGE Pins 1 and 3 Pins 2 and 4	Red
BRIDGE Pins 3 and 5 Pins 4 and 6	Green

[a] JMP11 Open; JMP12 Closed.

Relay Placement

Proper placement of the SEL-421 helps make certain that you receive years of trouble-free power system protection. Use the following guidelines for proper physical installation of the SEL-421.

Physical Location

You can mount the SEL-421 in a sheltered indoor environment (a building or an enclosed cabinet) that does not exceed the temperature and humidity ratings for the relay.

The relay is rated at Installation/Overvoltage Category II and Pollution Degree 2. This rating allows mounting the relay indoors or in an outdoor (extended) enclosure where the relay is protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity are controlled.

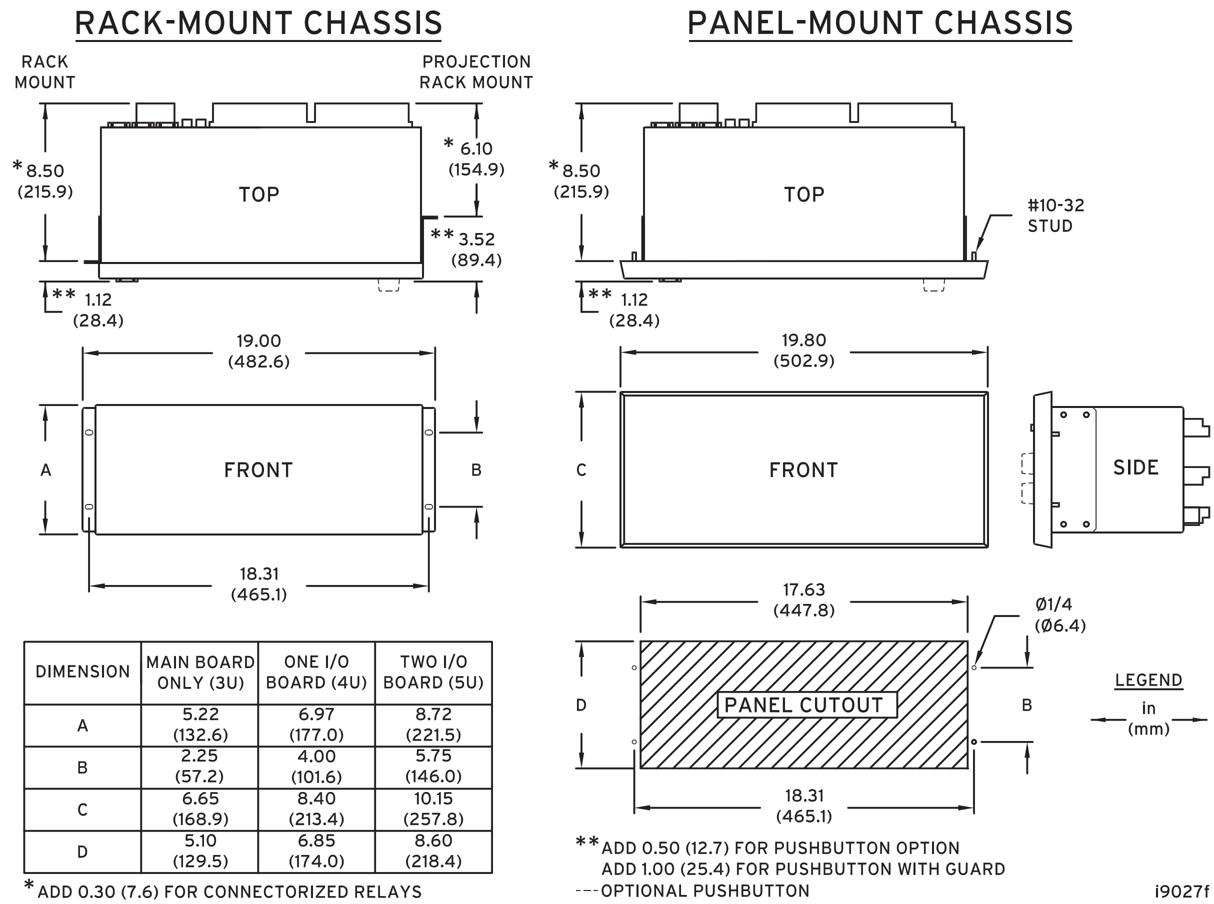
You can place the relay in extreme temperature and humidity locations. The temperature range over which the relay operates is –40° to +185°F (–40° to +85°C, see *Operating Temperature on page U.1.15*). The relay operates in a humidity range from 5 percent to 95 percent, no condensation, and is rated for installation at a maximum altitude of 2000 m (6560 feet) above mean sea level.

Rack Mounting

When mounting the SEL-421 in a rack, use the reversible front flanges to either semiflush-mount or projection mount the relay.

The semiflush mount gives a small panel protrusion from the relay rack rails of approximately 1.1 in. or 27.9 mm. The projection mount places the front panel approximately 3.5 in. or 88.9 mm in front of the relay rack rails.

See *Figure 2.26* for exact mounting dimensions for both the horizontal and vertical rack-mount relays. Use four screws of the appropriate size for your rack.



DIMENSION	MAIN BOARD ONLY (3U)	ONE I/O BOARD (4U)	TWO I/O BOARD (5U)
A	5.22 (132.6)	6.97 (177.0)	8.72 (221.5)
B	2.25 (57.2)	4.00 (101.6)	5.75 (146.0)
C	6.65 (168.9)	8.40 (213.4)	10.15 (257.8)
D	5.10 (129.5)	6.85 (174.0)	8.60 (218.4)

Figure 2.26 SEL-421 Chassis Dimensions

Panel Mounting

Place the panel-mount versions of the SEL-421 in a switchboard panel. See the drawings in *Figure 2.26* for panel cut and drill dimensions (these dimensions apply to both the horizontal and vertical panel-mount relay versions). Use the supplied mounting hardware to attach the relay.

Connection

⚠CAUTION
Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.

The SEL-421 is available in many different configurations, depending on the number and type of control inputs, control outputs, and analog input termination you specified at ordering. This subsection presents a representative sample of relay rear-panel configurations and the connections to these rear panels. Only horizontal chassis are shown; rear panels of vertical chassis are identical to horizontal chassis rear panels for each of the 3U, 4U, and 5U sizes.

When connecting the SEL-421, refer to your company plan for wire routing and wire management. Be sure to use wire that is appropriate for your installation with an insulation rating of at least 90°C.

Rear-Panel Layout

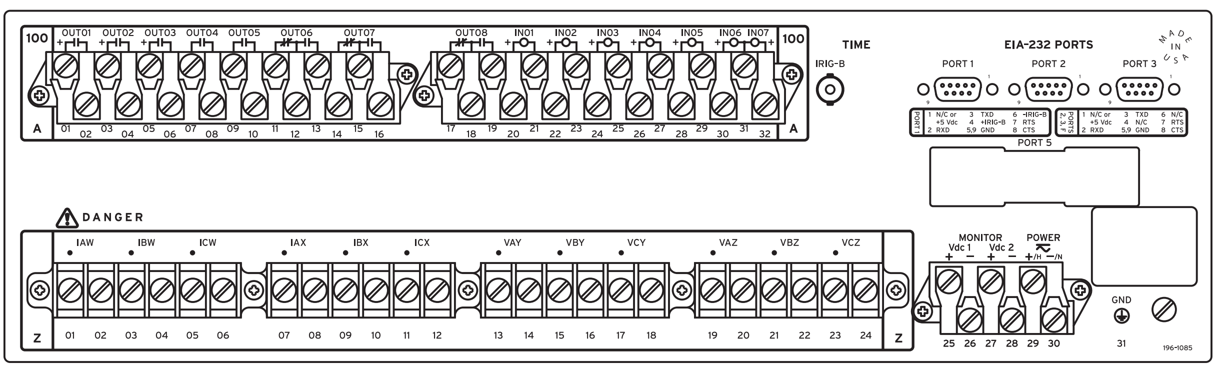
> **NOTE:** The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

Figure 2.27, *Figure 2.28*, *Figure 2.29*, and *Figure 2.30*, and *Figure 2.33* show some of the available SEL-421 rear panels.

All relay versions have screw terminal connectors for I/O, power, and battery monitor. You can order the relay with fixed terminal blocks for the CT and PT connections, or you can order SEL Connectorized rear-panel configurations that feature plug-in/plug-out PT connectors and shorting CT connectors for relay analog inputs. *Figure 2.28* shows the Connectorized 3U horizontal configuration of the SEL-421. For clarity, the figures do not show a communications card installed in **PORT 5**.

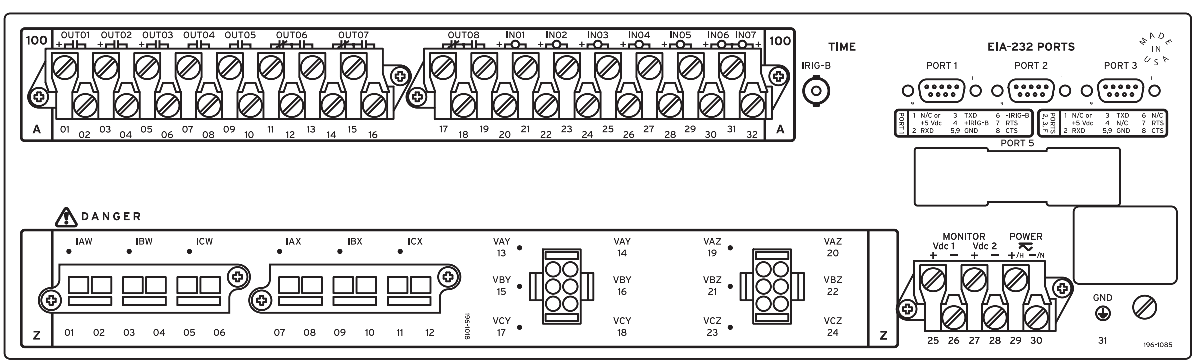
The screw terminal connections for the INT1 (or INT2) and the INT6 (or INT7) I/O interface boards are the same. The INT5 (or INT8) I/O interface board has control output terminals grouped in threes, with the fourth terminal as a blank additional separator (terminals 4, 8, 12, 16, 20, 24, 28, and 32). The INT3, INT4 and INT5 (or INT8) I/O interface boards both contain fast hybrid control outputs, but use a different terminal layout – see *Control Outputs on page U.2.7* for details.

For more information on the main board control inputs and control outputs, see *Main Board I/O on page U.2.10*. For more information on the I/O interface board control inputs and control outputs, see *I/O Interface Board Jumpers on page U.2.22*.



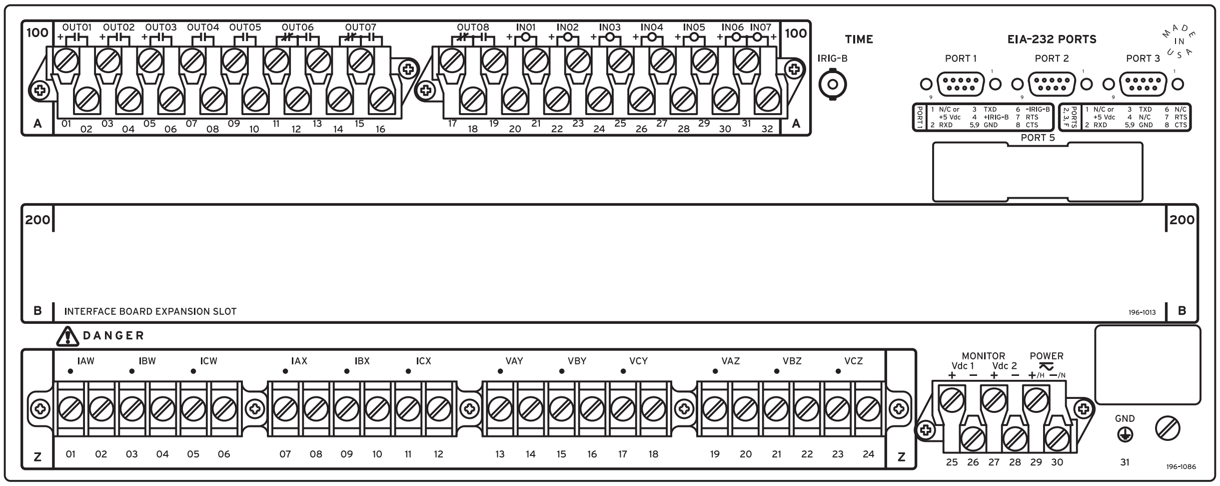
i3359d

Figure 2.27 3U Rear Panel, Main Board A



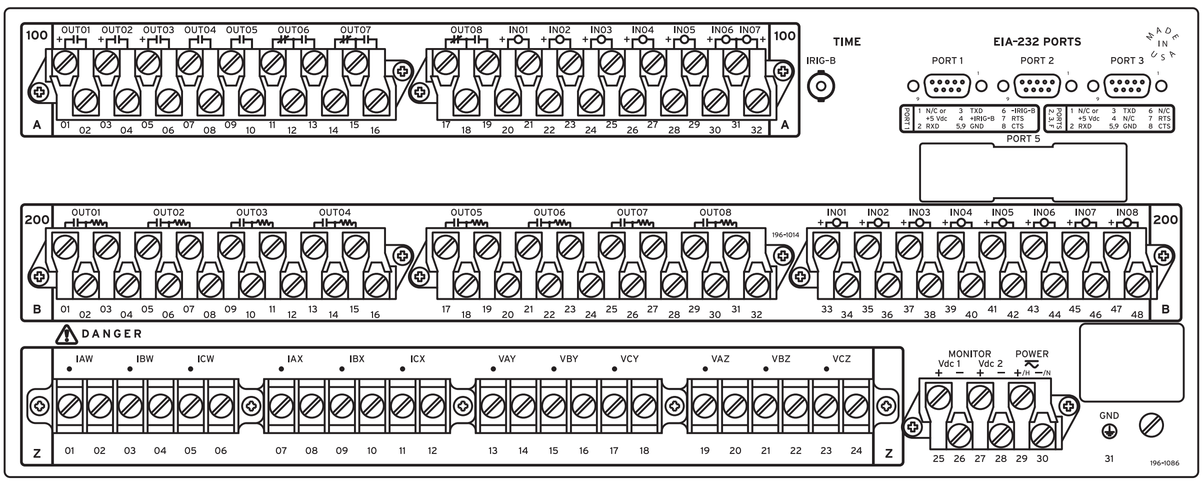
i3372e

Figure 2.28 3U Rear Panel, Main Board A, Connectorized



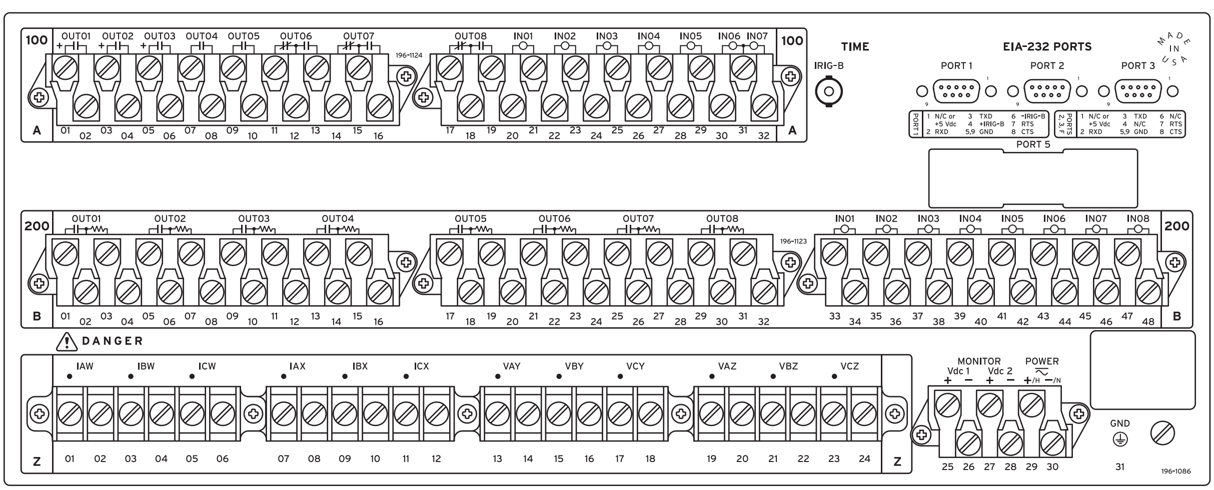
i3360d

Figure 2.29 4U Rear Panel, Main Board A, Without Optional I/O



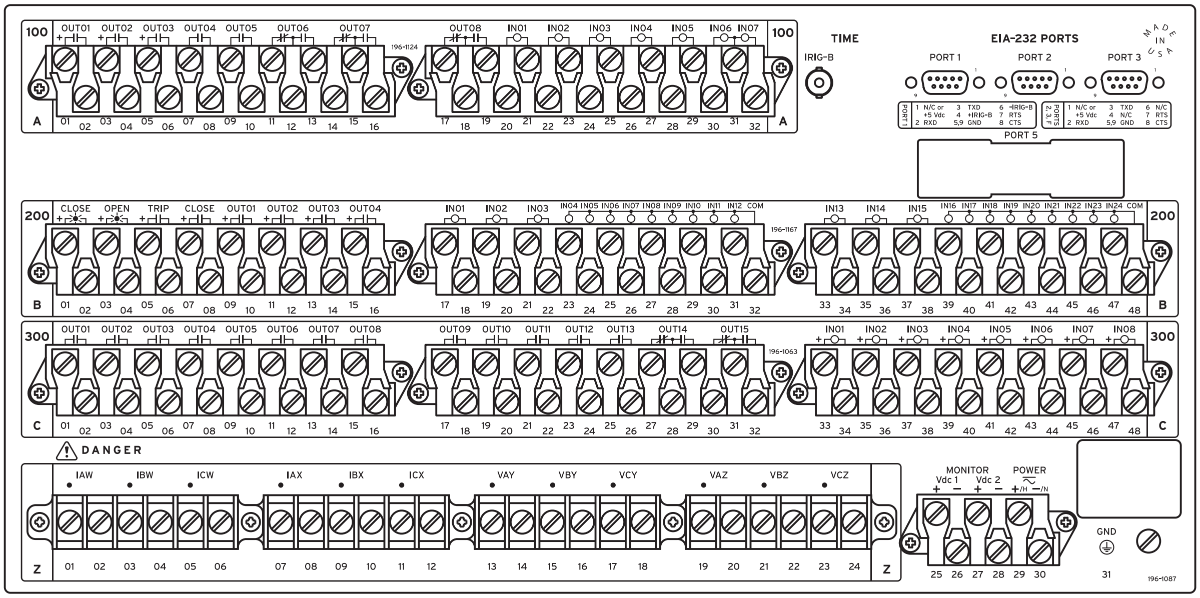
i3362e

Figure 2.30 4U Rear Panel, Main Board A, INT5 I/O Interface Board



i3928a

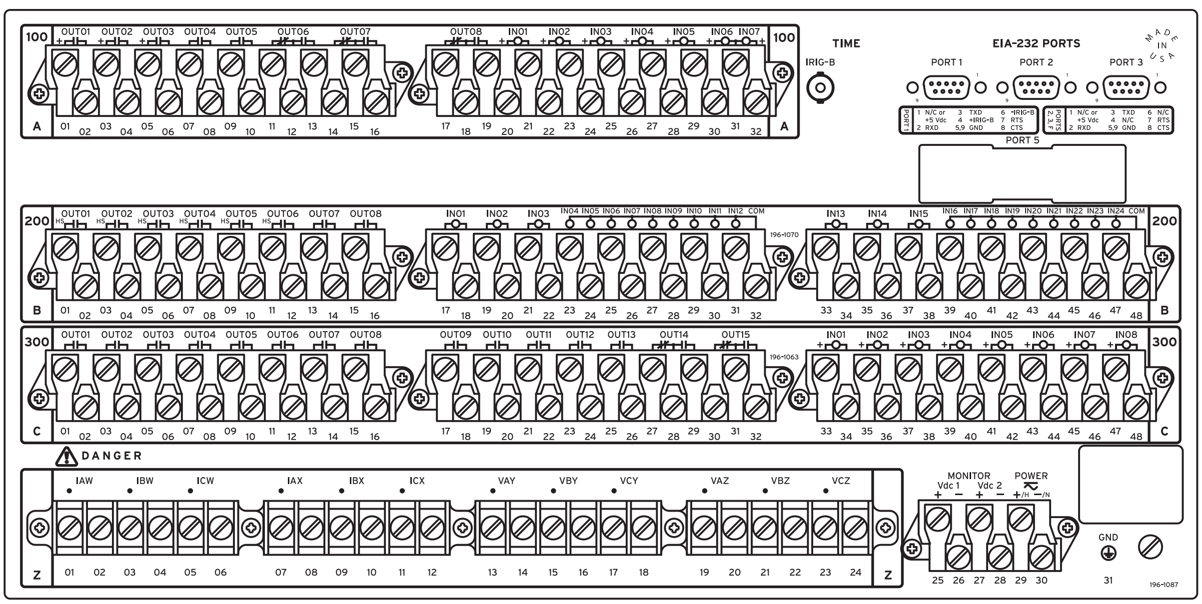
Figure 2.31 4U Rear Panel, Main Board B, INT8 I/O Interface Board



i4122a

Figure 2.32 5U Rear Panel, Main Board B, INT3 and INT1 I/O Interface Board

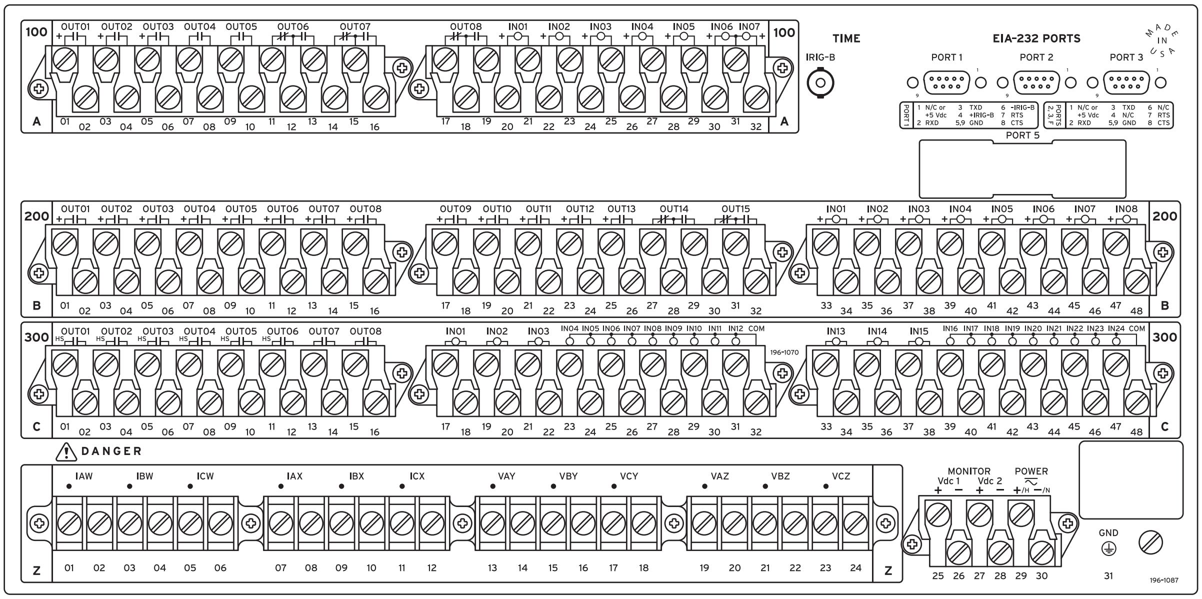
(The INT3 board is the 200-addresses slot; the INT1 board is the 300-addresses slot.)



i3812c

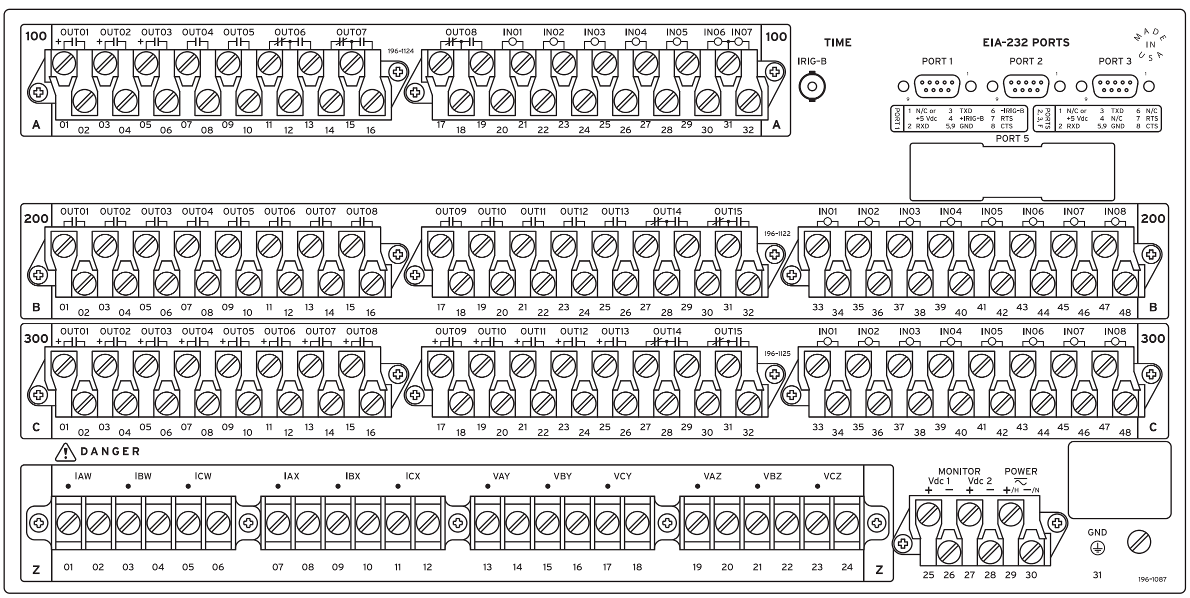
Figure 2.33 5U Rear Panel, Main Board A, INT4 and INT1 I/O Interface Board

(The INT4 board is the 200-addresses slot; the INT1 board is the 300-addresses slot.)



i3926a

Figure 2.34 5U Rear Panel, Main Board A, INT6 and INT4 I/O Interface Board



i3927a

Figure 2.35 5U Rear Panel, Main Board B, INT2 and INT7 I/O Interface Board

Rear-Panel Symbols

There are important safety symbols on the rear of the SEL-421 (see *Figure 2.36*). Observe proper safety precautions when you connect the relay at terminals marked by these symbols. In particular, the danger symbol located on the rear panel corresponds to the following: *Contact with instrument terminals can cause electrical shock that can result in injury or death*. Be careful to limit access to these terminals.

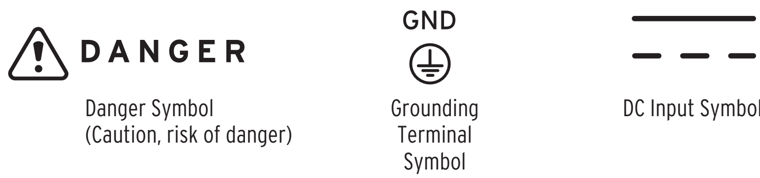


Figure 2.36 Rear-Panel Symbols

Screw Terminal Connectors

Terminate connections to the SEL-421 screw terminal connectors with ring-type crimp lugs. Use a #8 ring lug with a maximum width of 0.360 in. (9.1 mm). The screws in the rear-panel screw terminal connectors are #8-32 binding head, slotted, nickel-plated brass screws. Tightening torque for the terminal connector screws is 9 in-lb. to 18 in-lb. (1.0 Nm to 2.0 Nm).

You can remove the screw terminal connectors from the rear of the SEL-421 by unscrewing the screws at each end of the connector block. Perform the following steps to remove a screw terminal connector:

Step 1. Remove the connector by pulling the connector block straight out.

Note that the receptacle on the relay circuit board is keyed; you can insert each screw terminal connector in only one location on the rear panel.

Step 2. To replace the screw terminal connector, confirm that you have the correct connector and push the connector firmly onto the circuit board receptacle.

Step 3. Reattach the two screws at each end of the block.

Changing Screw Terminal Connector Keying

You can rotate a screw terminal connector so that the connector wire dress position is the reverse of the factory-installed position (for example, wires entering the relay panel from below instead of from above). In addition, you can move similar function screw terminal connectors to other locations on the rear panel. To move these connectors to other locations, you must change the screw terminal connector keying.

Inserts in the circuit board receptacles key the receptacles for only one screw terminal connector in one orientation. Each screw terminal connector has a missing web into which the key fits (see *Figure 2.37*).

If you want to move a screw terminal connector to another circuit board receptacle or reverse the connector orientation, you must rearrange the receptacle keys to match the screw terminal connector block. Use long-nosed pliers to move the keys.

Figure 2.38 shows the factory default key positions.

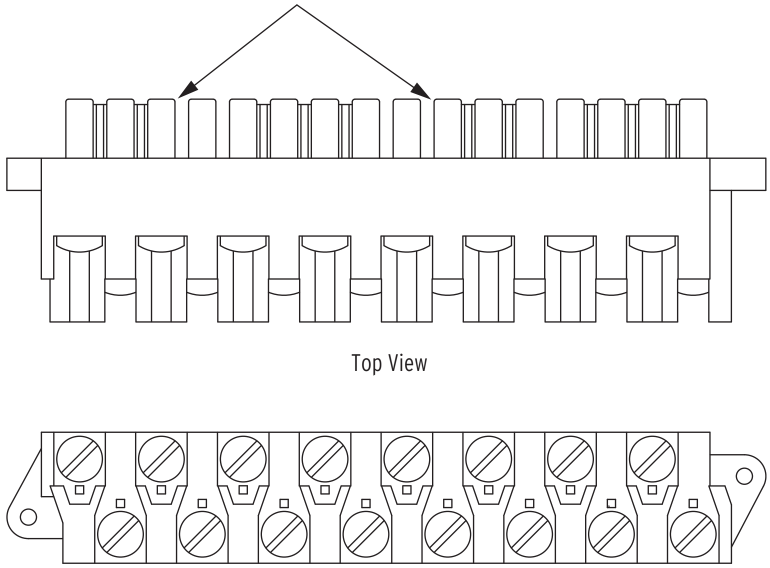


Figure 2.37 Screw Terminal Connector Keying

Grounding

Connect the grounding terminal (#Z31) labeled GND on the rear panel to a rack frame ground or main station ground for proper safety and performance.

This protective earthing terminal is in the lower right side of the relay panel (see *Figure 2.27*, *Figure 2.28*, *Figure 2.29*, and *Figure 2.30*, and *Figure 2.33*). The symbol that indicates the grounding terminal is shown in *Figure 2.36*.

Use 12–10 AWG (4 mm^2–6 mm^2) wire less than 6.6 feet (2 m) in length for this connection. This terminal connects directly to the internal chassis ground of the SEL-421.

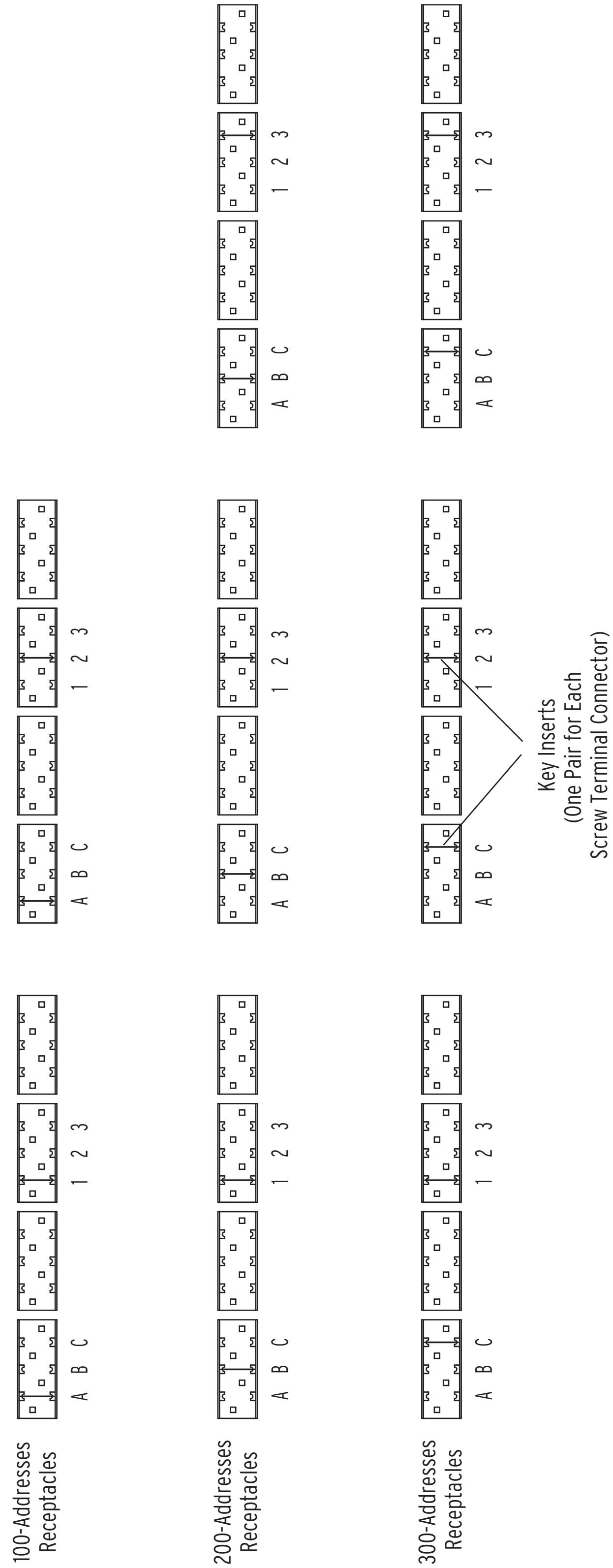


Figure 2.38 Rear-Panel Receptacle Keying, SEL-421

Power Connections

The terminals labeled **POWER** on the rear panel (#**Z29** and #**Z30**) must connect to a power source that matches the power supply characteristics that your SEL-421 specifies on the rear-panel serial number label. (See *Power Supply*

on page U.1.13, for complete power input specifications.) For the relay models that accept dc input, the serial number label specifies dc with the symbol shown in *Figure 2.36*.

NOTE: The combined voltages applied to the **POWER** and **MONITOR** terminals must not exceed 600 V (rms or dc).

The **POWER** terminals are isolated from chassis ground. Use 16–14 AWG (1.5 mm^2–2.1 mm^2) size wire to connect to the **POWER** terminals. Connection to external power must comply with IEC 60947-1 and IEC 60947-3 and must be identified as the disconnect device for the equipment.

Place an external disconnect device, switch/fuse combination, or circuit breaker in the **POWER** leads for the SEL-421; this device must interrupt both the hot (**H/+**) and neutral (**N/–**) power leads. The current rating for the power disconnect circuit breaker or fuse must be 20 A maximum. Be sure to locate this device within 9.8 feet (3.0 m) of the relay.

Operational power is internally fused by power supply fuse F1. *Table 2.11* lists the SEL-421 power supply fuse requirements. Be sure to use fuses that comply with IEC 127-2.

You can order the SEL-421 with one of three operational power input ranges listed in *Table 2.11*. Each of the three supply voltage ranges represents a power supply ordering option.

As noted in *Table 2.11*, model numbers for the relay with these power supplies begin 04210*n* (or 04211*n*), where *n* is 2, 4, or 6, to indicate low, middle, and high voltage input power supplies, respectively.

Note that each power supply range covers two widely used nominal input voltages. The SEL-421 power supply operates from 30 Hz to 120 Hz when ac power is used for the **POWER** input.

Table 2.11 Fuse Requirements for the SEL-421 Power Supply

Nominal Power Supply Voltage Rating	Power Supply Voltage Range	Fuse F1	Fuse Description	Model Number
24/48 V	18–60 Vdc	T6.3AH250V	5x20 mm, time-lag, 6.3 A, high break capacity, 250 V	042102 or 042112
48/125 V	38–140 Vdc or 85–140 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	042104 or 042114
125/250 V	85–300 Vdc or 85–264 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	042106 or 042116

The SEL-421 accepts dc power input for all three power supply models. The 48/125 Vdc supply also accepts 120 Vac; the 125/250 Vdc supply also accepts 120/240 Vac. When connecting a dc power source, you must connect the source with the proper polarity, as indicated by the **+** (terminal #**Z29**) and **–** (terminal #**Z30**) symbols on the power terminals. When connecting to an ac power source, the **+** terminal #Z29 is hot (**H**), and the **–** terminal #**Z30** is neutral (**N**).

Each model of the SEL-421 internal power supply exhibits low power consumption and a wide input voltage tolerance. For more information on the power supplies, see *Power Supply on page U.1.13*.

Power Supply 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.

> ⚠ **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.

> ⚠ **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.

You can replace a bad fuse in an SEL-421 power supply, or you can return the SEL-421 to SEL for fuse replacement. If you decide to replace the fuse, perform the following steps to replace the power supply fuse:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-421.

Step 3. Remove the relay from the rack or panel.

Step 4. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 5. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 6. Remove the rear-panel **EIA-232 PORT** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 7. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 8. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 9. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 10. Remove the screw terminal connectors.

a. Loosen the attachment screws at each end of the 100-addresses, 200-addresses, and 300-addresses screw terminal connectors.

b. Pull straight back to remove.

Step 11. Remove the top chassis plate by unscrewing seven screws from the chassis.

Step 12. Pull out the drawout tray containing the main board.

Step 13. Pull out the drawout tray containing the I/O interface board(s).

Step 14. Locate the power supply. Fuse F1 is at the rear of the power supply circuit board (see *Figure 2.39*).

Step 15. Examine the power supply for blackened parts or other damage. If you can see obvious damage, reinstall all boards and contact SEL to arrange return of the relay for repair.

Step 16. Remove the spent fuse from the fuse clips.

Step 17. Replace the fuse with an exact replacement (see *Table 2.11* for the proper fuse for your power supply).

Step 18. Reinstall the interface board.

Step 19. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

Step 20. Replace the chassis top on the relay and secure it with seven screws.

Step 21. Reconnect the cable removed in *Step 8* and reinstall the relay front-panel cover.

Step 22. Reattach the rear-panel connections.

Affix the screw terminal connectors to the appropriate 100-addresses, 200-addresses, and 300-addresses locations on the rear panel.

Step 23. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 24. Follow your company standard procedure to return the relay to service.

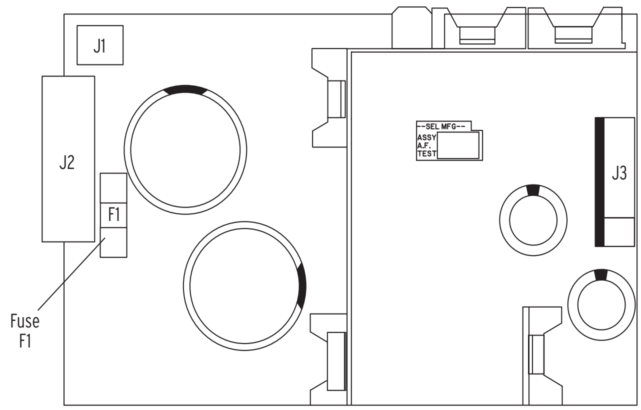


Figure 2.39 PS30 Power Supply Fuse Location

Monitor Connections (DC Battery)

NOTE: The combined voltages applied to the **POWER** and **MONITOR** terminals must not exceed 600 V (rms or dc).

The SEL-421 monitors two dc battery systems. For information on the battery monitoring function, see *Station DC Battery System Monitor on page A.2.21*.

Connect the positive lead of Battery System 1 to Terminal #**Z25** and the negative lead of Battery System 1 to Terminal #**Z26**. (Usually Battery System 1 is also connected to the rear-panel **POWER** input terminals.) For Battery System 2, connect the positive lead to Terminal #**Z27**, and the negative lead to Terminal #**Z28**.

Secondary Circuit Connections

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

The SEL-421 has two sets of three-phase current inputs and two sets of three-phase voltage inputs. *Shared Configuration Attributes on page U.2.1* describes these inputs in detail. The alert symbol and the word **DANGER** on the rear panel indicate that you should use all safety precautions when connecting secondary circuits to these terminals.

To verify these connections, use SEL-421 metering (see *Examining Metering Quantities on page U.4.33*). You can also review metering data in an event report that results when you issue the **TRIGGER** command (see *Triggering Data Captures and Event Reports on page A.3.4*).

Fixed Terminal Blocks

Connect the secondary circuits to the **Z** terminal blocks on the relay rear panel. Note the polarity dots above the odd-numbered terminals #**Z01**, #**Z03**, #**Z05**, #**Z07**, #**Z09**, and #**Z11** for CT inputs. Similar polarity dots are above the odd-numbered terminals #**Z13**, #**Z15**, #**Z17**, #**Z19**, #**Z21**, and #**Z23** for PT inputs.

Connectorized

⚠CAUTION
Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.

For the Connectorized SEL-421, order the wiring harness kit, SEL-WA0421. The wiring harness contains four prewired connectors for the relay current and voltage inputs.

You can order the wiring harness with various wire sizes and lengths. Contact your local Technical Service Center or the SEL factory for ordering information.

Perform the following steps to install the wiring harness:

Step 1. Plug the CT shorting connectors into terminals #**Z01** through #**Z06** for the **IW** inputs, and #**Z07** through #**Z12** for the **IX** inputs, as appropriate.

Odd-numbered terminals are the polarity terminals.

Step 2. Secure the connector to the relay chassis with the two screws located on each end of the connector.

When you remove the CT shorting connector, pull straight away from the relay rear panel.

As you remove the connector, internal mechanisms within the connector separately short each power system current transformer.

You can install these connectors in only one orientation.

Step 3. Plug the PT voltage connectors into terminals #**Z13** to #**Z18** for the VY inputs, and #**Z19** to #**Z24** for the VZ inputs, as appropriate.

Odd numbered terminals are the polarity terminals. You can install these connectors in only one orientation.

Control Circuit Connections

You can configure the SEL-421 with many combinations of control inputs and control outputs. See *Main Board I/O on page U.2.10* and *I/O Interface Boards on page U.2.12* for information about I/O configurations. This subsection provides details about connecting these control inputs and outputs. Refer to *Figure 2.2*, *Figure 2.10*, and *Figure 2.14* for representative rear-panel screw terminal connector locations.

Control Inputs

NOTE: The combined voltages applied to the INnnn and OUTnnn terminals must not exceed 600 V (rms or dc).

Table 2.3 lists the control inputs available with the SEL-421, and notes that some are Direct-Coupled, and some are Optoisolated.

Direct-Coupled

Direct-coupled control inputs are polarity sensitive. These inputs use direct-coupled circuitry, and have terminal markings to indicate polarity: a + mark appears for each input. Connect the positive sense of the control input to the **+** terminal. Although you cannot damage these inputs with a reverse polarity connection, a reverse polarity connection will cause the relay internal A/D converter to measure the input voltage incorrectly and the relay will no longer detect input changes (see *Control Inputs on page U.2.5*).

Note that the Main Board A I/O control inputs have one set of two inputs that share a common input leg. These inputs are **IN106** and **IN107** found on terminals #**A30**, #**A31**, and #**A32**.

Optoisolated

Optoisolated control inputs are not polarity sensitive. These inputs respond to voltage of either polarity, and can be used with ac control signals when properly configured.

Note that the Main Board B I/O control inputs have one set of two inputs that share a common input leg and INT3 and INT4 I/O interface boards have two sets of nine inputs that share a common leg (see *Figure 2.13*).

Assigning

To assign the functions of the control inputs, see *Operating the Relay Inputs and Outputs on page U.4.56*, or *SET G on page R.9.41* for more details. You can also use ACSELERATOR QuickSet to set and verify operation of the inputs.

Control Outputs

The SEL-421 has three types of outputs:

➤ Standard outputs (example: main board OUT104)

➤ Hybrid (high-current-interrupting) outputs (example: main board OUT101)

➤ Fast Hybrid (fast high-current-interrupting) outputs (example: INT4 or INT5 (or INT8) board OUT201, or OUT301)

See *Control Outputs on page U.2.7* for more information.

You can connect the Standard outputs and the Fast Hybrid (fast high-current-interrupting) outputs in either ac or dc circuits. Connect the Hybrid (high-current-interrupting) outputs to dc circuits only. The screw terminal connector legends alert you about this requirement by showing polarity marks on the Hybrid (high-current-interrupting) contacts.

Form A (SPST NO) contacts comprise the majority of the control outputs. Two pairs of Form C (DPST CO) contacts are on the main board, the INT1 (INT2) I/O interface board, and the INT6 (INT7) I/O interface board.

The INT4 and INT5 (INT8) I/O interface boards feature high-speed operation capability using Fast Hybrid control outputs. To limit the false pickup indications with digital inputs and light duty high-speed auxiliary relays, precharging resistors are available on the screw terminal connector for each pair of control output contacts for INT5 boards. See *Fast Hybrid (Fast High-Current-Interrupting) Control Outputs on page U.2.9* for further information, and *Figure 2.8* and *Figure 2.9* for resistor connection details.

Alarm Output

The SEL-421 monitors internal processes and hardware in continual self-tests. If the relay senses an out-of-tolerance condition, the relay declares a Status Warning or a Status Failure. The relay signals a Status Warning by pulsing the HALARM Relay Word bit (hardware alarm) to a logical 1 for five seconds. For a Status Failure, the relay latches the HALARM Relay Word bit at logical 1.

To provide remote alarm status indication, connect the b contact of OUT108 to your control system remote alarm input. *Figure 2.40* shows the configuration of the a and b contacts of control output OUT108.

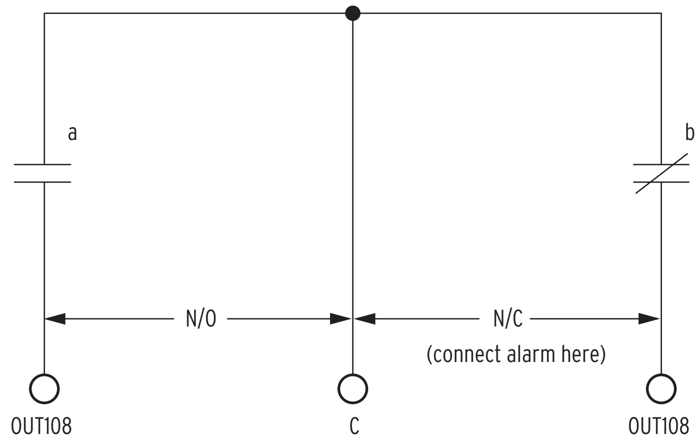


Figure 2.40 Control Output OUT108

Program OUT108 to respond to NOT HALARM by entering the following SELOGIC® control equation with a communications terminal, with ACSELERATOR QuickSet:

OUT108 := **NOT HALARM**

When the relay is operating normally, the NOT HALARM signal is at logical 1 and the b contacts of control output OUT108 are open.

When a status warning condition occurs, the relay pulses the NOT HALARM signal to logical 0 and the b contacts of OUT108 close momentarily to indicate an alarm condition.

For a status failure, the relay disables all control outputs and the OUT108 b contacts close to trigger an alarm. Also, when relay power is off, the OUT108 b contacts close to generate a power-off alarm. See *Relay Self-Tests on page U.6.38* for information on relay self-tests.

The relay pulses the SALARM Relay Word bit for software programmed conditions; these conditions include settings changes, access level changes, and alarming after three unsuccessful password entry attempts.

The SEL-421 also pulses the BADPASS Relay Word bit after three unsuccessful password entry attempts.

You can add the software alarm SALARM to the alarm output by entering the following SELOGIC control equation:

OUT108 := **NOT (HALARM OR SALARM)**

Tripping and Closing Outputs

To assign the control outputs for tripping and closing, see *Setting Outputs for Tripping and Closing on page U.4.62*. In addition, you can use the **SET O** command (see *SET on page R.9.40* for more details). You can also use the front panel to set and verify operation of the outputs (see *Set/Show on page U.5.28*).

Auxiliary {TRIP}/{CLOSE} Pushbuttons and OPEN/CLOSED LEDs (select models only)

Select relay models feature auxiliary **{TRIP}** and **{CLOSE}** pushbuttons and **OPEN** and **CLOSED** LED indicators. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

The pushbuttons and LEDs can be hard-wired into a substation trip and close control circuit and operate the same as a separate installation of external trip/close switches and LED indicators. *Figure 2.48* shows example trip and close circuit connections for a control scheme configuration with a dc substation voltage source. The pushbutton switches come set from the factory for dc operation (arc suppression enabled). To use an ac trip or close potential, the arc suppression must be disabled for one or both pushbuttons (see *Table 2.9*). The voltage operating ranges of the LEDs are selected by jumpers (see *Table 2.8*).

⚠WARNING
SEL-421 features such as Hot Line Tag and Synchronism Check do not supervise the auxiliary close pushbutton.

Since the trip and close buttons are functionally separate from the relay, a manual trip or close cannot be distinguished from an external protection or automation-initiated operation. Unless provisions are made in the control wiring, the action of the close pushbutton is unsupervised.

TIME Input Connections

IRIG-B Input Connection

NOTE: The position of the IRIG-B BNC connector changed when SEL-421 firmware version R112 was released. See 1k PPS Connection Not Required on page U.4.72 for details.

The SEL-421 accepts a demodulated IRIG-B signal through two types of rear-panel connectors. These **IRIG-B** inputs are through the BNC connector labeled **TIME IRIG-B** or through Pin **4** (+) and Pin **6** (–) of the rear-panel 9-pin D-subminiature connector **PORT 1** (see *Communications Ports Connections on page U.2.47* for other DB-9 connector pinouts and additional details).

These inputs accept the dc shift time code generator output (demodulated) IRIG-B signal with positive edge on the time mark. For more information on IRIG-B and the SEL-421, see *TIME Inputs on page U.2.11*.

The **PORT 1 IRIG-B** input circuit connects to a 330 Ω resistor in series with an optocoupler input diode. The optocoupler input diode forward voltage drop is about 1.5 V. Driver circuits should source approximately 10 mA through the circuit for the ON state. When you are using the **PORT 1** input, ensure that you connect Pins **4** and **6** with the proper polarity.

Where distance between the SEL-421 and the IRIG-B sending device exceeds the cable length recommended for conventional EIA-232 metallic conductor cables, you can use transceivers to provide isolation and to establish communication to remote locations.

Conventional fiber-optic and telephone modems do not support IRIG-B signal transmission. Use the SEL-2810 transceiver to provide long distance delivery of the IRIG-B signal to the SEL-421. The SEL-2810 includes a channel for the IRIG-B time code. These transceivers enable you to synchronize time precisely from IRIG-B time code generators (such as the SEL-2032 Communications Processor) over a fiber-optic communications link.

Use the IRIG-B BNC connector for synchrophasor and high-accuracy timekeeping applications—see *Configuring High-Accuracy Timekeeping on page U.4.71*. Make the connection using a 50 Ω coaxial cable assembly with a male BNC connector.

Obsolete TIME Input Connection

Previous SEL-421 relays had a **TIME 1k PPS** input BNC connector. When relay firmware version R112 was released, the rear-panel **TIME** inputs were reconfigured. If you have upgraded the firmware in a previous SEL-421, see *Using New SEL-421 Firmware in an Existing Relay on page U.4.73* for retrofit information.

The previous **1k PPS** BNC connector is the new **IRIG-B** connector. The previous **IRIG-B** BNC connector is not used. See *1k PPS Connection Not Required on page U.4.72* for details.

Replacing the Lithium Battery

You can replace a bad lithium battery in the SEL-421. Perform the following steps to replace the lithium battery.

Step 1. Follow your company standard procedure to remove a relay from service.

Step 2. Disconnect power from the SEL-421.

Step 3. Remove the relay from the rack or panel.

Step 4. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 5. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 6. Remove the rear-panel **EIA-232 PORTS** mating connectors.

Step 7. Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 8. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 9. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 10. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 11. Pull out the drawout tray containing the main board.

Step 12. Locate the lithium battery.

The lithium battery is at the front of the main board (see *Figure 2.19*).

Step 13. Remove the spent battery from beneath the clip of the battery holder.

Step 14. Replace the battery with an exact replacement.

Use a 3 V lithium coin cell, Ray-O-Vac® No. BR2335 or equivalent. The positive side (+) of the battery faces up.

Step 15. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

Step 16. Reconnect the cable removed in *Step 9* and reinstall the relay front-panel cover.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

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

⚠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.

⚠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.

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

Step 18. Set the relay date and time via the communications ports or front panel (see *Making Simple Settings Changes on page U.4.13*).

Step 19. Follow your company standard procedure to return the relay to service.

Communications Ports Connections

The SEL-421 has three rear-panel EIA-232 serial communications ports labeled **PORT 1**, **PORT 2**, and **PORT 3** and one front-panel port, **PORT F**. For information on serial communications, see *Establishing Communication on page U.4.4*, *Serial Communication on page R.4.2*, and *Serial Port Hardware Protocol on page R.5.1*.

In addition, the rear panel features a **PORT 5** for an optional communications card. For additional information about communications topologies and standard protocols that are available in the SEL-421, see *Network Connections on page U.2.48*, *Section 6: SEL Communications Processor Applications in the Applications Handbook*, *Section 7: Direct Network Communication in the Applications Handbook*, *Section 6: DNP3 Communications in the Reference Manual*, and *Section 8: IEC 61850 Communications in the Reference Manual*.

Serial Ports

The SEL-421 serial communications ports use EIA-232 standard signal levels in a D-subminiature 9-pin connector. To establish communication between the relay and a DTE device (a computer terminal, for example) with a D-subminiature 9-pin connector, use an SEL Cable C234A (see *Making an EIA-232 Serial Port Connection on page U.4.5*).

Figure 2.41 shows the configuration of SEL Cable C234A that you can use for basic ASCII and binary communication with the relay. A properly configured ASCII terminal, terminal emulation program, or ACSELERATOR QuickSet along with the C234A cable provide communication with the relay in most cases. See *Section 4: Communications Interfaces in the Reference Manual* for a list of hardware interfaces to the SEL-421.

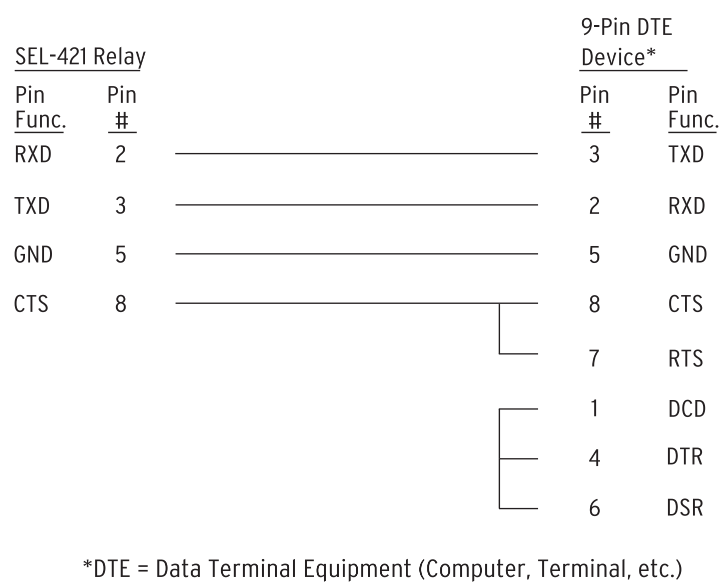


Figure 2.41 SEL-421 to Computer—D-Subminiature 9-Pin Connector

Serial Cables

⚠CAUTION
Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.

Using an improper cable can cause numerous problems or failure to operate, so you must be sure to specify the proper cable for application of your SEL-421. Several standard SEL communications cables are available for use with the relay. See *EIA-232 Communications Cables on page R.4.3* for information on recommended serial cables.

The following list provides additional rules and practices you should follow for successful communication using EIA-232 serial communications devices and cables:

➤ Route communications cables well away from power and control circuits. Switching spikes and surges in power and control circuits can cause noise in the communications circuits if power and control circuits are not adequately separated from communications cables.

➤ Keep the length of the communications cables as short as possible to minimize communications circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions.

➤ Ensure that EIA-232 communications cable lengths never exceed 50 feet, and always use shielded cables for communications circuit lengths greater than 10 feet.

➤ Modems provide communication over long distances and give isolation from ground potential differences that are present between device locations (examples are the SEL-28XX-series transceivers).

➤ Lower data speed communication is less susceptible to interference and will transmit greater distances over the same medium than higher data speeds. Use the lowest data speed that provides an adequate data transfer rate.

Network Connections

The optional Ethernet card for the SEL-421 can use either the connection on Port A or Port B to operate on a network. These ports work together to provide a primary and backup interface, as described in *Network Port Fail-Over Operation on page R.4.6*. The following list describes the Ethernet card port options.

➤ 10/100BASE-T. 10 Mbps or 100 Mbps communications using CAT 5 cable (category 5 twisted-pair) and an RJ-45 connector

➤ 100BASE-FX. 100 Mbps communications over multimode fiber-optic cable using an ST connector

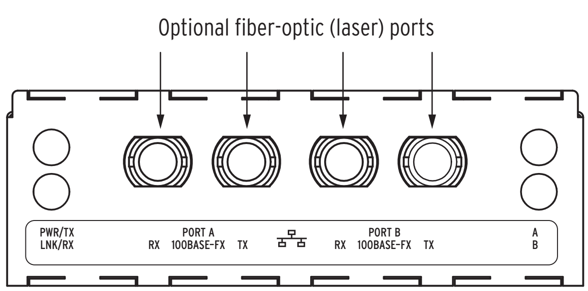


Figure 2.42 Example Ethernet Panel With Fiber-Optic Ports

Ethernet Card Rear-Panel Layout

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

⚠WARNING
Do not look into the fiber (laser) ports/connectors.

⚠WARNING
Do not look into the end of an optical cable connected to an optical output.

⚠WARNING
Do not perform any procedures or adjustments that this instruction manual does not describe.

⚠WARNING
During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.

⚠WARNING
Incorporated components, such as LEDs, transceivers, and laser emitters, are not user serviceable. Return units to SEL for repair or replacement.

Rear-panel layouts for the three Ethernet card port configurations are shown in *Figure 2.43–Figure 2.45*.

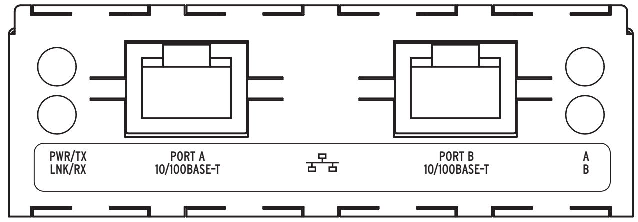


Figure 2.43 Two 10/100BASE-T Port Configuration

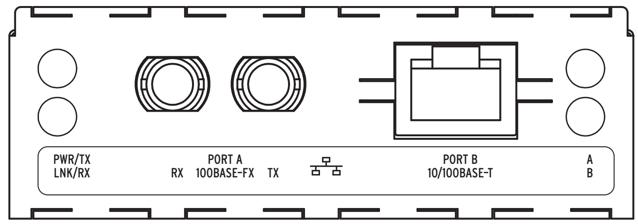


Figure 2.44 100BASE-FX and 10/100BASE-T Port Configuration

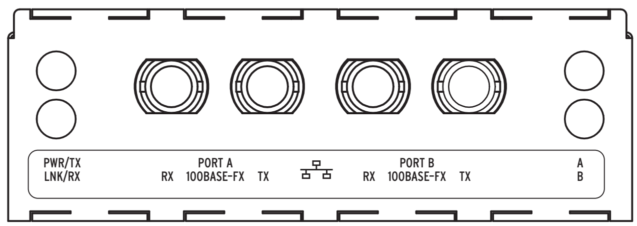


Figure 2.45 Two 100BASE-FX Port Configuration

Twisted-Pair Networks

NOTE: Use caution with UTP cables as these cables do not provide adequate immunity to interference in electrically noisy environments unless additional shielding measures are employed.

While Unshielded Twisted Pair (UTP) cables dominate office Ethernet networks, Shielded Twisted Pair (STP) cables are often used in industrial applications. The SEL-421 Ethernet card is compatible with standard UTP cables for Ethernet networks as well as STP cables for Ethernet networks.

Typically UTP cables are installed in relatively low-noise environments including offices, homes, and schools. Where noise levels are high, you must either use STP cable or shield UTP using grounded ferrous raceways such as steel conduit.

Several types of STP bulk cable and patch cables are available for use in Ethernet networks. If noise in your environment is severe, you should consider using fiber-optic cables. We strongly advise against using twisted-pair cables for segments that leave or enter the control house.

If you use twisted-pair cables, you should use care to isolate these cables from sources of noise to the maximum extent possible. Do not install twisted-pair cables in trenches, raceways, or wireways with unshielded power, instrumentation, or control cables. Do not install twisted-pair cables in parallel with power, instrumentation, or control wiring within panels, rather make them perpendicular to the other wiring.

You must use a cable and connector rated as Category 5 (CAT 5) to operate the twisted-pair interface (10/100BASE-T) at 100 Mbps. Because lower categories are becoming rare and because you may upgrade a 10 Mbps network to 100 Mbps, we recommend using all CAT 5 components.

Some industrial Ethernet network devices use 9-pin connectors for STP cables. The Ethernet card RJ-45 connectors are grounded so you can ground the shielded cable using a standard, externally shielded jack with cables terminating at the Ethernet card.

AC/DC Connection Diagrams

You can apply the SEL-421 in many power system protection schemes. *Figure 2.46* shows one particular application scheme with connections that represent typical interfaces to the relay for a single circuit breaker connection. *Figure 2.47* depicts typical connections for a dual circuit breaker protection scheme.

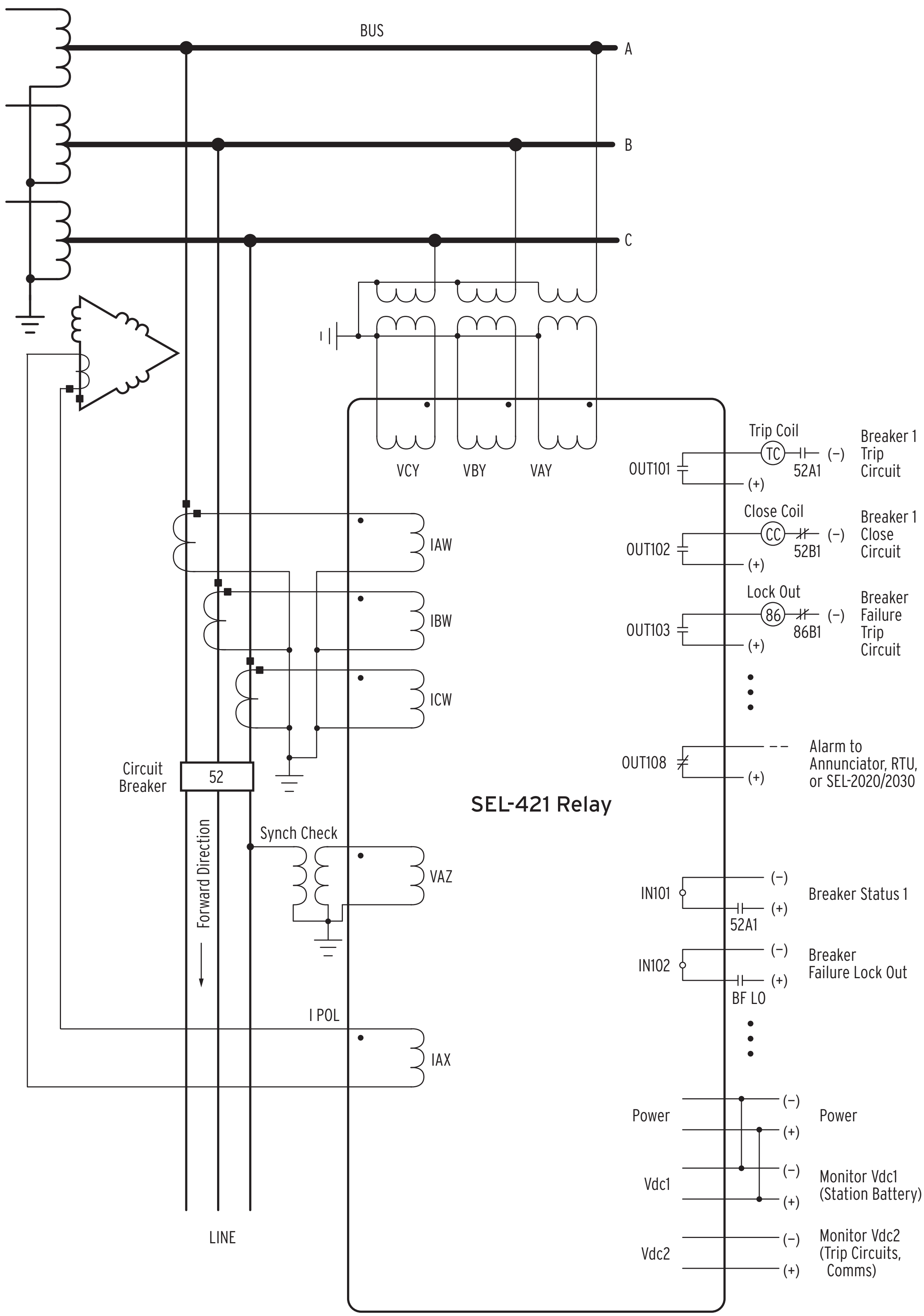


Figure 2.46 Typical External AC/DC Connections—Single Circuit Breaker

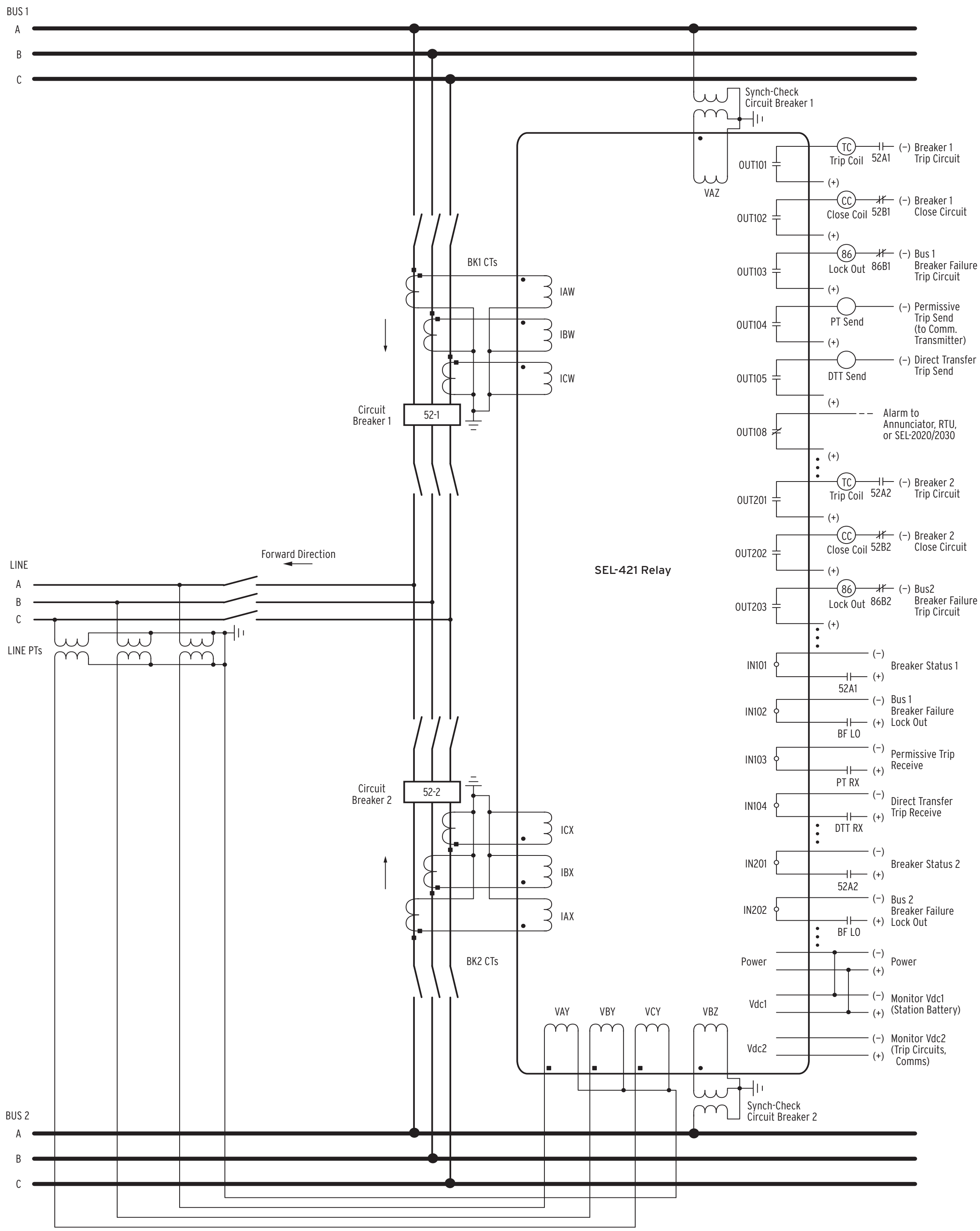


Figure 2.47 Typical External AC/DC Connections—Dual Circuit Breaker

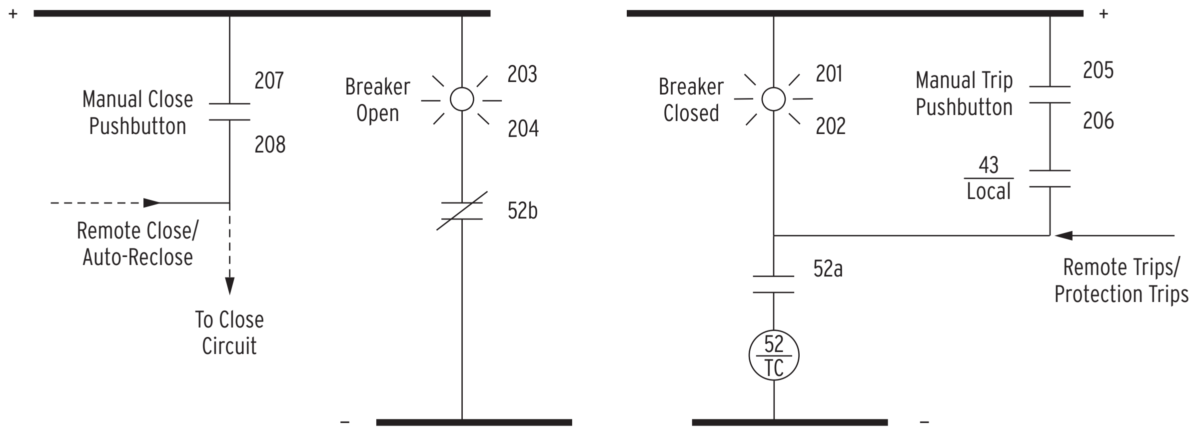


Figure 2.48 SEL-421 Example Wiring Diagram Using the Auxiliary {TRIP}/{CLOSE} Pushbuttons

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Section 3

PC Software

This section provides information on the following topics:

The SEL-421 Relay includes ACSELERATOR QuickSet® SEL-5030 software, a powerful relay settings, analysis, and measurement tool to aid you in applying and using the relay. ACSELERATOR QuickSet reduces engineering costs for relay settings, logic programming, and system analysis. ACSELERATOR QuickSet also makes it easier for you to do the following:

- Create and manage relay settings
  - Create settings for one or more SEL-421 relays
  - Store and retrieve settings with an IBM-compatible personal computer (PC)
  - Upload and download relay settings files to and from SEL-421 relays
- Analyze events
  - Use the integrated waveform and harmonic analysis tools
- Monitor real-time and relay-stored power system data
  - Use the human machine interface (HMI) to view metering, Relay Word bits, and circuit breaker monitor data
- Control the relay
  - Command relay operation through use of a graphical user interface (GUI) environment
  - Execute relay serial port commands in terminal mode
- Configure the serial port and passwords

SEL provides ACSELERATOR QuickSet for easier, more efficient configuration of relay settings, metering, and control. ACSELERATOR QuickSet gives you the advantages of rules-based settings checks, SELOGIC® control equation Expression Builder, operator control and metering HMI, and event analysis.

However, you do not have to use ACSELERATOR QuickSet to configure the SEL-421; you can continue to use an ASCII terminal or a computer running terminal emulation software to access all relay settings and metering.

Installing the Computer Software

Load ACSELERATOR QuickSet on an IBM-compatible PC. If you encounter any difficulties installing ACSELERATOR QuickSet, contact your Technical Service Center or the SEL factory for assistance. See *Factory Assistance on page U.6.45* for contact information.

System Requirements

To successfully install and use ACSELERATOR QuickSet, your PC must have the minimum resources listed in *Table 3.1*.

Table 3.1 System Requirements for ACSELERATOR QuickSet

Item	Description
Processor	Pentium® class, ≥ 90 MHz
Operating System/RAM	Microsoft® Windows® 98/ME/XP—64 MB RAM Microsoft Windows 2000—64 MB RAM Microsoft Windows NT®—32 MB RAM (64 MB recommended)
Hard drive	At least 100 MB available storage space
Communications Port	One EIA-232 serial port or one Ethernet port
Drives	CD-ROM for software installation
Monitor	SVGA 800 x 600 pixel resolution or greater (1024 x 768 pixel resolution recommended)
Pointing Device	Mouse or other pointing device

Installation

You can load ACSELERATOR QuickSet automatically if your computer autorun feature is enabled; this is Method A.

If autorun is not enabled on your computer, use the Windows **Run** command to load ACSELERATOR QuickSet; this is Method B.

Method A

Load ACSELERATOR QuickSet automatically:

Step 1. Turn on your PC and run the Windows operating environment.

Step 2. Close all other applications on your PC.

Step 3. Place the ACSELERATOR QuickSet CD-ROM in the PC CD-ROM drive.

The setup software runs automatically and the SEL **Software License Agreement** appears, as in *Figure 3.1*.

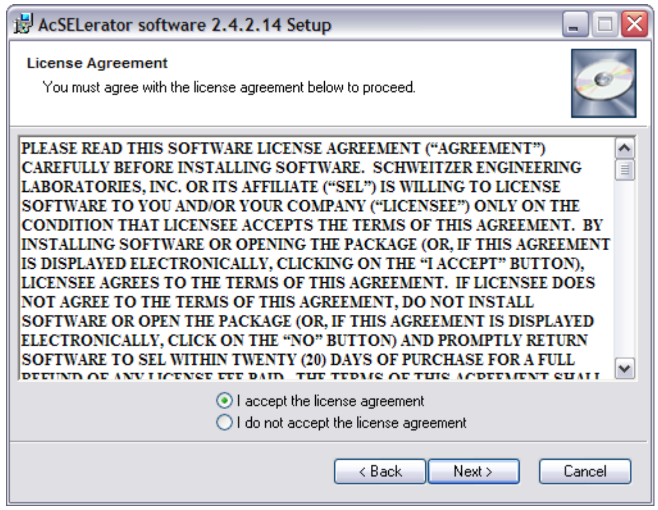


Figure 3.1 SEL Software License Agreement (Sample)

Method B

Load ACSELERATOR QuickSet with the Windows **Run** Command:

Step 1. If the **Setup** program does not start automatically, click **Start** > **Run** to load ACSELERATOR QuickSet.

Step 2. Type the command shown in *Figure 3.2*, being certain to use the correct drive letter for the CD-ROM drive in your PC (the CD-ROM drive in the *Figure 3.2* example is drive **D:**\).

Step 3. The SEL **Software License Agreement** appears (*Figure 3.1*).

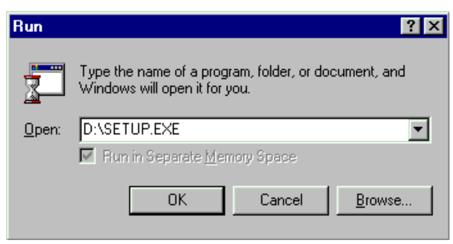


Figure 3.2 Windows Run Command Line to Load ACSELERATOR QuickSet

Step 4. Complete the software loading process.

Step 5. Read the **Software License Agreement** and follow the loading instructions as these instructions appear on the PC screen.

Starting ACSELERATOR QuickSet

You can use the Windows **Start** menu to open ACSELERATOR QuickSet:

Step 1. If you installed ACSELERATOR QuickSet to the **Program Manager** group, click **Start > Programs**.

Step 2. Click SEL **Applications** > ACSELERATOR QuickSet.

Step 3. If you used a custom program group, click **Start** and click ACSELERATOR QuickSet in the custom group.

You can also create a shortcut on the Windows Desktop (see your Windows documentation for instructions on creating a shortcut). Double-click the shortcut icon to start ACSELERATOR QuickSet from the shortcut.

Communications Setup

ACSELERATOR QuickSet uses the relay communications ports to communicate with the SEL-421. Configure the ACSELERATOR QuickSet **Communication Parameters** menu settings to communicate effectively with the relay.

You can also use a basic terminal emulation window any time you run ACSELERATOR QuickSet. Use the **Communication** menu to view and clear a **Connection Log**. For a step-by-step procedure using ACSELERATOR QuickSet to communicate with the relay, see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11*.

Communication Parameters

Use the **Communication Parameters** dialog box to configure relay communications settings. Select the **Communication** > **Parameters** from the top ACSELERATOR QuickSet toolbar to open this dialog box.

Figure 3.3 shows the ACSELERATOR QuickSet **Communication Parameters** dialog box.

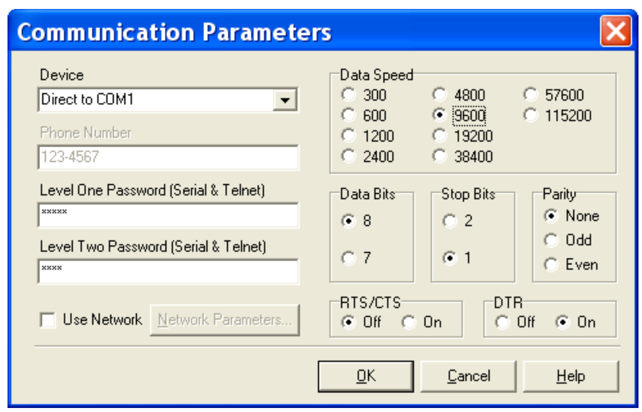


Figure 3.3 ACSELERATOR QuickSet Communication Parameters Dialog Box

Serial Setup

You can use serial communication via PORT 1, PORT 2, PORT 3, and PORT F (front panel). *Figure 3.3* shows the default serial port parameters (**9600**, **8**, **N**, **1**). Enter your relay **Level One** and **Level Two** passwords in the respective text boxes. (For complete information on passwords, see *Changing the Default Passwords: Terminal on page U.4.9*.)

If you choose a device from the **Device** text box that is a telephone modem, enter the dial-up telephone number in the **Phone Number** text box.

FTP Setup

Click the **Use Network** check box to access the **Network Parameters**. *Figure 3.4* shows the **Network Parameters** dialog box. For **FTP** (File Transfer Protocol) use **Telnet Port number 23**.

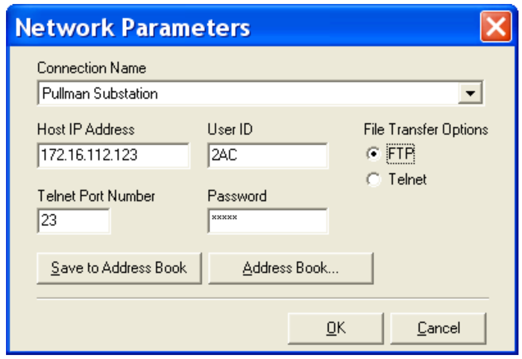


Figure 3.4 ACSELERATOR QuickSet Network Parameters Dialog Box: FTP

When you connect to a relay to use FTP, you must specify the access level and password.

Enter the access level command (**ACC**, **2AC**, for example) in the **User ID** text box and the corresponding access level password in the **Password** text box to control the relay at a specific access level (see *Changing the Default Passwords: Terminal on page U.4.9*).

Telnet Setup

Click the **Telnet** option button in the **Network Parameters** dialog box (see *Figure 3.5*) to connect to a relay for a **Telnet** session. The **Telnet** session uses the relay passwords in the **Communication Parameters** dialog box (*Figure 3.3*).

The default **Telnet Port Number** for accessing the relay is **T1PNUM := 23**. The default **Telnet Port Number** for communicating directly with an installed Ethernet card is **T2PNUM := 1024**.

See *Section 7: Direct Network Communication in the Applications Handbook* for information on changing the **Telnet Port Number**.

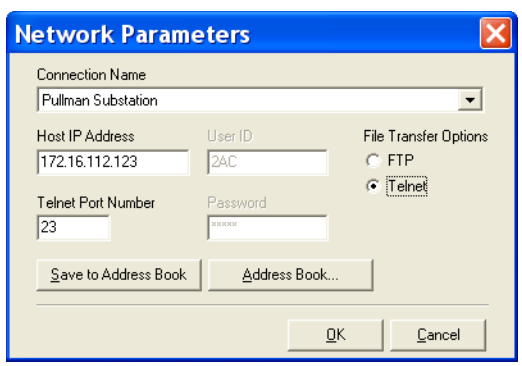


Figure 3.5 ACSELERATOR QuickSet Network Parameters Dialog Box: Telnet

Terminal Mode

The terminal emulation window is an ASCII interface between you and the relay. This is a basic terminal emulation with no file transfer capabilities. Many third-party terminal emulation programs are available with file transfer encoding schemes.

Click **Communication** > **Terminal** to start the terminal emulation window. Another convenient method to start the terminal is to type **<Ctrl+T>**.

Terminal Logging

When you check the **Terminal Logging** item in the **Communication** menu, ACSELERATOR QuickSet records communications events and errors in a log.

Click **Communication > Connection Log** to view the log.

Clear the log by selecting **Communication > Clear Connection Log**.

Settings Database Management and Drivers

Database Manager

ACSELERATOR QuickSet uses a relay database to save relay settings. ACSELERATOR QuickSet contains sets of all settings files for each relay that you specify in the **Database Manager**. See *Virtual File Interface on page R.5.11* for a list of the settings files in the SEL-421.

Choose appropriate storage backup methods and a secure location for storing your relay database files. Use the **File > Active Database** menu to retrieve a relay database from computer memory.

Relay Database

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

Perform the following steps to access and/or modify the database:

Step 1. Open the **Database Manager**.

Step 2. Click **File > Database Manager** in the ACSELERATOR QuickSet top toolbar.

A dialog box similar to *Figure 3.6* appears.

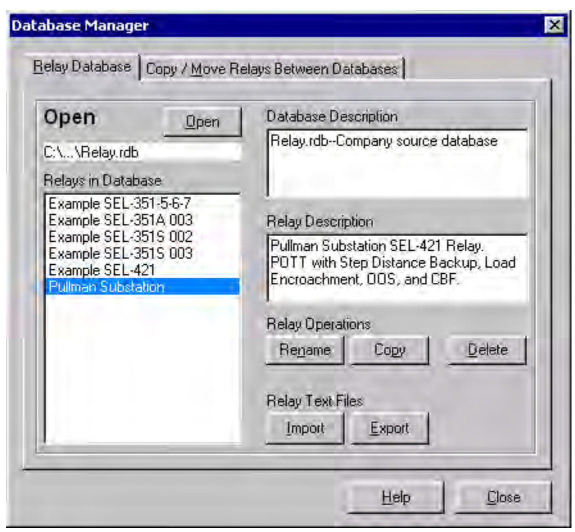


Figure 3.6 Database Manager Relay Database in ACSELERATOR QuickSet

Step 3. Enter descriptions for the database and for each relay in the database in the **Database Description** and **Relay Description** dialog boxes.

Type in the **Relay Description** dialog box special operating characteristics that describe the relay settings. These can include the protection scheme settings and communications settings.

Perform the following steps to create a new collection of relay settings:

Step 1. Highlight one of the relays listed in **Relays in Database** and click **Copy**.

ACSELERATOR QuickSet prompts you to provide a new name.

Step 2. Enter a new description in **Relay Description**.

Copy/Move Relays Between Databases

You can create multiple relay databases with the **Database Manager**; these databases are useful for grouping similar protection schemes or geographic areas.

Perform the following steps to copy or move a relay between databases:

Step 1. Select the **Copy / Move Relays Between Databases** tab to access the dialog box shown in *Figure 3.7*.

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

Step 3. Select or type a filename and click **Open**; for example, **Relay2.rdb** is the B relay database in *Figure 3.7*.

Step 4. Highlight a relay in the **Database A** list, select **Copy** or **Move**, and click the > button to create a new relay in **Database B**.

- ➢ **Copy** creates an identical relay that appears in both databases.
- ➢ **Move** removes the relay from one database and places the relay in another database.

Step 5. Reverse this process to copy or move relays from **Database B** to **Database A**.

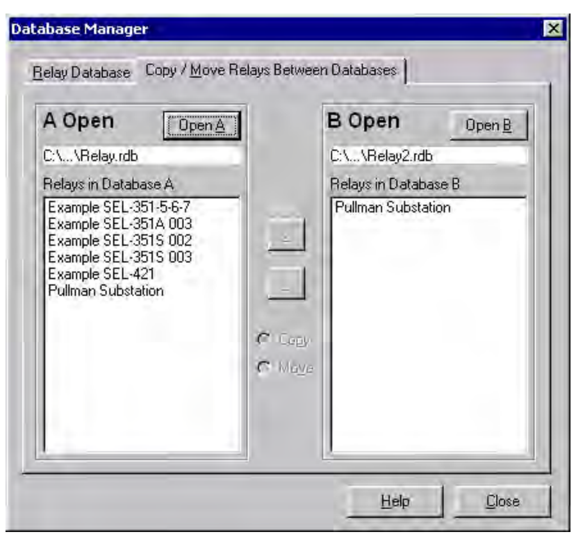


Figure 3.7 Database Manager Copy/Move in ACSELERATOR QuickSet

Create a New Database

Perform the following steps to create and copy an existing database of relays to a new database:

Step 1. Select the **File > Database Manager** to access the **Database Manager** dialog box.

Step 2. Select the **Copy / Move Relays Between Databases** tab in the **Database Manager** dialog box.

ACSELERATOR QuickSet opens the last active database and assigns it as **Database A** (see *Figure 3.7*).

Step 3. Click the **Open B** button.

ACSELERATOR QuickSet prompts you for a file location.

Step 4. Type a new database name, click the **Open** button, and answer **Yes.**

The program creates a new empty database.

Step 5. Load relays into the new database as in *Copy/Move Relays Between Databases on page U.3.7*.

Drivers

Relay settings folders in ACSELERATOR QuickSet are closely associated with the ACSELERATOR QuickSet relay driver that you used to create the settings. The relay settings and the ACSELERATOR QuickSet drivers must match.

Perform the following steps to ensure that the relay settings and ACSELERATOR QuickSet drivers match:

Step 1. Use any of the following methods to view the relay FID information:

- ➤ Enter the **STATUS** command.
- ➤ Click the **Status** button in the HMI tree view. See *Checking Relay Status on page U.4.10* for more information on viewing relay status.
- ➤ At a terminal (**<Ctrl+T>** from ACSELERATOR QuickSet), type **ID <Enter>**.

Step 2. View the ACSELERATOR QuickSet settings driver information at the bottom of the **Relay Editor** window (see *Figure 3.14*).

Step 3. Compare the ACSELERATOR QuickSet driver number and the relay FID number. The ACSELERATOR QuickSet driver Z-number and the corresponding part of the relay FID must match.

The first portion of the Z-number is the ACSELERATOR QuickSet settings driver version number (see *Figure 3.8*).

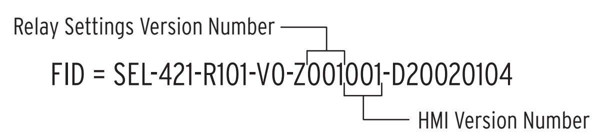


Figure 3.8 ACSELERATOR QuickSet Driver Information in the FID String

ACSELERATOR QuickSet reads the latter portion of the Z-number (ZXXX001, for example) to determine the correct HMI to display when you select the HMI **Meter and Control** menu. View the bottom of the HMI window to check the HMI driver number (see *Figure 3.9*).

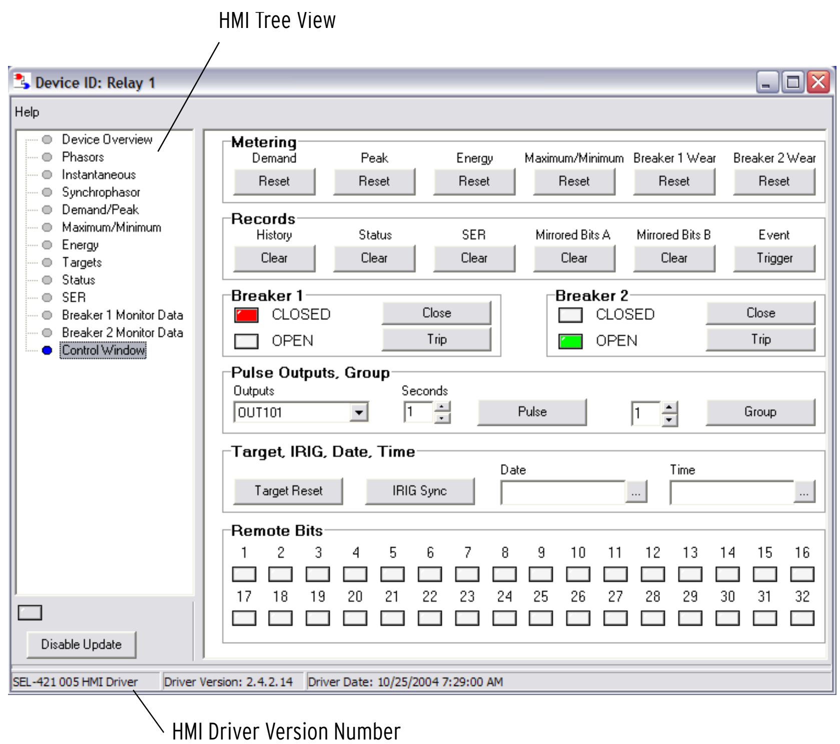


Figure 3.9 HMI Driver Version Number in the HMI Window

As SEL develops new drivers, you can update your existing ACSELERATOR QuickSet software with specific relay drivers for each SEL product that uses ACSELERATOR QuickSet. Contact your local Technical Service Center or the SEL factory for the latest ACSELERATOR QuickSet drivers.

Create and Manage Relay Settings

ACSELERATOR QuickSet gives you the ability to create settings for one or more SEL-421 relays. You can store existing relay settings downloaded from SEL-421 relays with ACSELERATOR QuickSet, creating a library of relay settings (see *Database Manager on page U.3.6*). You can then modify and upload these settings from your settings library to an SEL-421.

ACSELERATOR QuickSet makes setting the relay easy and efficient. For an example of setting the SEL-421 with ACSELERATOR QuickSet, see *Making Initial Global Settings: ACSELERATOR QuickSet on page U.4.25*.

Collected Settings

ACSELERATOR QuickSet arranges relay settings in easy-to-understand categories (for an explanation of settings organization, see *Making Simple Settings Changes on page U.4.13*). These categories of collected settings help you quickly set the relay.

Figure 3.10 is an example of relay settings categories in the **Relay Editor Settings** tree view. (Use the procedures described in *Settings Menu on page U.3.10* to view the tree views in *Figure 3.10*.)

ACSELERATOR QuickSet shows all of the settings categories in the settings tree view. When you enable and disable settings categories, the tree view remains constant, but when you click the tree view to access the settings in a disabled category, the disabled settings are dimmed.

For example, select the **Group 1 > Set 1 > Relay Configuration** branch of the **Settings** tree view and choose **N** for **E50Q**.

Click the **Negative-Sequence O/C** branch and observe that the **Negative-Sequence Overcurrent Elements** settings are dim.

If you select **1** for **E50Q**, then only the level 1 overcurrent element settings are active and the remainder of the **Negative-Sequence Overcurrent Element** settings are dim.

Figure 3.10 illustrates this feature of ACSELERATOR QuickSet.

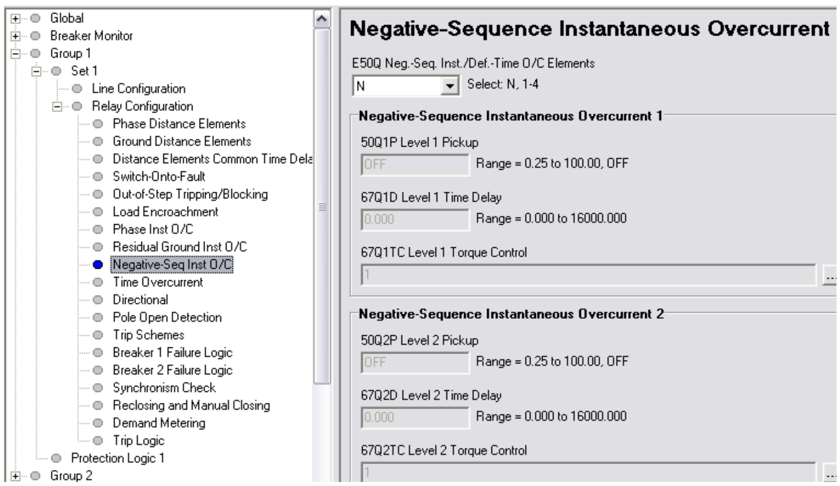


Figure 3.10 Sample Settings in ACSELERATOR QuickSet

Settings Menu

The **Settings** menu on the top ACSELERATOR QuickSet toolbar is the starting point for all settings entries. The menu items on the **Settings** menu are **New**, **Open**, and **Read**. All of these menu items open the **Relay Editor** (see *Relay Editor on page U.3.11*).

New

Selecting the **New** menu item creates new relay settings files. ACSELERATOR QuickSet makes the new settings files from the relay drivers that you specify in the **Settings Editor Selection** dialog box (see *Figure 3.11*).

ACSELERATOR QuickSet uses the Z-number in the relay FID string to create a particular version of relay settings (see *Drivers on page U.3.8*).

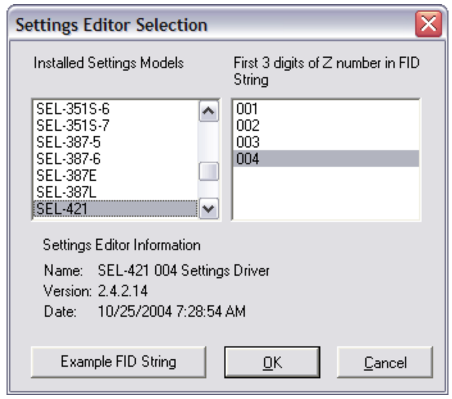


Figure 3.11 Selecting a Settings Driver in ACSELERATOR QuickSet

After selecting the relay model and settings driver, ACSELERATOR 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 (see *Relay Part Number on page U.3.12*).

Open

The **Open** menu item opens an existing relay from the active database folder (see *Figure 3.12*). ACSELERATOR QuickSet prompts you for a folder containing relay settings to load into the **Relay Editor**.

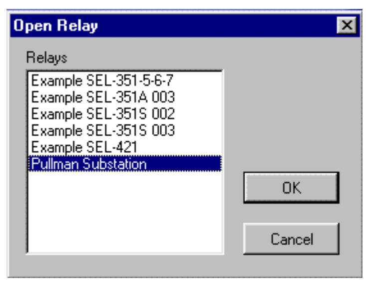


Figure 3.12 Opening Relay Settings in ACSELERATOR QuickSet

Read

When you select the **Read** menu item, ACSELERATOR QuickSet reads the relay settings from a connected relay. As ACSELERATOR QuickSet reads the relay, and a dialog box similar to *Figure 3.13* appears.

ACSELERATOR QuickSet uses serial protocols at a serial port or FTP from an Ethernet port to read settings from SEL devices.

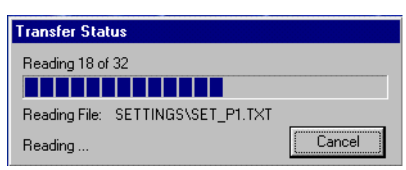


Figure 3.13 Reading Relay Settings in ACSELERATOR QuickSet

Relay Editor

Use the **Relay Editor** to enter relay settings. *Figure 3.14* illustrates the important features of the editor. These features include the ACSELERATOR QuickSet settings driver version number (the first three digits of the Z-number) in the lower left corner of the **Relay Editor**.

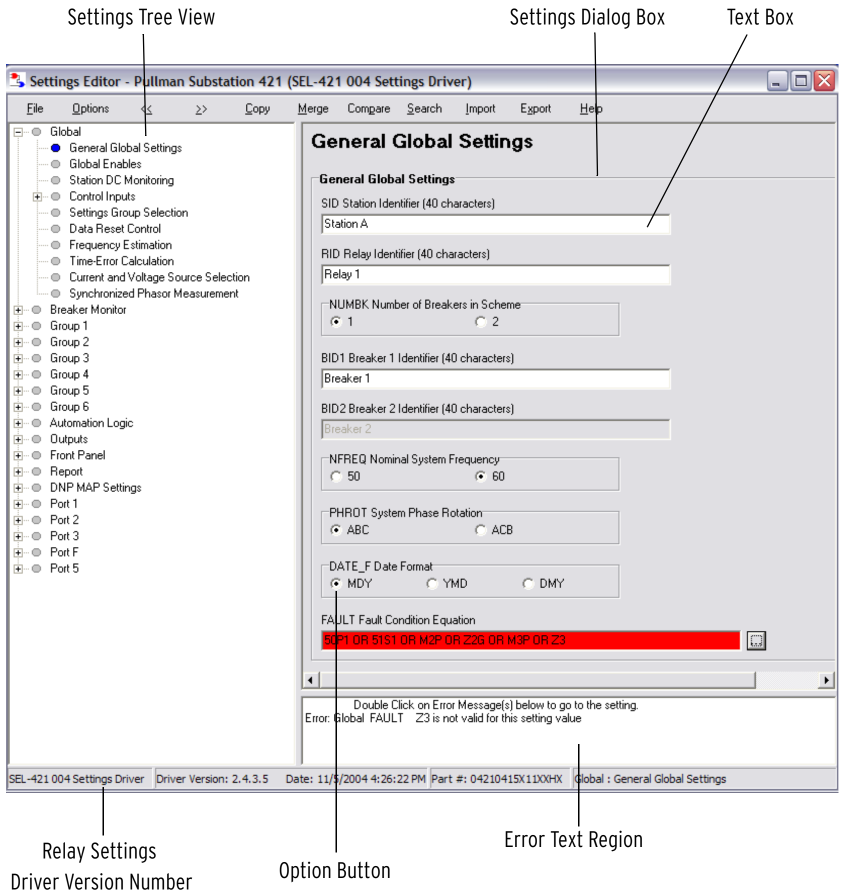


Figure 3.14 ACSELERATOR QuickSet Relay Editor

Entering Settings

Click the + marks and the buttons in the **Settings Tree View** to expand and select the settings class, instance, and category that you want to change.

Use **<Tab>** or click in a dialog box to edit a setting.

The right-click mouse button performs two special functions when you are editing settings: **Previous Value** and **Default Value**. To restore the previous value for a setting, right-click the setting and select **Previous Value**. Right-click the setting dialog box and select **Default Value** if you want to restore the factory default setting value.

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

Relay Part Number

The relay part number determines the settings that ACSELERATOR QuickSet displays and the functions that the software controls. When configuring ACSELERATOR QuickSet to control a particular relay, you should confirm that the ACSELERATOR QuickSet part number matches the relay part number so that you can access all of the settings you need for your relay.

Configuring the Part Number

Perform the following steps to configure the part number:

Step 1. Select the **Settings** menu on the ACSELERATOR QuickSet top toolbar and click **New**, **Open**, or **Read** to start the **Relay Editor** (see *Settings Menu on page U.3.10*).

Step 2. Once in the **Relay Editor**, click the **Options** menu on the **Relay Editor** toolbar (see *Figure 3.15*).

Step 3. Click **Part Number**.

Figure 3.15 Retrieving the Relay Part Number

The **Relay Part Number** dialog box appears, as shown in *Figure 3.16*.

Step 4. Use the arrows inside the text boxes to match corresponding portions of the **Relay Part Number** dialog box to your relay.

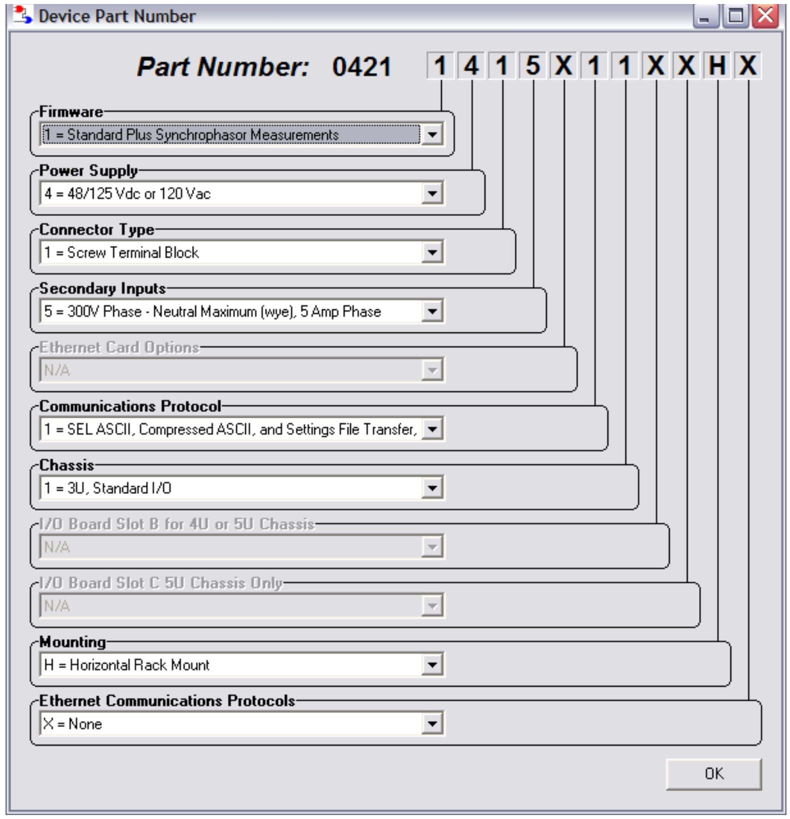


Figure 3.16 Setting the Relay Part Number in ACSELERATOR QuickSet

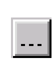
Expression Builder

SELOGIC control equations are a powerful means for customizing relay performance. Creating these equations can be difficult because of the large number of relay elements (Relay Word bits) and analog quantities in the relay.

ACSELERATOR QuickSet simplifies this process with the **Expression Builder**, a rules-based editor for programming SELOGIC control equations. The **Expression Builder** organizes relay elements, analog quantities, and SELOGIC control equation variables and focuses your equation decision-making. The **Expression Builder** checks basic rules and flags mistakes in SELOGIC control equation settings.

Access the Expression Builder

Settings dialog boxes (see *Figure 3.17*) in the **Relay Editor** window show the following (ellipsis) button:



Click this button of a SELOGIC equation to use the **Expression Builder**.

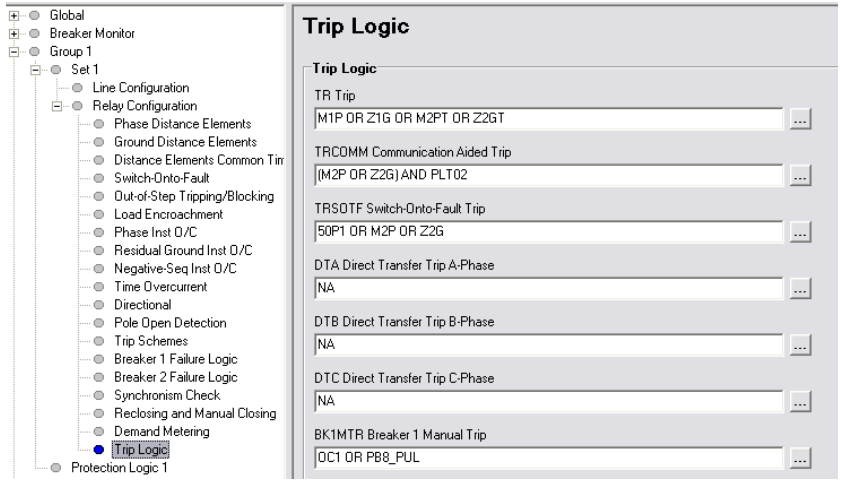


Figure 3.17 Location of the Expression Builder Option Buttons

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 except Protection Free-Form SELOGIC and Automation Free Form SELOGIC settings; see *Fixed SELOGIC Control Equations on page R.3.4*.)

Figure 3.18 shows the two sides of the **Expression Builder**, with the SELOGIC control equation that you are constructing at the top of the dialog box. Note the dark vertical line and the equals sign (**:=**) separating the equation left and right sides.

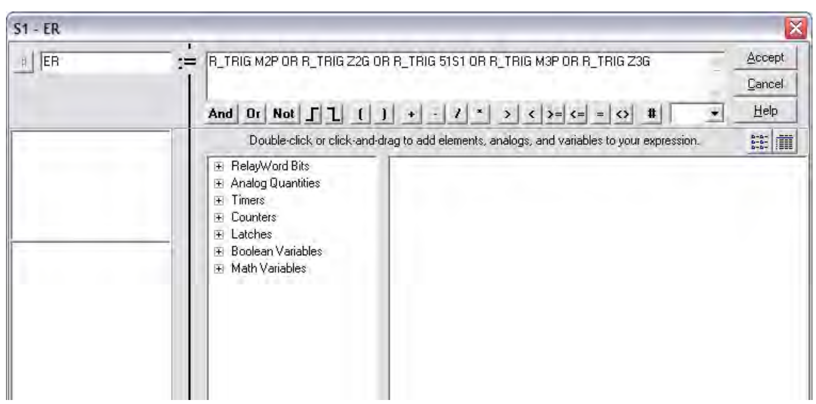


Figure 3.18 The ACSELERATOR QuickSet Expression Builder

Using the Expression Builder

For Protection Free-Form SELOGIC and Automation Free Form SELOGIC, select the type of result (LVALUE) for the SELOGIC control equation to use the **Expression Builder**. ACSELERATOR QuickSet shows these possibilities in the file box directly underneath the left side of the equation. The program shows the relay elements for each type of SELOGIC control equation (Boolean Variables, Math Variables, etc.).

On the right side of the equation (RVALUE), you can select broad categories of relay elements, analog quantities, counters, timers, latches, Boolean variables, and math variables. Select a category in the RVALUE tree view, and the **Expression Builder** displays all elements for that category in the list box at the bottom right side.

Directly underneath the right side of the equation, you can choose operations to include in the RVALUE. These operations include basic logic functions, rising and falling edge triggers, expression compares, and math functions.

For more information on programming SELOGIC control equations, see *Section 3: SELOGIC Control Equation Programming in the Reference Manual*.

Analyze Events

ACSELERATOR QuickSet has integrated analysis tools that help you retrieve information about protection system operations quickly and easily. Use the protection system event information that the SEL-421 stores to evaluate the performance of a protection system.

Event Waveforms

The SEL-421 records power system events for all trip situations and for other operating conditions that you program with SELOGIC control equations (see *SELOGIC Control Equation ER on page A.3.4*).

The relay provides two types of event data captures: high-resolution oscillography that uses raw sample per second data and event report oscillography that uses filtered sample per cycle data. See *Triggering Data Captures and Event Reports on page A.3.4* and *Generating an Event on page U.4.42* for information on recording events.

Use ACSELERATOR QuickSet to view high resolution and event report oscillograms, phasor diagrams, harmonic analyses, and settings.

Read History

You can retrieve event files stored in the relay and transfer these files to your PC. For information on the types of event files and data capture, see *Triggering Data Captures and Event Reports on page A.3.4*.

To download event files from the relay, open the ACSELERATOR QuickSet **Analysis** menu at the top ACSELERATOR QuickSet toolbar and click **View Event History**. The **Event History** dialog box appears (*Figure 3.19* is similar).

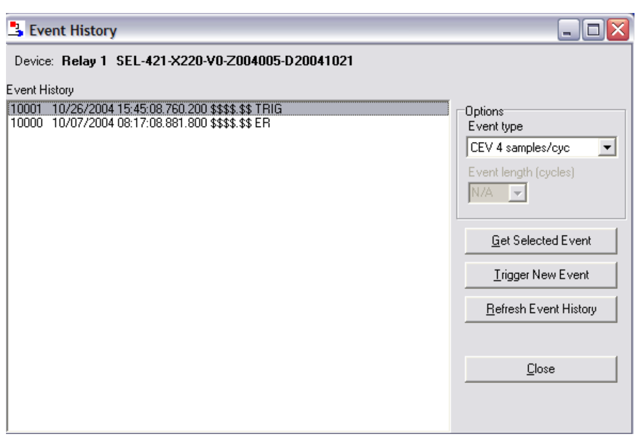


Figure 3.19 Retrieving Relay Event History

Get Event

Perform the following steps to view events:

Step 1. Highlight the event you want to view and click the **Get Selected Event** button.

For this exercise, choose Binary COMTRADE in the **Event Type** dialog box to select high-resolution oscillography. The other choices are CEV 4 samples/cyc and CEV 8 samples/cyc, which correspond to relay event reports of four or eight samples per cycle, respectively.

Step 2. When downloading is complete, ACSELERATOR QuickSet asks you to save the file on your PC.

Step 3. Once the file is saved, press the **Close** button, and then select the **Analysis** menu and click **View Event Files**.

Step 4. Open the oscillography file you just saved. It may be necessary to change the **Files of Type** selection to see the COMTRADE files in the file list.

NOTE: If your PC is loaded with SEL-5601 Analytic Assistant software (purchased separately), ACSELERATOR QuickSet® SEL-5030 Software automatically uses SEL-5601 to provide event analysis functionality. Some of the screen captures and related information may differ from the examples shown in this manual.

Step 5. ACSELERATOR QuickSet displays the **Event Waveform** dialog box and the event oscillogram (see *Figure 3.20* and *Figure 3.21*).

You can see high-accuracy time-stamp information on the event oscillogram.

When viewing the event oscillogram, use keyboard function keys to measure the time of oscillogram occurrences. These function keys and related functions help in event analysis

<F2>: go to trigger

<F3>: Cursor 1

<F4>: Cursor 2

The display shows the time difference between the **<F3>** and **<F4>** cursors.

Step 6. Click the **Pref** button at the bottom of the oscillogram and select **Time** (under **Time Units, Starting/Ending Row**).

Step 7. Click **OK**.

Step 8. Click on any point in a graph to observe the **Event Time** in microseconds of that data point at the bottom of the oscillogram.

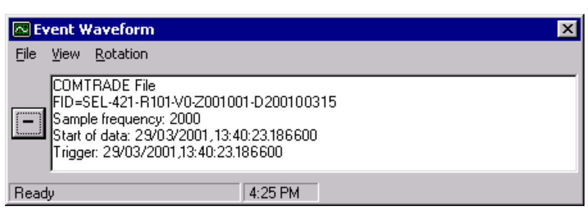


Figure 3.20 ACSELERATOR QuickSet Event Waveform Window

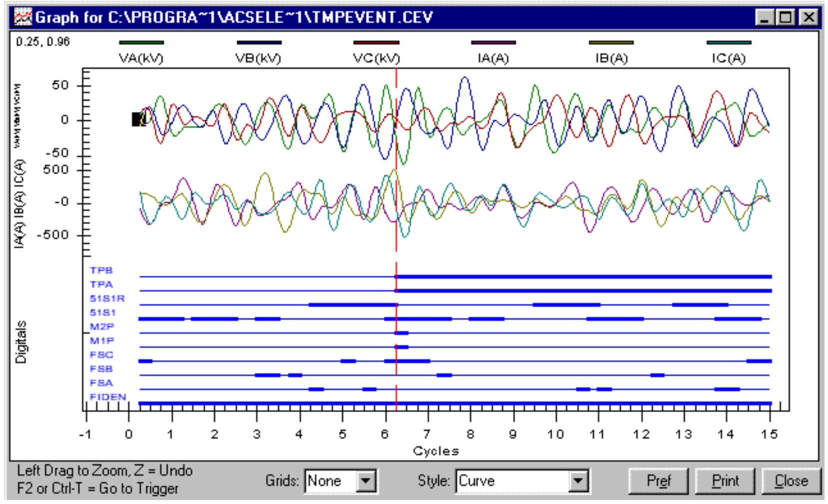


Figure 3.21 Sample Event Oscillogram

NOTE: The Phasors display is designed for 4 or 8-sample per cycle event reports. A warning message is displayed if you are viewing a COMTRADE file that cannot be properly represented in the phasor display.

You can also view other event displays:

Step 9. From the **Event Waveform** dialog box, select the **View** menu.

Step 10. Click **Phasors**, as shown in *Figure 3.22*, to view a sample-by-sample phasor display.

A phasor display similar to *Figure 3.23* appears.

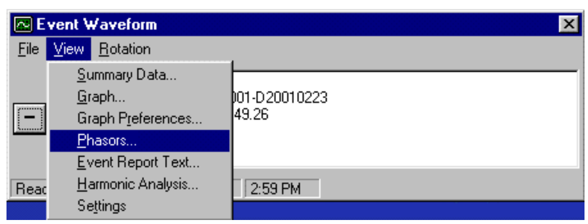


Figure 3.22 Retrieving Event Report Waveforms

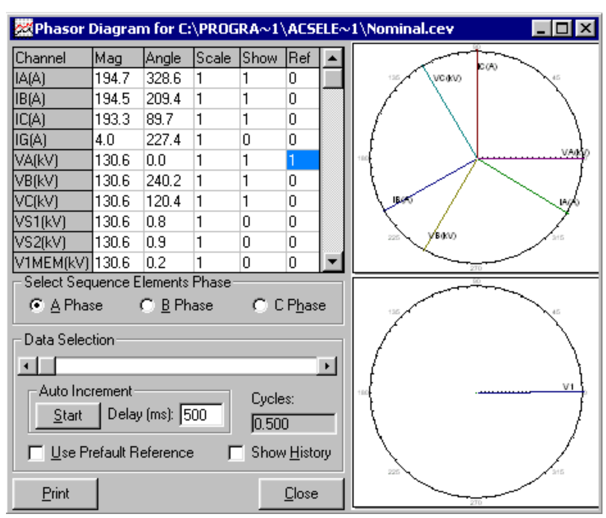


Figure 3.23 Sample Phasors Event Waveform Screen

ACSELERATOR QuickSet also presents a harmonic analysis of power system data for raw data binary COMTRADE event captures.

Step 1. From the **Event Waveform View** menu, click **Harmonic Analysis**.

A window similar to *Figure 3.24* appears.

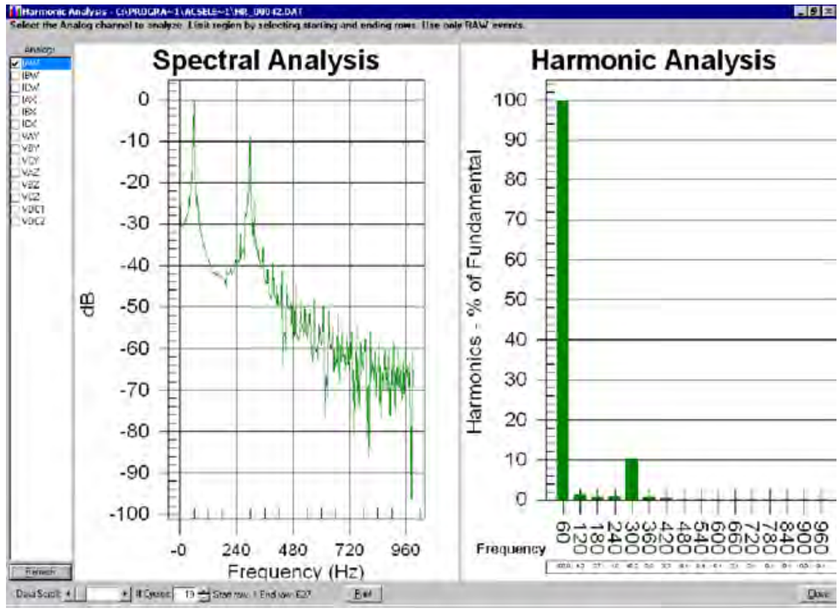


Figure 3.24 Sample Harmonic Analysis Event Waveform Screen

Step 2. On the left side of the **Harmonic Analysis** screen, choose the relay voltage and current channels to monitor for harmonic content.

You can view both a spectral analysis plot and a harmonic analysis bar chart.

Step 3. Click the arrows of the **Data Scroll** box or the **# Cycles** box to change the data analysis range.

Step 4. Click **Summary Data** on the **Event Waveform View** menu to see event summary information and to confirm that you are viewing the correct event.

Figure 3.25 shows a sample ACSELERATOR QuickSet **Event Report Summary** screen.

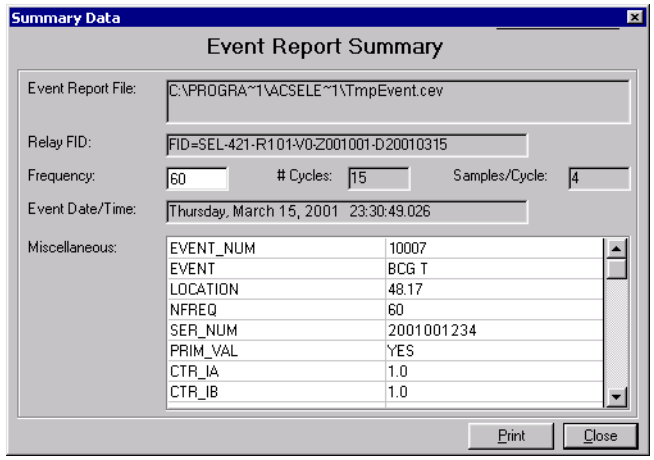


Figure 3.25 Sample Event Report Summary Screen

Step 5. Click **Settings** on the **Event Waveform View** menu to view the relay settings that were active at the time of the event.

Figure 3.26 shows a sample CEV-type event **Settings** screen.

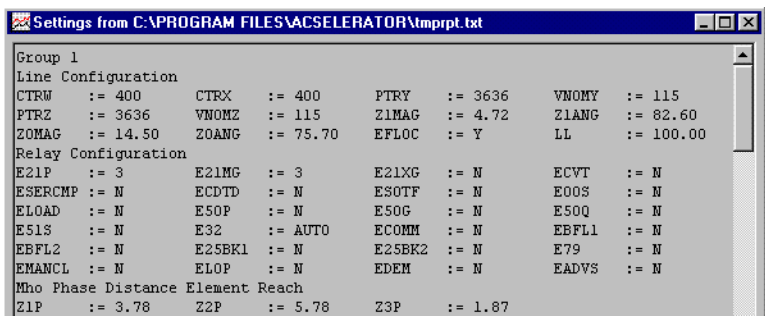


Figure 3.26 Sample Event Waveform Settings Screen

Open File

Computer-stored data captures are available as COMTRADE files (*.DAT) or compressed event report files (*.CEV).

Perform the following steps to open these files:

Step 1. Open the ACSELERATOR QuickSet **Analysis** menu and click **View Event Files** to view the waveforms in an event file stored on your computer.

The **Event Waveform** dialog box (similar to *Figure 3.20*) and an oscillographic event screen (similar to *Figure 3.21*) appear.

Step 2. At the **Event Waveform** dialog box, you can select the **Phasors** display, the **Harmonic Analysis** display, the **Summary Data** display, and the **Settings** display from the **Event Waveform** window (see *Read History on page U.3.16*).

HMI Meter and Control

Use the ACSELERATOR QuickSet HMI feature to view real-time relay information in a graphical format. Use the virtual relay front panel to read metering and targets and to operate the relay.

Open the ACSELERATOR QuickSet HMI

On the HMI menu, click **Meter and Control**.

ACSELERATOR QuickSet opens the HMI window and downloads the interface data. See the detailed examples in *View Metering: ACSELERATOR QuickSet on page U.4.37* for step-by-step instructions.

ACSELERATOR QuickSet HMI Features

You can use ACSELERATOR QuickSet to access many types of relay information and relay controls.

Step 1. Click the HMI menu at the top ACSELERATOR QuickSet toolbar and then click **Meter and Control** to access the ACSELERATOR QuickSet HMI.

Figure 3.27 shows the HMI tree view.

Table 3.2 lists the functions in the HMI tree view and a brief explanation of each function.

In the ACSELERATOR QuickSet HMI, an LED representation shows that a color is asserted or “on.”

The flashing LED representation in the lower left of each HMI screen indicates an active data update via the communications channel.

Step 2. Click the button marked **Disable Update** to suspend HMI use of the communications channel.

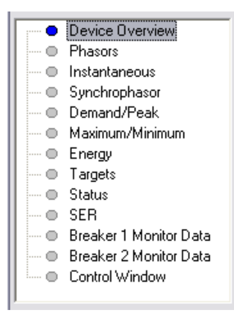


Figure 3.27 ACSELERATOR QuickSet HMI Features

Table 3.2 ACSELERATOR QuickSet HMI Tree View Functions

Function	Description
Device Overview	View general metering, selected targets, control input, control outputs, and the virtual front panel.
Phasors	A graphical and textual representation of phase and sequence voltage and current phasors.
Instantaneous	A table of instantaneous voltages, currents, powers, frequency, and dc monitor voltages.
Synchrophasors	A table showing synchrophasor data, if enabled.
Demand/Peak	A table showing demand and peak demand values. Reset buttons are in this display.
Max/Min	A table showing maximum/minimum metering quantities. A reset button is in this display.
Energy	A table showing energy import/export. A reset button is in this display.
Targets	View selected Relay Word bits in a row/column format.
Status	A list of relay status conditions.
SER	Sequential Events Recorder data listed oldest to newest, top to bottom. Set the range of SER records with the dialog boxes at the bottom of the display.
Breaker Monitor Data	A table showing the latest circuit breaker monitor data.
Control Window	Metering and records reset buttons, trip and close control, output pulsing, target reset, time and date set, group switch, and remote bit control.

Section 4

Basic Relay Operations

The SEL-421 Relay is a powerful tool for power system protection and control. Understanding basic relay operation principles and methods will help you use the relay effectively. This section presents the fundamental knowledge you need to operate the SEL-421, organized by task. These tasks help you become familiar with the relay and include the following:

Perform these tasks to gain a good understanding of relay operation, be able to confirm that the relay is properly connected, and be more effective when using the relay.

Inspecting a New Relay

⚠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.

The following items are included in your shipment from SEL:

- SEL-421 Relay
- Printed volume of the entire SEL-421 User's Guide
- CD-ROM containing the electronic version of the entire SEL-421 Relay Manual and the Customer Label Templates
- CD-ROM containing the ACSELERATOR QuickSet® SEL-5030 software program
- SEL Contact Card
- Configurable Front-Panel Label Kit

If any item is missing or damaged, please contact your distributor or SEL immediately.

Initial Inspection

Perform the following initial inspection when the relay arrives:

Step 1. Remove the protective wrapping from the SEL-421.

Step 2. Observe the outside of the front cover and the rear panel.

Step 3. Check that no significant scratches or dents are evident on any outer surface.

Step 4. Confirm that all terminal strips on the rear panel are secure.

Cleaning

Perform the following steps and use care when cleaning the SEL-421:

Step 1. Use a mild soap or detergent solution and a damp cloth to clean the relay chassis.

Be careful cleaning the front and rear panels because a permanent plastic sheet covers each panel; do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any relay surface.

Step 2. Allow the relay to air dry, or wipe dry with a soft dry cloth.

Verify Relay Configuration

When you first inspect the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. Examine the serial number label on the relay rear panel; *Figure 4.1* shows a sample rear-panel serial number label.

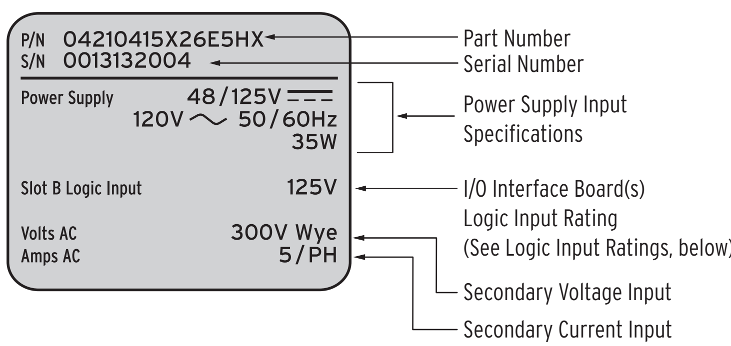


Figure 4.1 SEL-421 Serial Number Label

Figure 4.1 shows a serial number label for an SEL-421 with additional I/O in a 5U horizontal chassis. This example serial number label is for a 5 A-per-phase secondary current transformer input relay. For information on CT and PT inputs, see *Secondary Circuits on page U.2.4*.

The serial number label does not list power system phase rotation and frequency ratings, because you can use relay settings to configure these parameters. The factory defaults are ABC phase rotation and 60 Hz nominal frequency. See *Making Settings Changes: Initial Global Settings on page U.4.17* for details on setting these parameters.

The power supply specification in *Figure 4.1* indicates that this relay is equipped with a power supply that accepts a nominal 48/125 Vdc input. This power supply also accepts a 120 Vac input. Other power supply options include nominal 24/48 Vdc and 125/250 Vdc power supplies. The 125/250 Vdc power supply also accepts a 120/230 Vac input. Refer to the serial number label affixed to the back of your relay to determine the power supply voltage you should apply to the relay power supply input terminals. As this label indicates, the voltage source should be capable of providing at least 35 W. See *Power Supply on page U.1.13* for more information on power supply specifications.

Logic Input Ratings

The serial number label in *Figure 4.1* only lists control input voltages for I/O Interface Boards that have 24 optoisolated inputs, which is determined at ordering time. In the sample shown, only Slot B contains an INT4 I/O Interface board, so only one input rating appears. The other types of control inputs (Direct Coupled) have settable pickup voltages, and do not appear on the serial number label. See *Control Input Assignment on page U.4.65* for more information.

Connecting and Applying Power

Connect external power to the SEL-421 to perform the initial checkout and familiarization procedures in this section. For complete information on power connections, see *Power Connections on page U.2.38*.

Figure 4.2 shows the portion of the relay rear panel where you connect the power input.

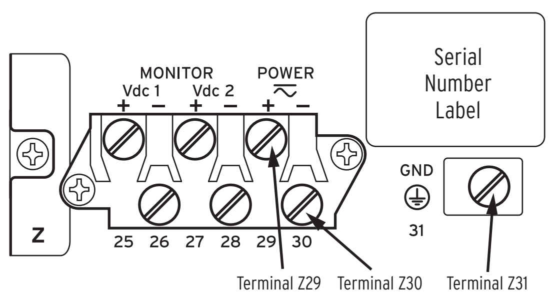


Figure 4.2 Power Connection Area of the Rear Panel

You can order the SEL-421 with one of three power supplies with nominal operating voltages: 24/48 Vdc, 48/125 Vdc, and 125/250 Vdc. The two higher voltage supplies, 48/125 Vdc and 125/250 Vdc, use ac input and dc input. The relay serial number label on the back of the relay lists voltage ranges that encompass the nominal voltages.

Table 4.1 shows the nominal voltage inputs and power supply voltage ranges for dc input, and ac inputs if applicable.

Table 4.1 Power Supply Voltage Inputs

Nominal DC Voltage Input	DC Input Range	AC Input Range (30–120 Hz)
24/48 Vdc	18–60 Vdc <35 W	N/A
48/125 Vdc	38–140 Vdc <35 W	120 Vac <120 VA
125/250 Vdc	85–300 Vdc <35 W	120/230 Vac <120 VA

Observe the following precautions when connecting power to the SEL-421:

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

Step 1. Always attach a safety ground as the first connection you make to the SEL-421.

Step 2. Connect the grounding terminal (#**Z31**) labeled **GND** on the rear panel to a rack frame ground or main station ground for proper safety and performance.

Step 3. Use 16 AWG (1.5 mm^2) wire (or heavier) to connect to the **POWER** terminals, observing the following:

➤ When you use a dc power source, you must connect the source with the proper polarity, as indicated by the **+** (Terminal #**Z29**) and **–** (Terminal #**Z30**) symbols on the power terminals.

➤ You can use ac input for the 48/125 Vdc power supply and the 125/250 Vdc power supply.

➤ The relay operates from 30 to 120 Hz (nominal 50/60 Hz) when alternating current supplies the **POWER** input.

Upon connecting power, you will see information on the front-panel LCD (liquid crystal display) and the **ENABLED** LED (light-emitting diode) will illuminate.

For complete information on the SEL-421 front panel, see *Front-Panel Operations on page U.5.1*.

Establishing Communication

Once you have applied the correct power input successfully, you are ready to operate the relay. Use the relay front panel and the communications ports to communicate with the relay.

Front-panel control of relay functions involves use of a menu system that you access through the LCD and the six navigational pushbuttons shown in *Figure 4.3*. For complete instructions on using the front-panel menu system, see *Navigating the Menus on page U.5.4*.

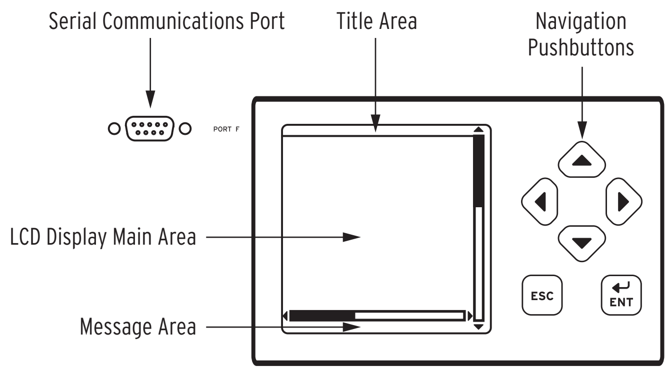


Figure 4.3 PORT F, LCD Display, and Navigation Pushbuttons

Fast and efficient communication with the relay is available through communications ports such as **PORT F**, also shown in *Figure 4.3*. A design philosophy for all SEL relays is that an ASCII or open terminal is all that you need to communicate with the relay. Many off-the-shelf computer programs provide terminal emulation. These programs are inexpensive and widely available.

Use the cable connections appropriate for your terminal configuration. See *Section 4: Communications Interfaces in the Reference Manual* for more information on communications ports.

All ASCII commands you send to the relay must terminate with a carriage return or carriage return/line feed; the terminal emulation program appends the necessary carriage return when you press <**Enter**>.

You can truncate commands to the first three characters: **EVENT 1 <Enter>** becomes **EVE 1 <Enter>**. Use upper- and lower-case characters without distinction, except in passwords, which are case sensitive. For a list of ASCII commands see *Section 9: ASCII Command Reference in the Reference Manual*.

Help

When you are using a terminal, you can access built-in relay help for each ASCII command. Relay help is access-level sensitive; you see only the ASCII commands for the present access level when you type **HELP <Enter>**. For in-depth information on a particular ASCII command, enter the command name after typing **HELP**. For example, for help on the **EVENT** ASCII command, type **HELP EVE <Enter>**.

When you are using ACSELERATOR QuickSet, press **<F1>** to get help, or select the **Help** menu from the ACSELERATOR QuickSet toolbars. The help information in ACSELERATOR QuickSet gives detailed information and sample screens in a GUI format.

Making an EIA-232 Serial Port Connection

The following steps use any popular computer terminal emulation software and SEL serial cables to connect to the SEL-421.

Use an SEL Cable C234A to connect a 9-pin computer serial port to the SEL-421. Use an SEL Cable C227A to connect a 25-pin computer serial port to the relay. See *Section 4: Communications Interfaces in the Reference Manual* for further information on serial communications connections. These and other cables are available from SEL. Contact the factory or your local distributor for more information.

Step 1. Connect the computer and the SEL-421 using the serial communications cable.

Use the 9-pin serial port labeled **PORT F** on the relay front panel.

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

Step 3. Start the computer terminal emulation program.

Step 4. Set your computer terminal emulation program serial communications parameters.

The default SEL-421 communications port settings are listed in *Table 4.2*.

Also set the terminal program to emulate either VT100 or VT52 terminals. These terminal emulations work best with SEL relays.

Table 4.2 General Serial Port Settings

Name	Description	Default
PROTO	Protocol (SEL, DNP[a], MBA, MBB, RTD, PMU)	SEL
SPEED	Data speed (300 to 57600, SYNC[b])	9600
DATABIT	Data bits (7, 8 bits)	8
PARITY	Parity (Odd, Even, None)	N
STOPBIT	Stop bits (1, 2, bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

[a] DNP protocol is an ordering option.
[b] SYNC setting only available when PROTO := MBA or MBB.

Step 5. To check the communications link, press **<Enter>** to confirm that you can communicate with the relay.

You will see the Access Level 0 = prompt at the left side of your computer screen (column 1).

If you do not see the prompt, check the cable connections and confirm the settings for the default communications parameters of *Table 4.2* in your terminal emulation program.

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

You will see a computer screen display similar to *Figure 4.4*. (Text that you type is emphasized in bold letters.)

If you see jumbled characters, change the terminal emulation type in the computer terminal program.

```
=QUIT <Enter>

Relay 1                                        Date: 03/15/2001  Time: 00:01:05.209
Station A                                      Serial Number: 2001001234
=
```

Figure 4.4 Report Header

When you communicate with the relay at the Access Level 0 = prompt, you are in security Access Level 0. You cannot control relay functions at this level.

Higher access levels are password protected and allow increased control over relay operation. For more information on access levels and password protection, see *Changing the Default Passwords: Terminal on page U.4.9*.

Changing the Default Passwords

NOTE: Perform the password-change steps described in Changing the Default Passwords: Terminal on page U.4.9.

It is extremely important that you change the factory default passwords programmed in the SEL-421. Setting unique passwords for the relay access levels increases the security of your substation and the power system.

This subsection begins with information on the access level/password system in the SEL-421 and includes an example of changing the default passwords.

Access Levels

Access levels control whether you can perform different operations within the SEL-421. These security levels are labeled 0, 1, B, P, A, O, 2, and C. *Figure 4.5* presents an overview of the general access level structure in the relay.

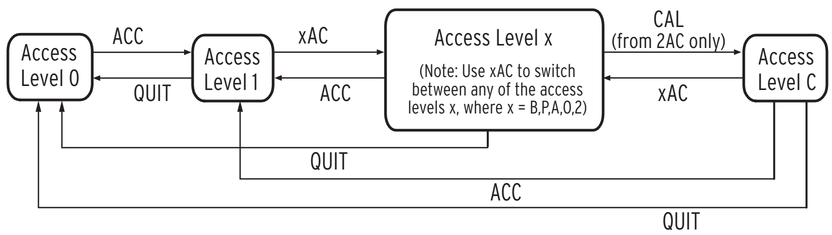


Figure 4.5 Access Level Structure

Access Level 0 is the least secure and most limited access level, and Access Level 2 is the most secure level at which you have total relay functionality. (Access Level C is reserved for SEL factory operations. Only go to Access Level C to change the Level C password or under the direction of an SEL employee.) For example, from Access Level 1, you can view settings but you cannot change settings.

Table 4.3 lists access levels and operator functions for the SEL-421.

Table 4.3 SEL-421 Access Levels

Access Level	Prompt	Allowed Operations
0	=	Log in to Access Level 1; some test diagnostics.
1	=>	View data and status information.
B	==>	Access Level 1 functions plus breaker control and data.
P	P=>	Access Level B functions plus protection settings.
A	A=>	Access Level B functions plus automation settings.
O	O=>	Access Level B functions plus output settings.
2	=>>	Perform all relay access level functions.
C	==>>	SEL calibration-specific functions. For a list of commands available, contact SEL.

The SEL-421 performs command interpretation and execution according to your validated access level. Each access level has a password that the relay must verify before you can control the relay at that level. *Table 4.4* lists the access level commands with corresponding passwords.

Table 4.4 Access Level Commands and Passwords

Access Level	Command	Factory Default Password
0	QUIT	(None)
1	ACCESS	OTTER
B	BACCESS	EDITH
P	PACCESS	AMPERE
A	AACCESS	VOLTA
O	OACCESS	WATT
2	2ACCESS	TAIL
C	CAL	Sel-1

Communications Ports Access Levels

⚠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.

Entrance to the higher security levels is sequential. You must first enter a correct password to move from Access Level 0 to Access Level 1.

To enter Access Levels B, P, A, O, and 2, you must enter a correct password from Access Level 1. For example, to go to the O (Output) Access Level from Access Level 1, type **OAC <Enter>**. At the `Password: ?` prompt, type your Access Level O password.

To enter Access Level C, you must enter a correct password from Access Level 2.

Use the relay **QUIT** command from any access level to return the relay to Access Level 0. To reestablish control at a previous access level from Access Level 1, you must use the access level commands and passwords to log in to that previous access level.

When a connection with the SEL-421 times out, the relay reduces the access level to Access Level 0 for that communications port connection.

The MAXACC port setting can be used to limit the maximum access level permitted on a port. This can be useful to restrict what remote users can do.

Front-Panel Access Levels

The lowest access level for the front panel is Access Level 1. To enter Access Levels B, P, A, O, and 2, you must enter a correct password from Access Level 1.

The front-panel LCD displays a password prompt when you attempt to control the relay at any access level higher than Access Level 1. (For more information on entering passwords from the front panel, see *Password on page U.5.14*.)

The front-panel `MAIN MENU` item `RESET ACCESS LEVEL` returns the relay to Access Level 1. In addition, when the front-panel inactivity timer times out (indicated by the `ROTATING DISPLAY` on the front-panel LCD), the relay returns the front-panel access level to Access Level 1.

ACCESS Command

NOTE: You can shorten relay commands to the first three letters of the full command. See Section 9: ASCII Command Reference in the Reference Manual for more information.

Enter the **ACCESS (ACC)** command to change to Access Level 1. Passwords are case sensitive; you must enter a password exactly as set.

If you enter the password correctly, the SEL-421 moves to Access Level 1 and the Access Level 1 => prompt appears. If you are at a higher access level (B, P, A, O, and 2), you can reduce the access level to Access Level 1 by entering the **ACC** command. The relay performs no password validation to reduce the present access level.

Higher Access Level Commands

Enter the commands in *Table 4.4* to enter access levels above Access Level 1. For example, enter the **2ACCESS** (**2AC**) command to change to Access Level 2.

If you are presently at Access Level 1, B, P, A, or O, typing **2AC <Enter>** causes the SEL-421 to prompt you to type the Access Level 2 password. If the present level is Access Level 0, the SEL-421 responds with `Invalid Access Level`. The relay asserts alarm Relay Word bit SALARM when entering Access Level B, P, A, O, and 2 from a lower access level.

If you are unable to enter the correct password after the third failed attempt, the SEL-421 asserts the BADPASS and SALARM Relay Word bits for one second and displays on a communications terminal screen the following error message:

```
WARNING: ACCESS BY UNAUTHORIZED PERSONS STRICTLY PROHIBITED
```

In addition, you cannot make further access level entry attempts for 30 seconds. The relay terminates the communications connection after the third failed attempt when you use Ethernet via an Ethernet card, DNP3 (Distributed Network Protocol Version 3.0), and MIRRORED BITS® communications virtual terminal mode. For more information on these protocols, see *Section 5: SEL Communications Protocols in the Reference Manual* and *Section 6: DNP3 Communications in the Reference Manual*.

If your connection to the SEL-421 has an inactivity time-out (in the **SET P** port settings), the SEL-421 automatically closes the communications connection and changes to Access Level 0 when the time-out occurs.

Passwords

⚠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.

Valid passwords are character sequences of as many as twelve characters. Valid password characters are any printable ASCII character. HMI password entry is limited to upper- and lower-case letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel. Passwords are case sensitive.

It is important that you change all of the passwords from their default values. This will protect you from unauthorized access.

Use strong passwords. Strong passwords contain a mix of the valid password characters in a combination that does not spell common words in any portion of the password.

Changing the Default Passwords: Terminal

Step 1. Confirm that the relay is operating (see *Connecting and Applying Power on page U.4.3*).

Step 2. Establish communication with the SEL-421 (see *Making an EIA-232 Serial Port Connection on page U.4.5* to learn how to use a terminal to communicate with the relay).

Step 3. Enter Access Level C (level 2 is sufficient except when changing the level C password).

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password **OTTER** and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. At the password prompt, type **TAIL <Enter>**.

e. Type **CAL <Enter>**.

f. At the password prompt, type **Sel-1 <Enter>**.

You will see the Access Level C ==>> prompt.

NOTE: Passwords are case sensitive; you must enter passwords exactly as set.

Step 4. To set a new password for Access Level 2, type the following:

PAS 2 nE2Pw- <Enter>

(**nE2Pw-** becomes the new strong password.)

The relay will return the word Set and the Access Level 2 =>> prompt.

Step 5. Set new passwords for each access level.

In a similar manner as the previous step, create new strong passwords for each access level.

Step 6. Commit these passwords to memory, permanently record your new passwords, and store this permanent record in a secure location.

To eliminate password verification for an access level, enter **DISABLE** in place of the new password. This action will disable the password of that level; therefore, the relay does not check for a password upon entering that access level.

Using **DISABLE** is not recommended. Always set a unique, strong password in the relay for each access level. Failure to do this can severely jeopardize the security of your substation and the power system.

After you enter a new password, the relay pulses the Relay Word bit SALARM for one second and responds Set. The relay responds with the message Password Disabled if you used the **DISABLE** parameter.

If you forget a password, or encounter difficulty changing the default passwords in *Changing the Default Passwords: Terminal on page U.4.9*, you can temporarily disable password verification. See *Jumpers on page U.2.18* for information on the password disable jumper J18B.

Checking Relay Status

With continual self-testing, the SEL-421 monitors the internal operation of all circuits to verify optimal performance of relay functions. If an internal circuit, protection algorithm, or automation algorithm enters an out-of-tolerance operating range, the relay reports a status warning. In the unlikely event that an internal failure occurs, the relay reports a status failure. For more information on relay status, see *Relay Self-Tests on page U.6.38*.

You can check relay status through a communications port by using a terminal, terminal emulation computer program, or ACSELERATOR QuickSet. In addition, you can use the relay front panel to view status information.

Checking Relay Status: Terminal

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Enter Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **STA <Enter>**. The relay returns a status terminal screen similar to that in *Figure 4.6*.

```
=>STA <Enter>

Relay 1                                         Date: 03/15/2001  Time:07:02:50.776
Station A                                        Serial Number: 000101234

FID=SEL-421-R101-V0-Z001001-D20010315            CID=0x9aed

Failures
  No Failures

Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
=>
```

Figure 4.6 Relay Status

Step 3. Type **STA A <Enter>** to view all relay status entries.

For more information on relay status report items, see *STATUS on page R.9.48*.

Checking Relay Status: ACSELERATOR QuickSet

You can use ACSELERATOR QuickSet to check relay status. Use the **HMI > Meter Control** menu to view status conditions.

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

NOTE: The DTR parameter has no effect on communications with the SEL-421 relay.

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, click **Communication > Communication Parameters**.

You will see the **Communication Parameters** dialog box similar to *Figure 4.7*.

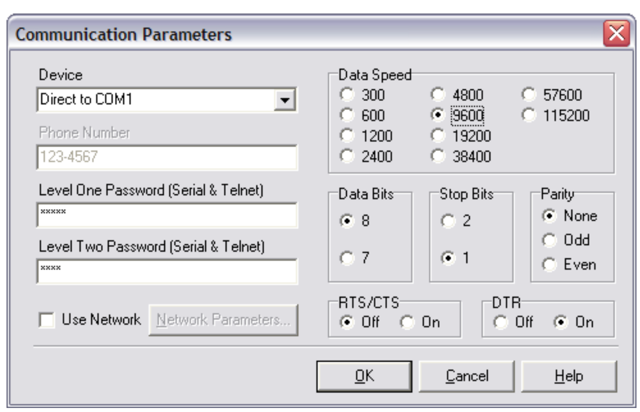


Figure 4.7 ACSELERATOR QuickSet Port Parameters and Password Entry

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

The defaults are **9600**, **8**, **1**, **None**, and **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters and connect to the relay.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

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

a. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

b. Click **OK** to accept changes and close the dialog box.

Step 3. Click **Meter and Control** in the top toolbar HMI menu to start the ACSELERATOR QuickSet operator interface.

Step 4. Click the **Status** button of the HMI tree view (see *Figure 4.8*).

ACSELERATOR QuickSet displays the relay status with a display similar to that in *Figure 4.6*.

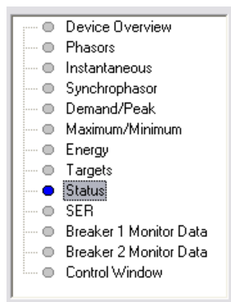


Figure 4.8 Retrieving Relay Status: ACSELERATOR QuickSet

Checking Relay Status: Front Panel

Use the front-panel display and navigation pushbuttons to check SEL-421 status. See *Section 5: Front-Panel Operations* for information on using the relay front panel.

Step 1. Apply power to the relay, and note that the LCD shows a sequence of screens called the ROTATING DISPLAY.

(If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **{ENT}** pushbutton to display the MAIN MENU of *Figure 4.9*.

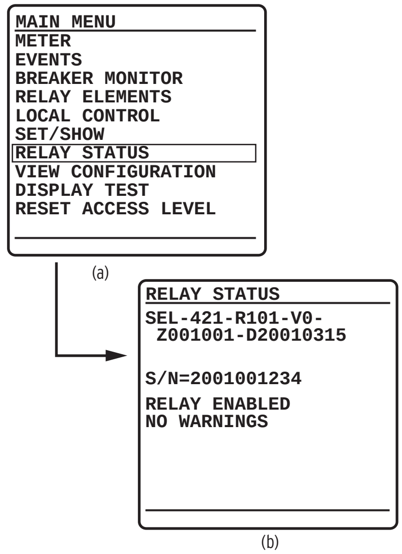


Figure 4.9 Checking Relay Status: Front-Panel LCD

Step 3. View the relay status:

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the RELAY STATUS action item (see *Figure 4.9*).

b. Press the **{ENT}** pushbutton.

You will see the RELAY STATUS screen (the second screen of *Figure 4.9*).

Step 4. Press the **{ESC}** key to return to the MAIN MENU.

Step 5. Press **{ESC}** again to return to the ROTATING DISPLAY.

For more information on the front-panel screen presentations and the items in the STATUS screens, see *Relay Status on page U.5.32*.

Making Simple Settings Changes

The SEL-421 settings structure makes setting the relay easy and efficient. Settings are grouped logically, and you do not see relay elements that are not used in your selected protection scheme.

For example, if you select only three levels of a particular type of overcurrent protection, the corresponding Level 4 overcurrent element settings do not appear on the communications terminal screen. Hiding unused elements and settings that you have not enabled greatly simplifies the task of setting the SEL-421.

ACSELERATOR QuickSet uses a similar method to focus your attention on the active settings. Unused relay elements and inactive settings are dimmed (grayed) in the ACSELERATOR QuickSet menus. See *Section 3: PC Software* for more information on ACSELERATOR QuickSet.

Settings Structure

The SEL-421 settings structure assigns each relay setting to a specific location based on the setting type. A top-down organization allocates relay settings into these layers:

- Class
- Instance
- Category
- Setting

Examine *Figure 4.10* to understand the settings structure in the SEL-421. The top layer of the settings structure contains classes and instances. Class is the primary sort level; all classes have at least one instance, and some classes have multiple instances. Settings classes and related instances for the SEL-421 are listed in *Table 4.5*.

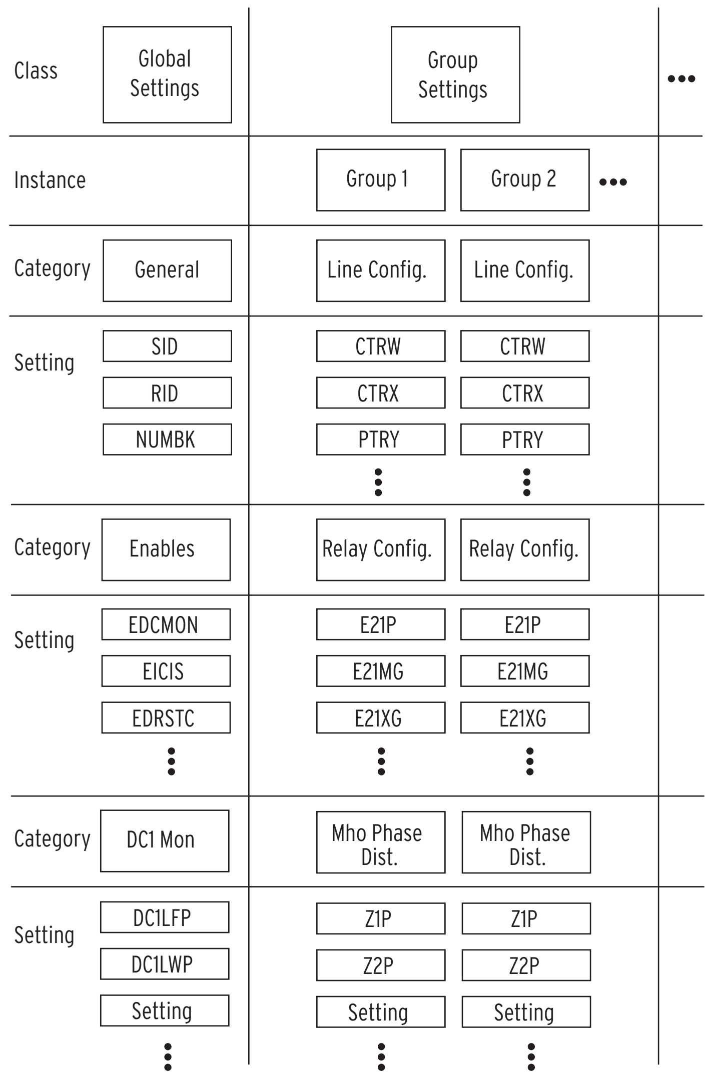


Figure 4.10 Relay Settings Structure Overview

Table 4.5 Settings Classes and Instances

Class	Description	Instance	Description	ASCII Command	Access Level
Global	Relay-wide applications settings	Global		SET G	P, A, O, 2
Group	Individual scheme settings	Group 1 • • • Group 6	Group 1 settings • • • Group 6 settings	SET 1, SET S 1 • • • SET 6, SET S 6	P, 2
Breaker Monitor	Circuit breaker monitoring settings	Breaker Monitor		SET M	P, 2
Port	Communications port settings	PORT F PORT 1 • • • PORT 3 PORT 5	Front-panel port PORT 1 settings • • • PORT 3 settings Communications card settings	SET P F SET P 1 • • • SET P 3 SET P 5	P, A, O, 2
Report	Event report and SER[a] settings	Report		SET R	P, A, O, 2
Front Panel	Front-panel HMI settings	Front Panel		SET F	P, A, O, 2
Protection SELOGIC® control equations	Protection-related SELOGIC control equations	Group 1 • • • Group 6	Group 1 protection SELOGIC control equations • • • Group 6 protection SELOGIC control equations	SET L 1 • • • SET L 6	P, 2
Automation SELOGIC control equations	Automation-related SELOGIC control equations	Block 1[b] • • • Block 10	Block 1 automation SELOGIC control equations • • • Block 10 automation SELOGIC control equations	SET A 1 • • • SET A 10	A, 2
DNP	Direct Network Protocol data remapping	DNP		SET D	P, A, O, 2
Output SELOGIC control equations	Relay control output settings and MIRRORED BITS communication transmit equations	Output		SET O	O, 2
Alias	Set aliases	Analog or digital quantities		SET T	P, A, O, 2

[a] SER is the Sequential Events Recorder; see SER (Sequential Events Recorder) on page A.3.34.
[b] The SEL-421-1 and SEL-421-2 have only one block of automation SELOGIC control equations.

Note that some settings classes have only one instance and you do not specify the instance designator when accessing these classes. An example is the Global settings class. You can view or modify Global settings with a communications terminal by entering **SET G** as shown in the ASCII Command column of *Table 4.5*. The relay presents the Global settings categories at the **SET G** command; no instance numbers follow **SET G**.

Conversely, the Port settings command has five instances (PORT F, PORT 1, PORT 2, PORT 3, and PORT 5). To access the PORT 1 settings, type **SET P 1 <Enter>**. If you do not specify which port to set, the relay defaults to the active port (the port you are presently using).

The Group settings can have the optional one-letter acronym **S** attached to the command; you can enter **SET 1** or **SET S 1** for Group 1 settings, **SET 2** or **SET S 2** for Group 2 settings, etc. If you do not specify which group to set, the relay defaults to the present active group. If Group 6 is the active group, and you type **SET <Enter>**, for example, you will see the settings prompts for the Group 6 settings.

Settings: Terminal

When you change settings (with any **SET** command) from a terminal, the relay shows the setting category, prompt, present value, and action prompt.

Figure 4.11 shows two settings examples: multiple-line settings (SID and RID) and an in-line setting (NUMBK) for relay Global settings from Access Level P (protection). The relay prompts you for input by presenting an action prompt. You have many options for navigating the settings at the `?` action prompt.

Table 4.6 lists the operations possible from a settings action prompt.

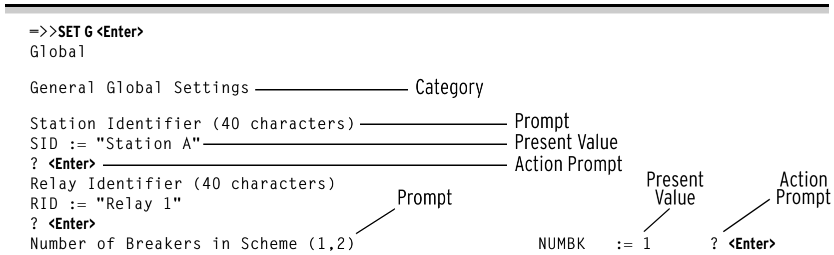


Figure 4.11 Components of SET Commands

Table 4.6 Actions at Settings Prompts

Action	Relay Response
<Enter>	Accept setting and move to the next setting; if at the last setting, exit settings.
[*value*] <Enter>	Enter the given *value* and move to the next setting if valid; if at the last setting, exit settings.
^ <Enter>	Move to the previous setting; if at the top of settings, stay at the present setting.
< <Enter>	Move to the top of the previous settings category; if at the top of settings, stay at the present setting.
> <Enter>	Move to the top of the next settings category; if in the last category, exit settings.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the `Save settings (Y,N) ?` prompt.
<Ctrl+X>	Abort the editing session without saving changes.

When you exit settings entry from the **SET** commands, the relay responds, `Save settings (Y,N) ?`. If you answer **Y <Enter>**, the relay writes the new settings to nonvolatile storage. If you answer **N <Enter>**, the relay discards any settings changes you have made.

Making Settings Changes: Initial Global Settings

You must configure the SEL-421 for specific conditions found in the power system where you are connecting the relay. In particular, you must set the nominal frequency and phase rotation.

The procedure in the following steps assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords. See *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords.

This example jumps to a Global setting that is not at the beginning of the Global settings list. Thus, you enter **SET G**, the setting name, and **<Enter>**. To start at the beginning of the Global settings, simply type **SET G <Enter>** without a settings name.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 2 => prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Type **SET G NFREQ <Enter>** (this sets the nominal system frequency using the **NFREQ** setting, which has options of 50 Hz and 60 Hz).

The relay responds with a terminal screen display similar to the beginning of *Figure 4.12*.

```
=>>SET G NFREQ <Enter>
Global

General Global Settings

Nominal System Frequency (50,60 Hz)                      NFREQ   := 60     ? <Enter>
System Phase Rotation (ABC,ACB)                          PHROT   := ABC    ? <Enter>
Date Format (MDY,YMD,DMY)                                DATE_F  := MDY    ? YMD <Enter>
Fault Condition Equation (SELogic Equation)
FAULT := 50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G
?  END <Enter>

.
.
.

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.12 Initial Global Settings

Step 3. Accept the default settings.

a. For a 60 Hz system, simply press **<Enter>** to accept the NFREQ existing value of 60 (Hz).

The relay presents the next setting, which is the PHROT (phase rotation) setting.

b. Type **<Enter>** to accept the ABC phase rotation default.

Step 4. Set the date format:

The SEL-421 reports dates in three formats: MDY, YMD, and DMY (where M = month, D = date, and Y = year).

a. For this procedure type **YMD <Enter>.**

At each setting in turn, the relay presents the settings prompt, name, present value, and action prompt.

Note that SELOGIC control equation settings, such as FAULT in *Figure 4.12*, appear on multiple lines.

b. If you make a mistake or want to go backward through the settings, type the ^ character (on most computer keyboards, this is a shifted numeral 6) and **<Enter>**.

Refer to *Table 4.6* for this and other navigational aids.

Step 5. End the settings session.

a. Type **END <Enter>** at the FAULT action prompt.

(The FAULT SELOGIC control equation remains unchanged.)

The relay next scrolls a readback of all the Global settings, eventually displaying the following prompt:

`Save settings (Y,N) ?` prompt

(In *Figure 4.12*, a vertical ellipsis represents the relay information during readback.)

b. Examine the settings readback to verify your new settings.

c. Answer **Y <Enter>** to save your new settings.

The TERSE Option

You can avoid viewing the entire class settings summary the relay displays when you type **END <Enter>** midway through a settings class or instance.

On slow data speed links, waiting for the complete settings readback can clog your automation control system or take too much of your time for a few settings changes. Eliminate the settings readback by appending **TERSE** to the **SET** command.

Text-Edit Mode Line Editing

Some SEL-421 settings present multiple input lines to your terminal; you use basic line text editing commands to construct the setting. For display, the relay references each line of the setting by line number, not by the setting name. See *Making Text-Edit Mode Settings Changes on page U.4.19* for an example of a text-edit mode setting.

While in the text-edit mode, you see a prompt consisting of the line number and the present setting for that line. You can keep the setting, enter a new setting, or delete the setting. *Table 4.7* lists the commands for text-edit mode.

Table 4.7 Actions at Text-Edit Mode Prompts

Action	Relay Response
<Enter>	Accept the setting and move to the next line; if at the last line or at a blank line, exit settings.
>*n* <Enter>	Move to line *n*. If this is beyond the end of the list, move to a blank line following the last line.
^ <Enter>	Move to the previous line; if at the first line, stay at the present line.
< <Enter>	Move to the first line.
> <Enter>	Move to a blank line following the last line.
LIST <Enter>	List all settings and return to the present action prompt.
DELETE [*n*] <Enter>	Delete the present line and subsequent lines for a total of *n* lines; *n* = 1 if not provided. Lines after deletion shift upward by the number of lines deleted.
INSERT <Enter>	Insert a blank line at the present location; the present line and subsequent lines shift downward.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the "Save settings (Y,N) ?" prompt.
<Ctrl+X>	Abort editing session without saving changes.

Use commas to separate the items in a text-edit mode setting when you are entering multiple items per line. After you enter each line, the relay checks the validity of the setting. If the entered setting is invalid, the relay responds with an error message and prompts you again for the setting.

Making Text-Edit Mode Settings Changes

The procedure in the following steps familiarizes you with basic text-edit mode line editing. You set Display Point 1 through Display Point 3 to show the status of Circuit Breaker 1, Circuit Breaker 2, and the operational state (on or off) of the transformer cooling fans near the circuit breaker bay where you have installed the SEL-421. See *Display Points on page U.5.10* for information on programming display points.

For this example, use inputs IN101, IN102, and IN105. You can use other inputs for your particular application. See *Control Inputs on page U.2.5* for more information on control inputs.

This procedure assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*) In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9*) to change the default access level passwords.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Access the display point settings.

a. Type **SET F <Enter>** to modify the front-panel settings.

b. Advance through the front-panel settings (repeatedly type **>** and then **<Enter>**) until you reach the **Display Points and Aliases** category.

Figure 4.13 shows a representative terminal screen. The relay displays the first line that you can edit. For the case of display points, the line number is the display point number.

Step 3. At the Line 1 settings `?` prompt, type the following to create Display Point 1:

IN101,CB1,CLOSED,OPEN <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `2:` followed by the settings `?` prompt (see *Figure 4.14*).

Step 4. At the Line 2 settings `?` prompt, type the following to create Display Point 2:

IN102,CB2,CLOSED,OPEN <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `3:` followed by the settings `?` prompt (see *Figure 4.14*).

Step 5. At the **Display Points and Aliases** prompt, use the text-edit mode line editing commands to list the active display points. Type the following:

NOTE: Use quotation marks when entering alias strings that contain spaces or punctuation marks, as shown in the IN105 example, Step 6.

LIST <Enter>.

After showing the active display points, the relay returns to line `3:` followed by the settings `?` prompt.

Step 6. Type the following to create Display Point 3:

IN105,"5 MVA XFMR Fans",ON,OFF <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `4:` followed by the settings `?` prompt (see *Figure 4.13*).

Step 7. Type **END <Enter>** to end the editing session.

The relay scrolls a readback of all the Front-Panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (A vertical ellipsis in *Figure 4.13* represents the readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can verify the new display point information.

Step 8. Answer **Y <Enter>** to save the new settings.

```
Display Points and Aliases
(Boolean) : RWB Name, "Alias", "Set String", "Clear String", "Text Size"
(Analog) : Analog Quantity Name, "User Text and Formatting", "Text Size"

1:
? IN101,CB1,CLOSED,OPEN <Enter>
2:
? IN102,CB2,CLOSED,OPEN <Enter>
3:
? LIST <Enter>

1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S

3:
? IN105,"5 MVA XFMR Fans",ON,OFF <Enter>
4:
?  END <Enter>
              .
              .
              .
Display Points and Aliases
(Boolean) : RWB Name, "Alias", "Set String", "Clear String", "Text Size"
(Analog) : Analog Quantity Name, "User Text and Formatting", "Text Size"

1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S
3: IN105,"5 MVA XFMR Fans","ON","OFF",S

              .
              .
              .

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.13 Using Text-Edit Mode Line Editing to Set Display Points

This procedure proposes connecting the transformer bank fan sensor to relay input IN105. In the **SET G** (GLOBAL) command, verify that the assertion level (setting IN105P) and the debounce time (setting IN105PU and IN105DO) are correct for your fan-running sensor. To access separate input parameters, you must first enable independent control input settings with setting EICIS. To change the input conditioning, enter these settings:

EICIS := **Y** Independent Control Input Settings (Y, N)

IN105P := **80** Input IN105 Pickup Level (15–265 Vdc)

IN105PU := **0.3750** Input IN105 Pickup Delay (0.0000–5 cyc)

IN105DO := **0.3750** Input IN105 Dropout Delay (0.0000–5 cyc)

Use the appropriate interface hardware to connect the fan-running sensor to IN105. Choose any relay input that conforms to your requirements. See *Control Inputs on page U.2.5* for more information on SEL-421 control inputs.

Deleting a Display Point

This example shows how you can delete a previously used display point. In the **SET F** command, at the Display Points and Aliases prompt, use the text-edit mode line editing commands to set and delete the display points. This procedure shows two previously programmed display points that indicate on the front-panel LCD the status of Circuit Breaker 1 and Circuit Breaker 2. Relay control inputs IN101 and IN102 are the Relay Word bits for the Circuit Breaker 1 and Circuit Breaker 2 display points, respectively (see *Making Text-Edit Mode Settings Changes on page U.4.19*). You can use other inputs for your particular application. See *Control Inputs on page U.2.5* for more information on control inputs.

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9*).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Access the Display Points and Aliases prompt.

a. Enter the **SET F** command.

b. Advance through the front-panel settings (repeatedly type **>** and then **<Enter>**) until you reach the **Display Points and Aliases** category.

Figure 4.14 shows a representative terminal screen. The relay displays the first line that you can edit. For display points, the line number is the display point number.

```
Display Points and Aliases
(Boolean) : RWB Name, "Alias", "Set String", "Clear String", "Text Size"
(Analog) : Analog Quantity Name, "User Text and Formatting", "Text Size"

1: IN101,"CB1","CLOSED","OPEN",S
?  LIST <Enter>

1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S
3: IN105,"5 MVA XFMR Fans","ON","OFF",S

1: IN101,"CB1","CLOSED","OPEN",S
?  <Enter>
2: IN102,"CB2","CLOSED","OPEN",S
?  DELETE <Enter>
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
?  LIST <Enter>

1: IN101,"CB1","CLOSED","OPEN",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S

2: IN105,"5 MVA XFMR Fans","ON","OFF",S
?  END <Enter>
              .
              .
              .
Display Points and Aliases
(Boolean) : RWB Name, "Alias", "Set String", "Clear String", "Text Size"
(Analog) : Analog quantity Name, "User Text and Formatting", "Text Size"

1: IN101,"CB1","CLOSED","OPEN",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S

              .
              .
              .
Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.14 Using Text-Edit Mode Line Editing to Delete a Display Point

Step 3. List the present display points.

a. Type **LIST <Enter>** at the **Control Points and Aliases** prompt.

b. After showing the active display points, the relay returns to line `1:` followed by the settings `?` prompt.

Step 4. Type **<Enter>** once to proceed to the line 2 present value and settings `?` prompt.

Step 5. Type **DELETE <Enter>** to delete Display Point 2.

Step 6. Type **LIST <Enter>** to examine the remaining display points.

Former **Display Point 2** is eliminated, and **Display Point 3** moves up to position 2.

The relay returns to line `2:` followed by the settings `?` prompt.

Step 7. Type **END <Enter>** to end the settings process.

The relay next scrolls a readback of all the Front-Panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (In *Figure 4.14*, a vertical ellipsis represents this scrolling readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can verify the new display point information.

Step 8. Answer **Y <Enter>** to save your new settings.

Alias Settings

Rename, or assign up to 200 alias names to any Relay Word bit or analog quantity in the relay. This is very useful when programming using SELogic® control equations or analyzing SER and event report data. Assigning alias names is also a text-edit type entry, with the same syntax as the display point entries.

Use the **SHO T** command to view the default settings, as shown in *Figure 4.15*.

```
=>>SHO T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
=>>
```

Figure 4.15 Default Alias Settings

Making Text-Edit Mode Alias Changes

Assign the alias name THETA to math variable PMV01 and the alias TAN to math variable PMV02. These variables are then used in calculating the tangent of theta, using their alias names in the equation.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the `=>` prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the `=>>` prompt.

Step 2. Type **SET T <Enter>** to access the alias settings.

Figure 4.16 shows a representative computer terminal screen.

Step 3. Type **> <Enter>** for the relay to display the first line that you can edit.

Step 4. Type **PMV01,THETA <Enter>** at the Line 2 `?` settings prompt to set the alias for PMV01.

The relay verifies that this is a valid entry, then responds with the next line prompt `3:` followed by the `?` settings prompt.

Step 5. Type **PMV02,TAN <Enter>** at the Line 3 `?` settings prompt to set the alias for PMV02.

The relay verifies that this is a valid entry, then responds with the next line prompt `4:` followed by the `?` settings prompt.

Step 6. Type **END <Enter>** to end the settings session.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y, N) ?` prompt. At the end of the readback information, just before the `Save settings (Y, N) ?` prompt, you can verify the new display point information.

Step 7. Type **Y <Enter>** to save the new settings.

```
=>>SET T <Enter>

Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
?  <Enter>
2:
?  PMV01,THETA <Enter>
3:
?  PMV02,TAN <Enter>

4:

?  END <Enter>

Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
2: PMV01,"THETA"
3: PMV02,"TAN"

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 4.16 Using Text-Edit Mode Line Editing to Set Aliases

Use the alias names, instead of the Relay Word bits, in SELOGIC control equation programming. *Figure 4.17* shows an example of an alias used in protection logic programming.

```
=>>SET L <Enter>

Protection 1

1: PLT02S := PB2_PUL AND NOT PLT02 #COMM SCHEME ENABLED
?  > <Enter>
9:
?  THETA:=IO1FA <Enter>
10:
?  TAN:=SIN(THETA)/COS(THETA) <Enter>
11:
?  END <Enter>
Protection 1
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 4.17 Using Text-Edit Mode Line Editing to Set Protection Logic

Settings: ACSELERATOR QuickSet

You can use ACSELERATOR QuickSet to develop settings for the SEL-421 offline. ACSELERATOR QuickSet automatically checks interrelated settings and alerts you to out-of-range settings. Upload the off-line ACSELERATOR QuickSet settings to the relay via the communications ports. See *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* for an introductory tutorial on using ACSELERATOR QuickSet.

You can also use ACSELERATOR QuickSet as a terminal program to interact in real time with the relay. For an introduction to ACSELERATOR QuickSet and all of features of this software, see *Section 3: PC Software*.

Making Initial Global Settings: ACSELERATOR QuickSet

ACSELERATOR QuickSet makes setting the relay an easy task. The purpose of the procedure in the following steps is to familiarize you with reading, modifying, and sending settings with ACSELERATOR QuickSet.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet; see *Section 3: PC Software* and *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11*.

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Communication Parameters**.

You will see the **Communication Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

The defaults are **9600**, **8**, **1**, **None**, and **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Type **<Ctrl+T>** to open the ACSELERATOR QuickSet terminal window.

f. Type **<Enter>** to see whether the communications link is active between ACSELERATOR QuickSet and the relay.

You will see the Access Level 0 = prompt in the terminal window.

g. Exit the terminal window.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. On the **Settings** menu, click **Read** to read the present configuration in the SEL-421.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Select **Global** settings.

a. Click the plus mark (+) next to the **Global** branch of the left-hand ACSELERATOR QuickSet tree structure shown in *Figure 4.18*.

b. Click **Global Settings/Enables**.

You will see the **Global Settings/Enables** window with **General Global Settings** and **Global Enables** (see *Figure 4.19*).

Step 5. Change settings.

a. Click the button for the correct option for NFREQ and PHROT to specify your system frequency and phase rotation.

When you tab or click to the next field, the relay validates the new setting.

b. The right-click mouse button performs two special functions when you are editing settings: **Previous Value** and **Default Value**.

➢ Right-click in the setting dialog box and select **Previous Value** if you want to revert to the setting value before you made a change.

➢ Right-click in the setting dialog box and select **Default Value** if you want to restore the factory default setting value.

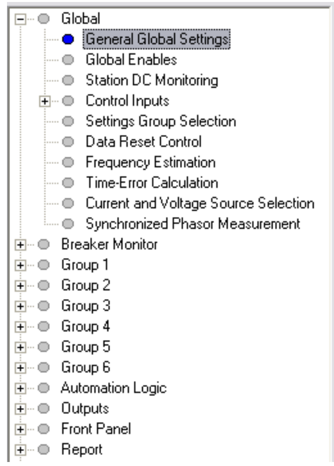


Figure 4.18 Selecting Global Settings in ACSELERATOR QuickSet

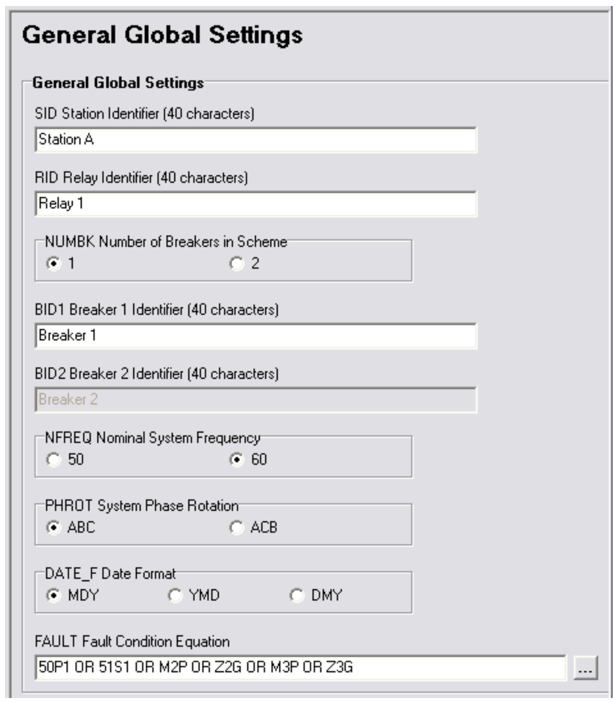


Figure 4.19 ACSELERATOR QuickSet Global Settings Window

Step 6. Save the new settings in ACSELERATOR QuickSet.

a. On the **Relay Editor File** menu, click **Save**.

b. Specify a **Relay Name**.

c. Click **OK**.

Step 7. Upload the new settings to the SEL-421.

a. On the **File** menu, click **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay, as shown in the first dialog box of *Figure 4.20*.

b. Click the check box for **Global**.

c. Click **OK**.

ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.20*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.20 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

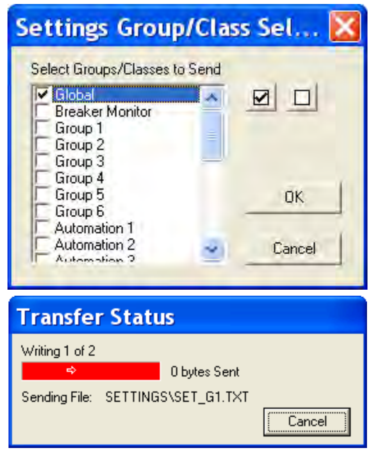


Figure 4.20 Uploading Global Settings to the SEL-421

Settings: Front Panel

You can use the relay front panel to enter some of the relay settings. The SEL-421 presents the settings in order from class to instance (if applicable) to category to the particular setting, in a manner similar to setting the relay using a terminal.

Use the LCD and the adjacent navigation pushbuttons to enter each character of the setting in sequence. This can be a laborious process for some settings (e.g., long SELOGIC control equations). However, if you need to make a quick correction or have no faster means to make settings, settings functions are available at the front panel. For more information on making settings changes from the front panel, see *Set/Show on page U.5.28*.

Entering DATE and TIME from the Front Panel

The purpose of the procedure in the following steps is to familiarize you with entering data from the SEL-421 front panel. Refer to *Connecting and Applying Power on page U.4.3* before performing this example.

Step 1. Prepare to use the front panel by applying power to the relay.

Note that the relay front-panel display shows a sequence of LCD screens called the ROTATING DISPLAY. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **{ENT}** pushbutton to display the MAIN MENU of *Figure 4.21*.

Step 3. View the settings screens.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the SET/SHOW action item (see *Figure 4.21*).

b. Press the **{ENT}** pushbutton.

You will see the SET/SHOW submenu (the second screen in *Figure 4.21*).

Step 4. View the date/time screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the DATE/TIME action item (*Figure 4.21*, second screen).

b. Press the **{ENT}** pushbutton.

The relay next displays the DATE/TIME submenu (the third screen of *Figure 4.21*).

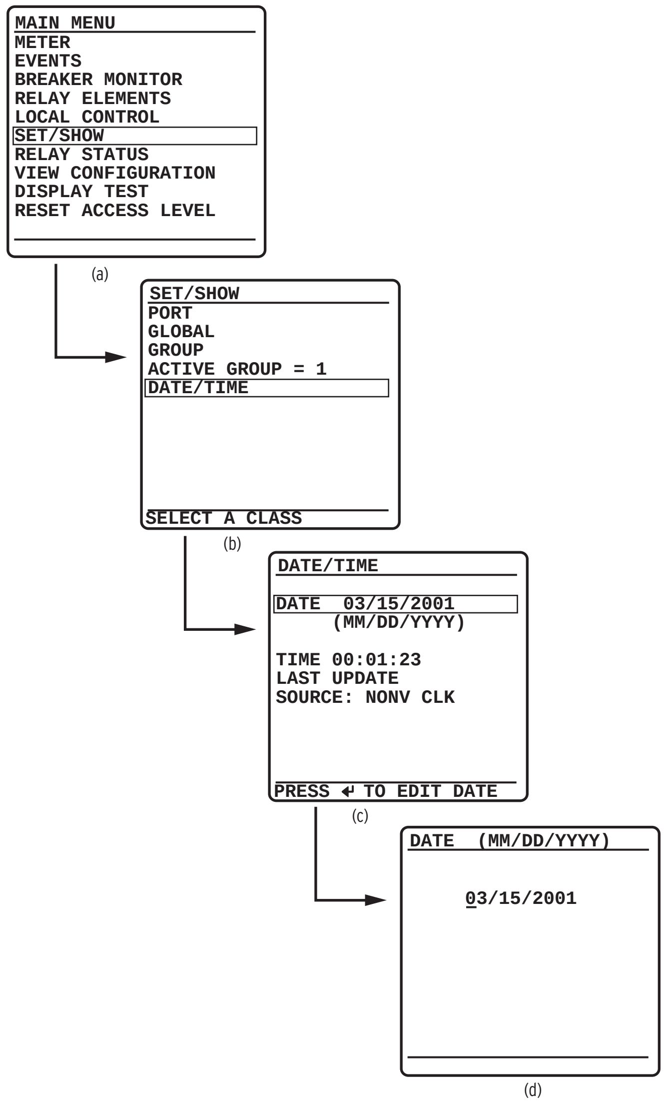


Figure 4.21 DATE and TIME Settings: Front-Panel LCD

Step 5. Set the date.

a. Press the **{ENT}** pushbutton.

The relay shows the last screen of *Figure 4.21*, the DATE edit screen.

b. Use the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to increase and decrease the date position numbers.

Step to the next or previous position by using the **{Left Arrow}** and **{Right Arrow}** pushbuttons.

c. When finished adjusting the new date, press **{ENT}**.

The relay returns the display to the DATE/TIME submenu. Note that the relay reports the TIME SOURCE as FP DATE (front-panel date).

Step 6. Press **{ESC}** repeatedly to normalize the front-panel display.

Changing a Relay Setting From the Front Panel

The purpose of the procedure in the following steps is to provide additional practice at entering relay settings from the front panel. In this example, you change the PORT F front-panel communications port settings.

Step 1. View the MAIN MENU.

a. If you have been using the front panel (as in the previous example), press the **{ESC}** key repeatedly until you see the MAIN MENU.

b. If the relay is displaying the ROTATING DISPLAY, press the **{ENT}** pushbutton to display the MAIN MENU.

The first screen of *Figure 4.22* shows the MAIN MENU at the beginning of the front-panel settings process.

Step 2. View the settings screens.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the SET/SHOW action item (see *Figure 4.22*).

b. Press the **{ENT}** pushbutton. You will see the SET/SHOW submenu (the second screen in *Figure 4.22*).

Step 3. Select PORT F.

a. Highlight PORT and press the **{ENT}** pushbutton.

The relay displays the PORT instances (the third screen of *Figure 4.22*).

b. Choose the port you want to configure by using the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to move the screen arrow.

For this example, select PORT F and press **{ENT}**.

Step 4. View the **Communications Settings** category screen.

a. The relay shows the fourth screen of *Figure 4.22*, the PORT F category screen. Use the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to select the settings category.

b. For this example, highlight **Communications Settings** and press **{ENT}**.

The relay displays the fifth screen of *Figure 4.22*, the Communications Settings screen.

Step 5. Change settings.

a. Highlight the SPEED setting.

b. Press **{ENT}**.

(The relay possibly requires a password here; see *Passwords on page U.4.9* and *Section 5: Front-Panel Operations*.)

The LCD displays the SPEED selection submenu that has all the possible choices for serial data speeds.

The highlight in the sixth screen of *Figure 4.22* indicates the default setting of 9600 (bps).

c. Use the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to select a different speed.

d. Once you have selected a data speed, press the **{ENT}** pushbutton.

NOTE: Once you have changed communications parameters, you must change the corresponding parameters in your terminal emulation program to communicate with the relay via a communications port.

Step 6. End the settings session.

a. The relay returns to the previous category settings list screen. Press **{ESC}** to return to the categories screen where you see the Save Settings item at the bottom of the screen.

b. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight Save Settings and press **{ENT}**.

c. Highlight YES, and then press **{ENT}**.

The relay validates the setting and returns to the PORT screen (the third screen of *Figure 4.22*).

Step 7. Press **{ESC}** repeatedly to return to the MAIN MENU.

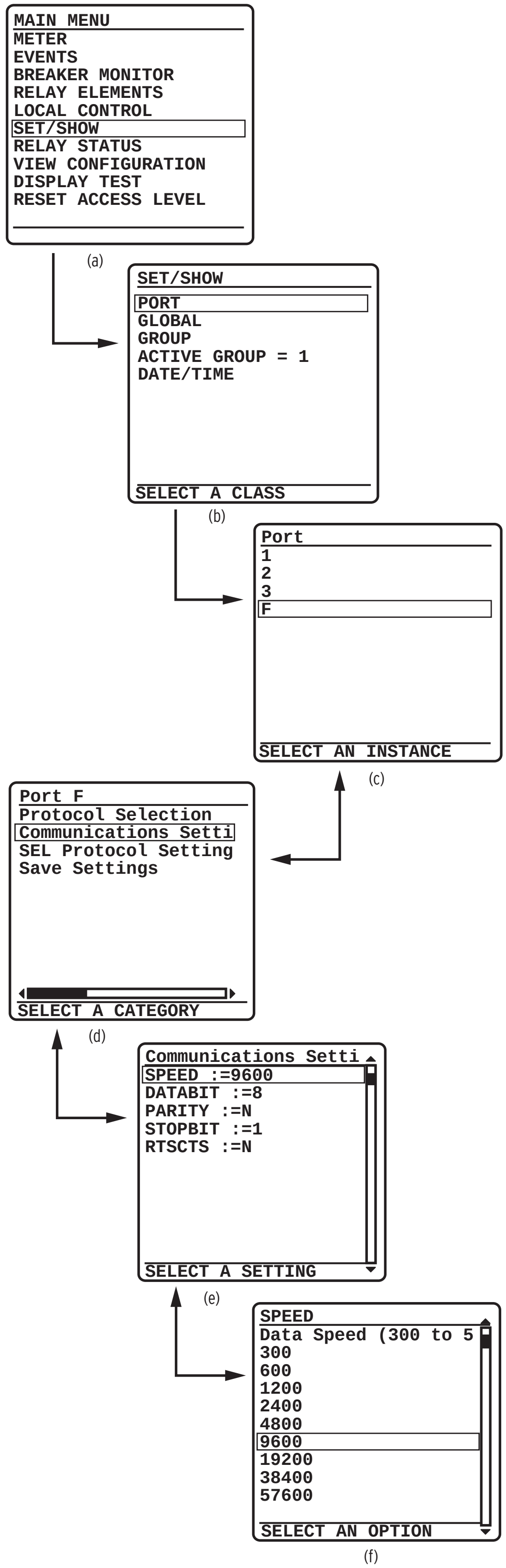


Figure 4.22 SETTINGS Menus

Examining Metering Quantities

The SEL-421 features high-accuracy power system metering. You can view fundamental and rms quantities by using a communications terminal, ACSELERATOR QuickSet, or the front panel. For more information on SEL-421 metering, see *Metering on page A.2.26*.

View Metering: Terminal

The procedure in the following steps shows how to use a terminal or terminal emulation computer program to view power system metering. In this example, you connect specific voltages and currents for a 5 A, 60 Hz relay. Scale these quantities appropriately for your particular relay. For more information on testing the relay and making test connections, see *Section 6: Testing and Troubleshooting*.

NOTE: If the relay is in service, disable any output circuits (such as trip and close) to avoid an unintended relay operation caused by test signals.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Set the relay to a nominal operation mode.

a. Use a terminal to perform the initial global settings relay setup in *Making Settings Changes: Initial Global Settings on page U.4.17*.

b. Set the relay for 60-Hz operation, ABC phase rotation.

Step 3. Set the relay for a basic voltage and current configuration (see *Figure 4.23*). Use the terminal to set global settings ESS := 1.

a. Type **SET G ESS TERSE <Enter>**.

b. Type **1 <Enter>** if the ESS setting is not 1.

c. Type **END <Enter>** to finish this settings session.

d. Answer **Y <Enter>** to the save settings prompt.

```
=>>SET G ESS TERSE <Enter>
Global

Current and Voltage Source Selection

Current and Voltage Source Selection (Y,N,1,2,3,4)          ESS   := N     ? 1 <Enter>
Line Current Source (IW,COMB)                               LINEI := IW    ? END <Enter>

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.23 Setting ESS: Terminal

Step 4. Set CT and PT ratios. Use the terminal to confirm that Group 1 setting CTRW := 200 (the current transformer W-input ratio), and PTRY := 2000 (the potential transformer Y-input ratio).

a. Type **SET CTRW TERSE <Enter>**.

b. If the CTRW setting is not 200, type **200 <Enter>**.

c. Proceed as shown in *Figure 4.24* to PTRY and change PTRY to 2000, if needed.

d. Type **END <Enter>** to finish this settings session.

e. Answer **Y <Enter>** to the save settings prompt.

```
=>>SET CTRW TERSE <Enter>

Group 1

Line Configuration

Current Transformer Ratio - Input W (1-50000)      CTRW   := 1000   ? 200 <Enter>
Current Transformer Ratio - Input X (1-50000)      CTRX   := 1000   ? <Enter>
Potential Transformer Ratio - Input Y (1-10000)    PTRY   := 2000   ? END <Enter>

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.24 Setting CTRW and PTRY: Terminal

Step 5. Turn the relay power off.

Step 6. Connect analog inputs.

a. If three voltage sources and three current sources are available, connect the sources to the relay as shown in *Figure 4.25*.

If three voltage sources and two current sources are available, use the connection diagram of *Figure 4.26*.

b. Apply 67 V per phase (line-to-neutral) in ABC phase rotation.

c. Apply 2.0 A per phase, in phase with the applied phase voltages.

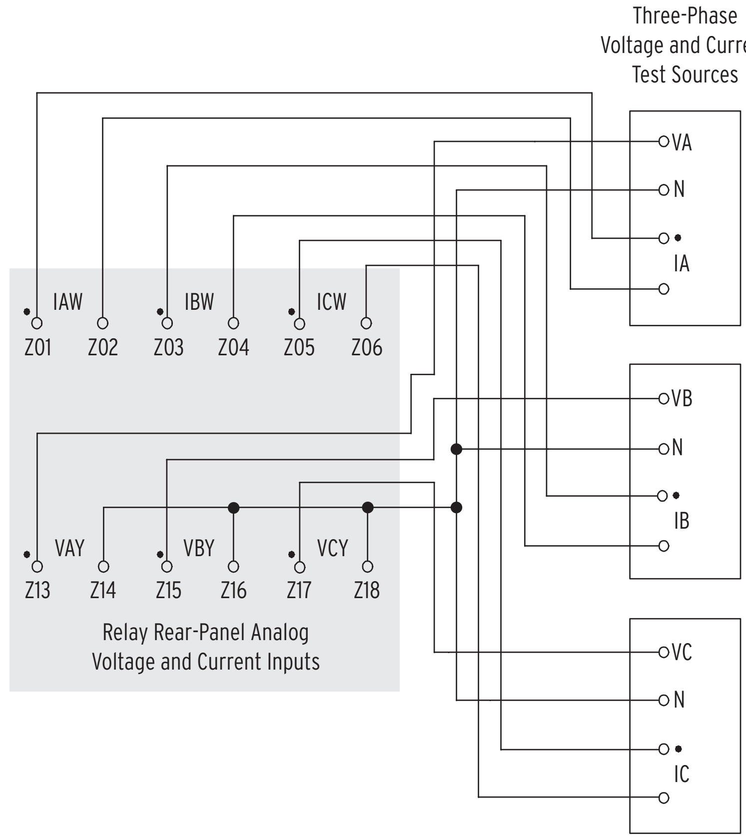


Figure 4.25 Test Connections Using Three Voltage Sources/Three Current Sources

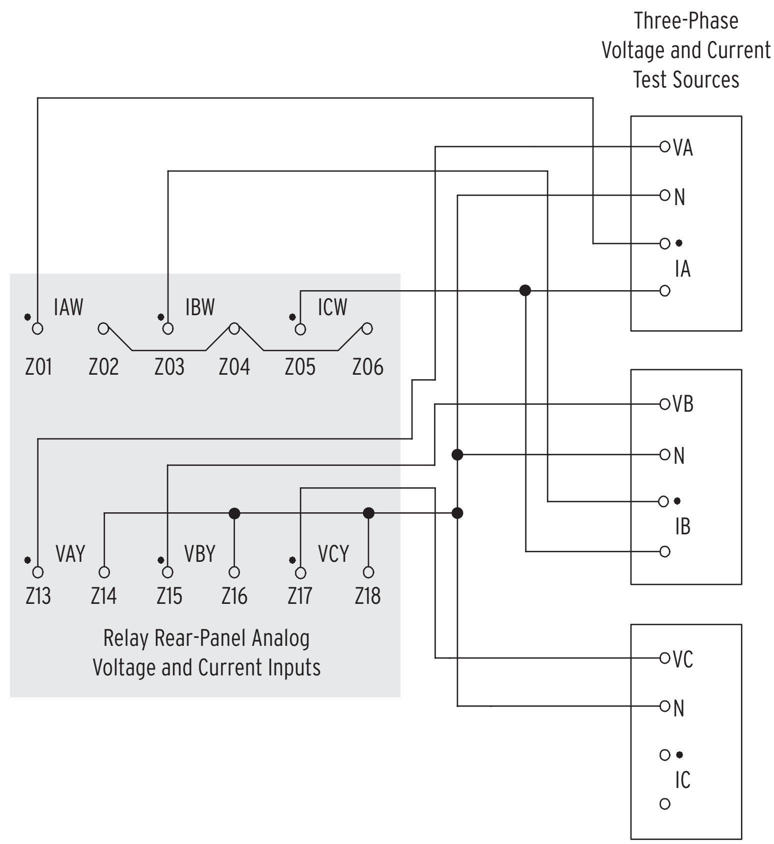


Figure 4.26 Test Connections Using Two Current Sources for Three-Phase Faults and METER Test

Step 7. Turn the relay power on.

Step 8. View metering.

a. Type **ACC <Enter>** to log-in to relay Access Level 1.

b. Type your password and press **<Enter>**.

c. Type **MET <Enter>**.

The relay displays the fundamental frequency (50 Hz or 60 Hz) metering information in a manner similar to that in *Figure 4.27*.

```
=>>MET <Enter>

Relay 1                                    Date: 02/26/2004  Time: 01:35:05.221
Station A                                  Serial Number: 0000000000

                      Phase Currents
                 IA        IB        IC
I MAG (A)       398.882   399.041   398.784
I ANG (DEG)      -1.18    -120.97    119.21

                      Phase Voltages              Phase-Phase Voltages
                 VA        VB        VC        VAB       VBC       VCA
V MAG (kV)      133.994   133.986   133.953   231.903   231.815   232.450
V ANG (DEG)      -0.17    -120.02    120.18     29.91    -89.92    150.01

                    Sequence Currents (A)       Sequence Voltages (kV)
                  I1        3I2       3I0      V1        3V2       3V0
MAG             398.901     2.159     2.588   133.977     0.692     0.713
ANG (DEG)        -0.98    -62.68   -115.80     0.00    -53.25   -120.79

                   A           B           C             3P
P (MW)            53.44       53.46       53.41         160.31
Q (MVAR)           0.95        0.89        0.91           2.75
S (MVA)           53.45       53.47       53.42         160.33
POWER FACTOR       1.00        1.00        1.00           1.00
                    LAG         LAG         LAG            LAG

FREQ (Hz)       60.00       VDC1(V)    125.00    VDC2(V)    48.00

=>>
```

Figure 4.27 Terminal Screen MET Metering Quantities

The metering quantities of *View Metering: Terminal on page U.4.33* are the fundamental line quantities. Other variants of the **MET** command give different relay metering quantities. For example, you can see the line rms (harmonics-included) quantities by issuing the **MET RMS** command. See *Metering on page A.2.26* and *METER on page R.9.28* for more information on the **MET** command.

View Metering: ACSELERATOR QuickSet

Use the procedures in the following steps to examine the SEL-421 metering with the ACSELERATOR QuickSet HMI.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Set the relay to a nominal operation mode. Perform the initial global settings relay setup of *Making Initial Global Settings: ACSELERATOR QuickSet on page U.4.25* to set the relay for 60-Hz operation, ABC phase rotation.

Step 4. Set a basic voltage and current configuration.

a. In the ACSELERATOR QuickSet **Settings** tree view, double-click the **Global** entry of the **Settings** tree view to expand the **Global** branch (see *Figure 4.28*).

b. Click the **Current and Voltage Source Selection** branch.

You will see the **Current and Voltage Source Selection** dialog box of *Figure 4.28*.

c. Click the down button to select **1** for **ESS Current and Voltage Source Selection**.

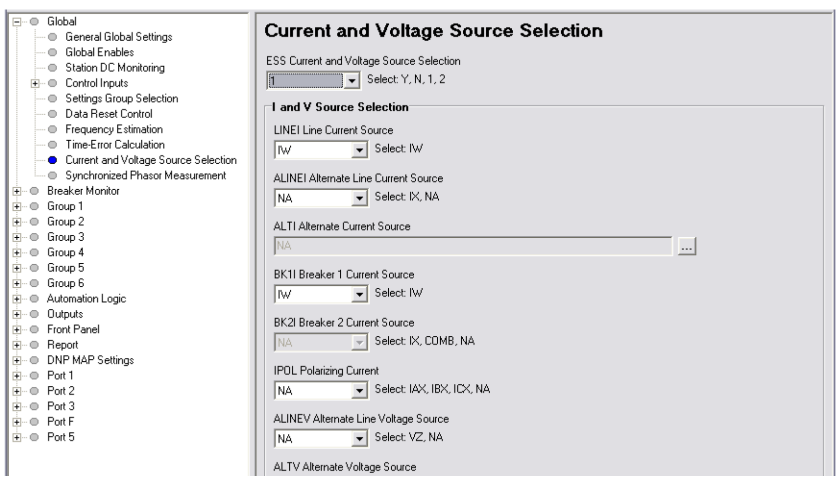


Figure 4.28 Global Alternate Source Selection Settings in ACSELERATOR QuickSet

Step 5. Set PT and CT ratios.

a. In the ACSELERATOR QuickSet **Settings** tree view, click the **+** mark next to **Group 1** to expand this branch (see *Figure 4.29*).

b. Click the plus (+) mark next to **Set 1**.

c. Click **Line Configuration**.

You will see the **Line Configuration** window similar to *Figure 4.29*.

d. Confirm that setting **CTRW Current Transformer Ratio - Input W** is **200**, and the **PTRY Potential Transformer Ratio - Input Y** is **2000**.

e. Save the settings and send the **Group 1** settings if you change the settings (see *Step 6* and *Step 7*).

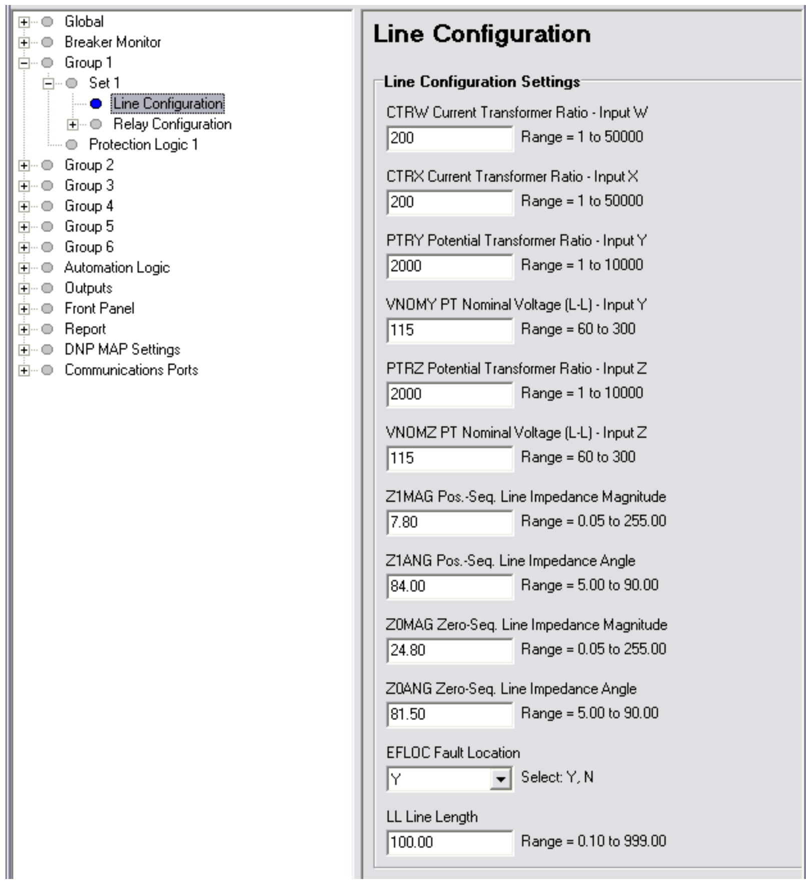


Figure 4.29 Group 1 Terminal Configuration Settings: ACSELERATOR QuickSet

Step 6. Start the ACSELERATOR QuickSet operator interface.

Step 7. In the top toolbar HMI menu, click **Meter and Control**.

Step 8. Click the **Phasors** button of the HMI tree view (see *Figure 4.30*) to view phasors.

ACSELERATOR QuickSet displays fundamental line metering quantities with a display similar to *Figure 4.31*. (The test setup is adjusted for an approximately 30-degree lagging current.)

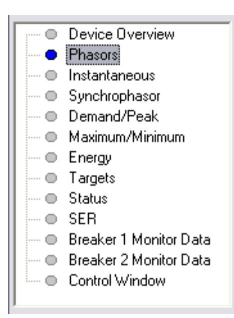


Figure 4.30 HMI Tree View: ACSELERATOR QuickSet

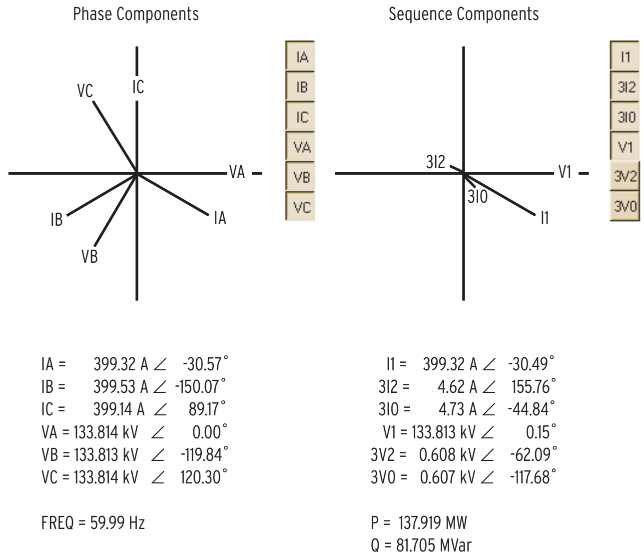


Figure 4.31 Phasor Metering Quantities: ACSELERATOR QuickSet HMI

Step 9. Click the **Instantaneous** button of the HMI tree view to see metering information similar to the terminal display of *Figure 4.27*. Click the Synchrophasors, Demand/Peak, Maximum/Minimum, or Energy buttons in the HMI tree view to see more types of metering, with displays similar to the terminal commands **MET PM**, **MET D**, **MET M**, and **MET E**, respectively.

View Metering: Front Panel

You can use the front-panel display and navigation pushbuttons to view the metering quantities of the SEL-421 (see *Meter on page U.5.15* for more information on viewing metering on the relay front panel). The screens in this procedure are for one circuit breaker, and this example assumes that you have not enabled the demand metering and synchronism check features.

Step 1. Prepare to use the front panel by applying power to the relay.

Note that the LCD shows a sequence of screens called the ROTATING DISPLAY. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **{ENT}** pushbutton to display the MAIN MENU at the top of *Figure 4.32*.

Step 3. View the metering selection screen.

a. Highlight the METER action item (see the first screen of *Figure 4.32*).

b. Press the **{ENT}** pushbutton.

The relay displays the METER submenu (the second screen in *Figure 4.32*).

Step 4. View the metering screens.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the FUNDAMENTAL METER action item (see *Figure 4.32*, middle screen).

b. Press the **{ENT}** pushbutton.

The relay displays the first FUNDAMENTAL METER screen (the third screen of *Figure 4.32*).

c. Use the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to move among the fundamental line quantities metering screens.

Step 5. Press the **{ESC}** pushbutton repeatedly to return to the MAIN MENU.

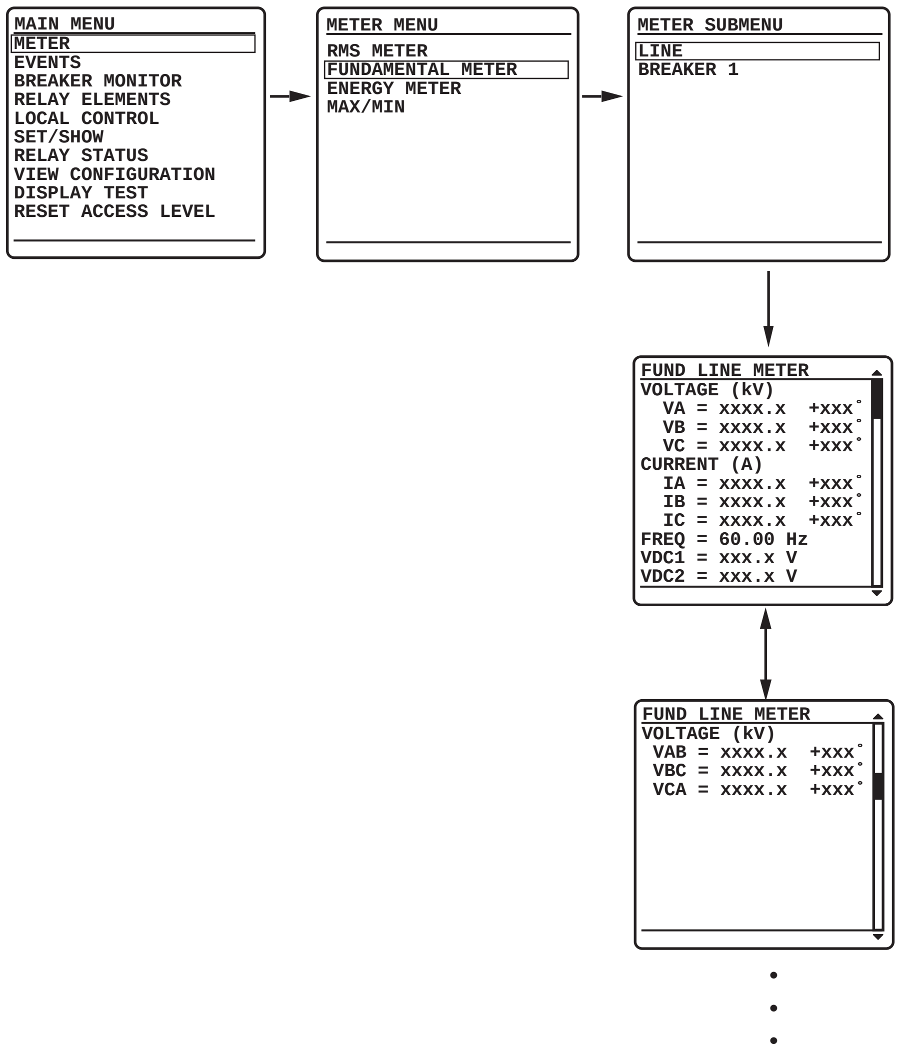


Figure 4.32 Front-Panel Screens for METER

Reading Oscillograms, Event Reports, and SER

The SEL-421 has great capabilities for storing and reporting power system events. These include high-resolution oscillography with sampling as high as 8 kHz, event reports that encompass important variables in the power system, and the SER that reports changing power system conditions and relay operating states.

You can view oscillograms taken from high-resolution raw data or from filtered event report data. Each type of presentation gives you a unique view of the power system. High-resolution oscillograms are useful for viewing system transients and dc artifacts outside the relay filter system; event report oscillograms give you a picture of the quantities that the relay used in the protection algorithms.

The examples listed in this subsection give step-by-step procedures to acquaint you with these features. *Section 3: Analyzing Data in the Applications Handbook* gives a complete discussion of these relay features.

Generating an Event

To view high-resolution raw data oscillograms and event reports, you must generate a relay event. High-resolution oscillography and event reports use the same event triggering methods. The relay uses three sources to initiate a data capture: Relay Word bit TRIP asserts, SELOGIC control equation ER (event report trigger), and the **TRI** command. (Factory default setup no longer includes the **PUL** command as an event report trigger. You can add the **PUL** command by entering the Relay Word bit TESTPUL in the ER SELOGIC control equation; see *Test Commands on page U.6.5*.)

Triggering an Event

You can use an event trigger to initiate capturing power system data. The procedure in the following steps shows how to use the ACSELERATOR QuickSet HMI to generate the **TRI** command, which triggers an event capture. In this example, the relay uses default parameters to record the event. These parameters are at a sampling rate (SRATE) of 2000 samples per second (2 kHz), a pretrigger or prefault recording length (PRE) of 0.1 seconds, and an event report length (LER) of 0.5 seconds. See *Duration of Data Captures and Event Reports on page A.3.5* for complete information on changing these default settings to match your application.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*). In addition, you should perform *View Metering: Terminal on page U.4.33* to connect secondary test voltages and currents, and to set the relay to meter these quantities correctly.

Step 1. Connect voltage and current sources to the relay secondary voltage and secondary current inputs (use the connections of *View Metering: Terminal on page U.4.33* and *Figure 4.25* or *Figure 4.26*).

Step 2. Apply power to the relay and establish communication.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and click **Port Parameters**.

You will see the **Port Parameter**s dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 3. Confirm the correct ACSELERATOR QuickSet software passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

NOTE: The **Trigger New Event** button in the Event History dialog box may also be used. See Figure 4.36.

Step 4. In the top toolbar HMI menu, click **Meter and Control** to start the ACSELERATOR QuickSet operator interface.

Step 5. Click the **Control Window** button of the HMI tree view (see *Figure 4.33*).

ACSELERATOR QuickSet displays the **Control Window** similar to that in *Figure 4.34*.

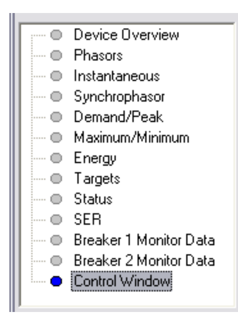


Figure 4.33 ACSELERATOR QuickSet HMI Tree View

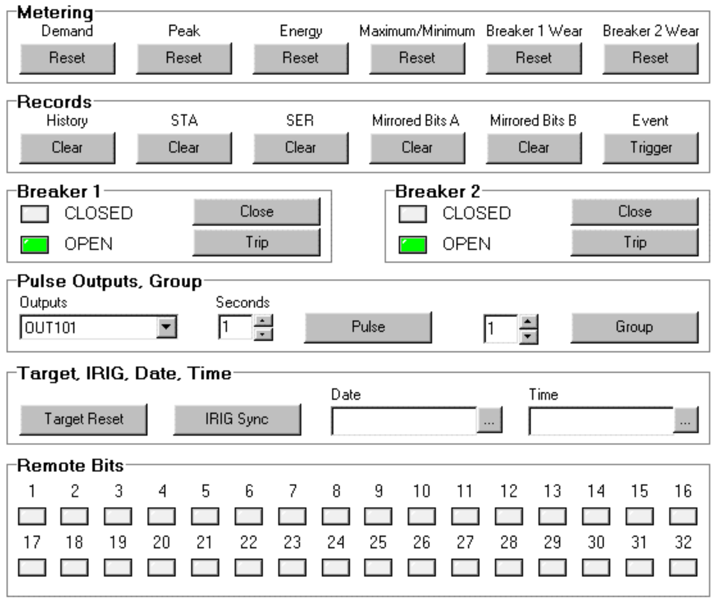


Figure 4.34 ACSELERATOR QuickSet HMI Control Window

Step 6. Trigger an Event.

a. Click the **Event Trigger** box to trigger an event.

ACSELERATOR QuickSet displays a prompt in a dialog box similar to that in *Figure 4.35*.

b. Click **Yes** to trigger an event.

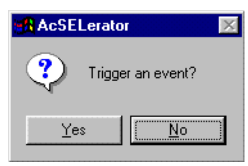


Figure 4.35 Event Trigger Prompt: ACSELERATOR QuickSet

Reading the Event History

The SEL-421 has two convenient methods for checking whether you successfully captured power system data. You can view the event history data with ACSELERATOR QuickSet, or you can examine internal relay file folders for the recorded data.

Reading the Event History: ACSELERATOR QuickSet

The procedure in the following steps shows how to use the ACSELERATOR QuickSet HMI to gather relay event history information. See *Event History on page A.3.31* for more information on event history.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

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

a. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

b. Click **OK** to accept changes and close the dialog box.

Step 3. To view the event history report, open the ACSELERATOR QuickSet **Analysis** menu and click **View Event History**.

You will see the **Event History** dialog box similar to that in *Figure 4.36*.

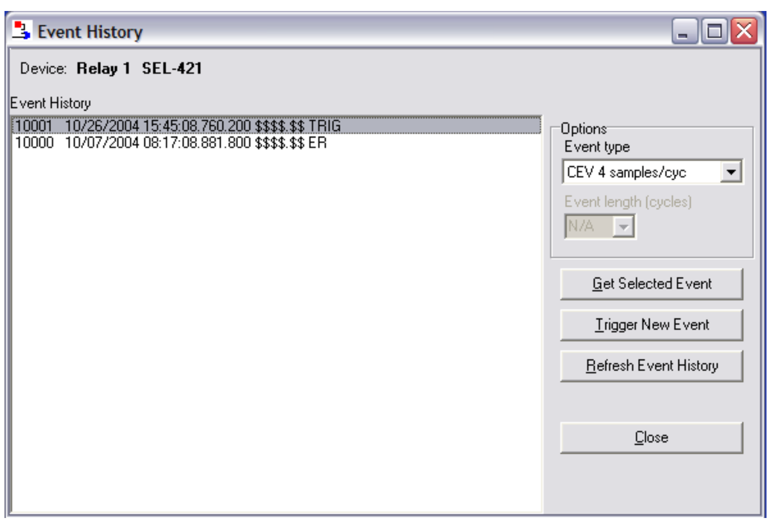


Figure 4.36 Relay Event History Dialog Box

Reading the Event History: Terminal

The procedure in the following steps shows how to use the SEL-421 file structure to confirm that you captured power system data with an event trigger. This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **HIS <Enter>** to examine the event history

You will see a screen display similar to *Figure 4.37*.

```
=>HIS <Enter>

Relay 1                                     Date: 10/27/2004  Time: 10:22:23.895
Station A                                   Serial Number: 0000000000

#       DATE         TIME      EVENT  LOCAT    CURR GRP TARGETS
10001 10/26/2004 15:45:08.760 TRIG  $$$$.$$   638  1
10000 10/07/2004 08:17:08.881 ER    $$$$.$$     0  1
=>
```

Figure 4.37 Sample HIS Command Output: Terminal

For more information on the event history, see *Event History on page A.3.31*.

Viewing High-Resolution Oscillograms

Once you have successfully generated an event, you can view high-resolution oscillograms and event report oscillograms about this event. When gathered from a field-installed relay, this information helps you assess power system operating conditions. In addition, when you first install the relay, this reporting information helps you confirm that you have connected the relay correctly.

The SEL-421 outputs high-resolution oscillography data in the binary COMTRADE file format (*IEEE/ANSI standard C37.111-1999*). File transfer is the only mechanism for retrieving high-resolution COMTRADE data from the relay.

The SEL-5601 Analytic Assistant is a program you can use to view COMTRADE data. Many third-party software suppliers can provide you with programs to display and manipulate COMTRADE files.

Retrieving High-Resolution COMTRADE Data: Terminal

The relay recorded the event triggered in *Triggering an Event on page U.4.42*. The procedure in the following steps shows you how to retrieve the high-resolution raw oscillography data for this event.

Perform the steps listed in *Triggering an Event on page U.4.42* before executing the instructions in this example. For this procedure, you must use a communications terminal emulation computer program capable of file transfers (this function is not available in ACSELERATOR QuickSet).

If you need help finding a terminal emulation program, contact the SEL factory or your local Technical Service Center.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR EVENTS <Enter>** to view the contents of the SEL-421 events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 4.38*.

The relay shows three high-resolution oscillography files with the file extensions .HDR, .CFG, and .DAT for each event.

This procedure uses HR_10001 as the number of the event that you recently triggered; use the event number corresponding to your triggered event.

```
=>>FILE DIR EVENTS <Enter>

C4_10000.TXT                        R   10/07/2004 08:17:08
C4_10001.TXT                        R   10/26/2004 15:45:08
C8_10000.TXT                        R   10/07/2004 08:17:08
C8_10001.TXT                        R   10/26/2004 15:45:08
CHISTORY.TXT                        R
E4_10000.TXT                        R   10/07/2004 08:17:08
E4_10001.TXT                        R   10/26/2004 15:45:08
E8_10000.TXT                        R   10/07/2004 08:17:08
E8_10001.TXT                        R   10/26/2004 15:45:08
HISTORY.TXT                         R
HR_10000.CFG                        R   10/07/2004 08:17:08
HR_10000.DAT                        R   10/07/2004 08:17:08
HR_10000.HDR                        R   10/07/2004 08:17:08
HR_10001.CFG                        R   10/26/2004 15:45:08
HR_10001.DAT                        R   10/26/2004 15:45:08
HR_10001.HDR                        R   10/26/2004 15:45:08
=>>
```

Figure 4.38 EVENTS Folder Files

Step 3. Type **FILE READ EVENTS HR_10001.* <Enter>** to ready the relay to transfer the HR_10001.HDR, HR_10001.CFG, and HR_10001.DAT files to your computer.

Step 4. Download the files. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

- ➢ Specify the destination file location in your computer file storage system and file name.
- ➢ Select the transfer type as **Y-Modem** (if this transfer type is not already enabled).
- ➢ Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

When these files have transferred successfully, you have the entire COMTRADE file for the high-resolution raw data capture.

Step 5. Use the SEL-5601 Analytic Assistant, ACSELERATOR QuickSet, or other COMTRADE-capable programs to play back high-resolution raw data oscillograms of the high-resolution raw data capture files you just transferred.

Retrieving High Resolution COMTRADE Data: ACSELERATOR QuickSet

The procedure in the following steps shows how to use ACSELERATOR QuickSet to view the event that you triggered in *Triggering an Event on page U.4.42*. You can use this procedure to view other events stored in the SEL-421.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Open the ACSELERATOR QuickSet **Analysis** menu and click **View Event History** to view the Event History.

You will see the **Event History** dialog box similar to that shown in *Figure 4.39*.

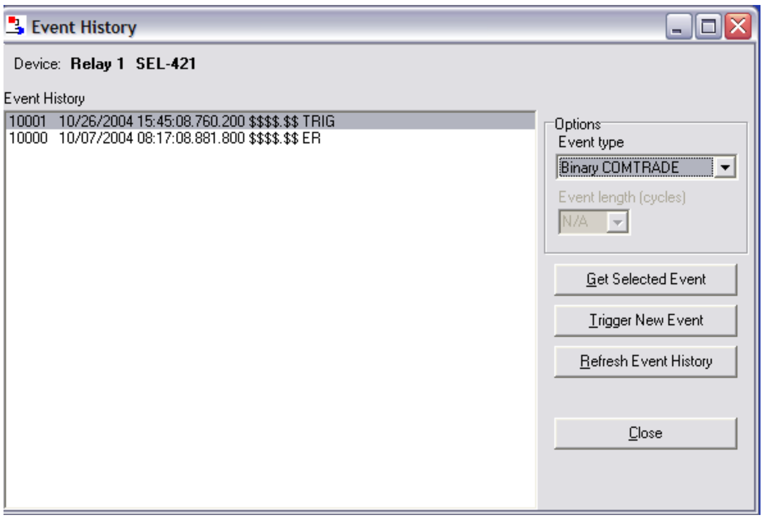


Figure 4.39 Relay Event History Dialog Box in ACSELERATOR QuickSet

Step 4. Get the event.

a. Select Binary COMTRADE in the **Event Type** dialog box.

b. Highlight the event you want to view and click the **Get Selected Event** button.

c. After getting the event ACSELERATOR QuickSet prompts you to save the event file (.DAT) in a directory.

d. Click Analysis > View Event Files and select the saved event file (.DAT).

e. Press Open.

ACSELERATOR QuickSet then presents the window similar to that in *Figure 4.40* and the sample event oscillogram of *Figure 4.41*.

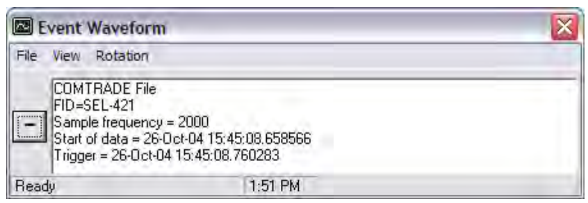


Figure 4.40 ACSELERATOR QuickSet Event Waveform Window

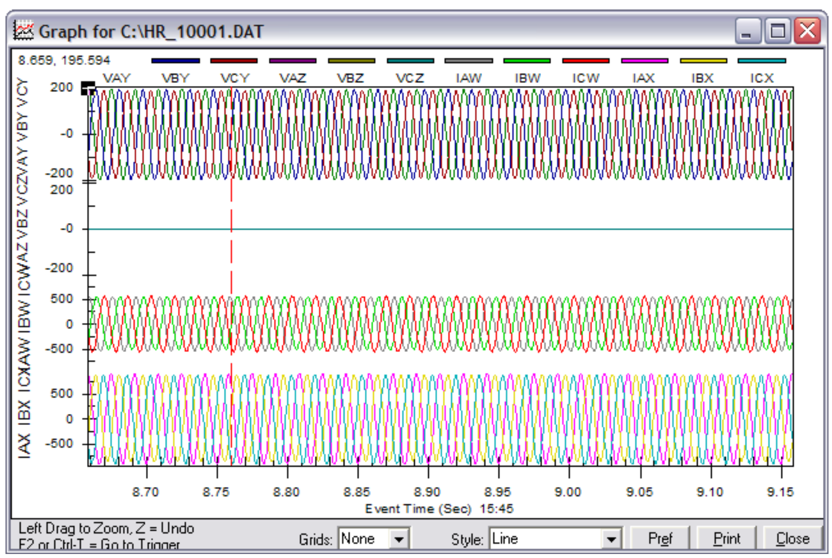


Figure 4.41 Sample Event Oscillogram

You can also examine a phasors display, an event harmonic analysis display, and the event summary from the **Event Waveform View** menu. See *Analyze Events on page U.3.16* and *Section 3: Analyzing Data in the Applications Handbook* for more information.

Viewing Event Report Data

Examine relay event reports to inspect the operating quantities the SEL-421 used at each triggered event. Unlike the raw data samples/second high-resolution oscillography files, these reports contain the filtered samples/cycle data the relay uses to make protection decisions. Event reports are useful for determining why the relay operated for a particular set of power system conditions. For more information on event reports, see *Event Report on page A.3.12*.

Retrieving Event Report Data Files: Terminal

The relay recorded the event triggered in *Triggering an Event on page U.4.42*. The procedure in the following steps shows you how to retrieve the event report data files for this event. Perform the steps listed in *Triggering an Event on page U.4.42* before executing the instructions in this example. For this procedure, you must use a terminal program capable of Ymodem protocol file transfer.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR EVENTS <Enter>** to view the events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 4.38*.

In the figure, the relay shows two event report files: E4_10001.TXT and E8_10001.TXT, and two Compressed ASCII event report files: C4_10001.TXT and C8_10001.TXT.

Step 3. Type **FILE READ EVENTS C8_10001.TXT <Enter>** to transfer the Compressed ASCII event report file to your computer.

Step 4. Download the file. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

- Specify the destination file location in your computer file storage system and file name.
- Select the transfer type as **Y-Modem** (if not already enabled).
- Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

Step 5. When this file has transferred successfully, use the SEL-5601 Analytic Assistant to play back the event report oscillograms of the 8-samples/cycle event report file you just transferred.

Use the ASCII command **CEVENT** to retrieve event report files in Compressed ASCII format. See *SEL Compressed ASCII Commands on page R.5.4* and *CEVENT on page R.9.5* for more information.

Viewing SER Records

The relay SER records relay operating changes and relay element states. In response to an element change of state, the SER logs the element, the element state, and a time stamp. Program the relay elements that the relay stores in the SER records, thus capturing significant system events such as an input/output change of state, element pickup/dropout, recloser state changes, etc.

The SEL-421 stores the latest 1000 entries to a nonvolatile record. Use the relay communications ports or ACSELERATOR QuickSet to view the SER records. For more information on the SER, see *Section 3: Analyzing Data in the Applications Handbook*.

The latest 200 SER events are viewable from the front panel. For more information, see *Section 5: Front-Panel Operations*.

Setting the SER and Examining an SER Record: ACSELERATOR QuickSet

The procedure in the following steps shows you how to use ACSELERATOR QuickSet to program relay elements into the SER. Also, use these procedures to review SER records with ACSELERATOR QuickSet.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Download the present configuration in the SEL-421 by clicking **Settings > Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Click the **Report** branch of the ACSELERATOR QuickSet **Settings** tree view structure (see *Figure 4.42*) to view the SER settings entry screen.

You will see the **SER Points and Aliases** window similar to *Figure 4.43*.

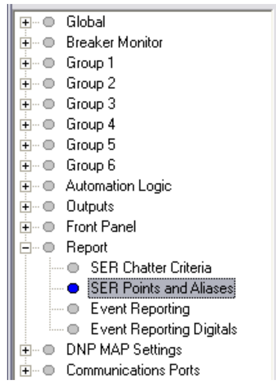


Figure 4.42 Selecting SER Points and Aliases Settings: ACSELERATOR QuickSet

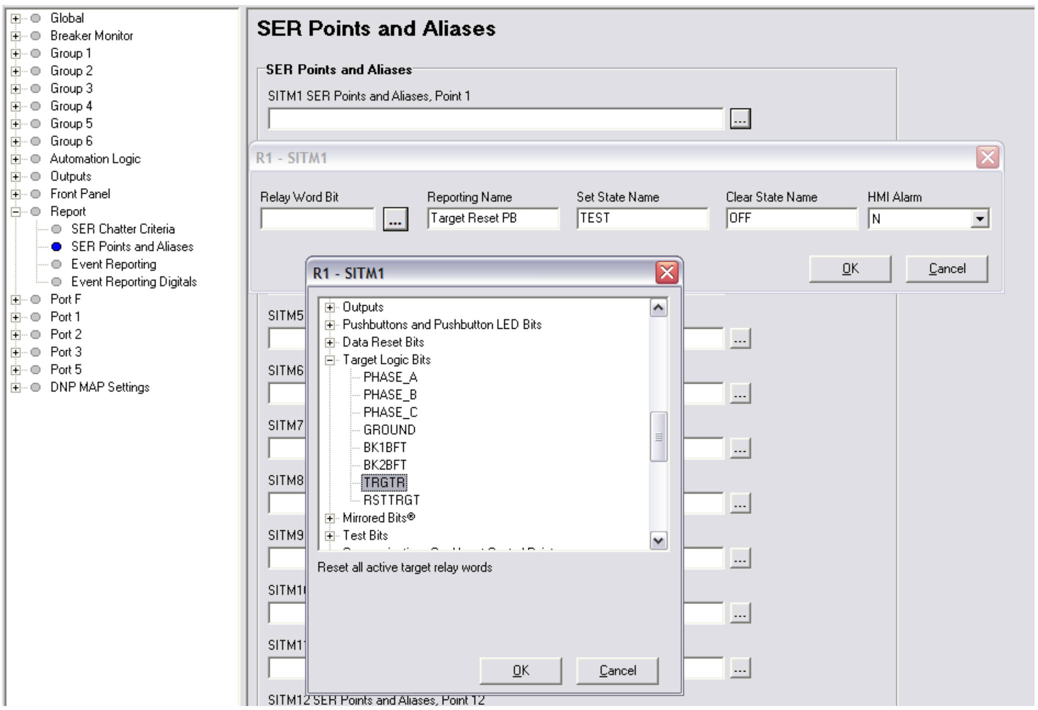


Figure 4.43 SER Points and Aliases Settings: ACSELERATOR QuickSet

Step 5. Enter SER trigger settings.

a. For this example, open the entry form by clicking the ... button beside the **SITM1 SER Points and Aliases, Point 1** entry field. We will set this SER point to report the operation of the Target Reset pushbutton.

b. Click the ... button beside the **Relay Word Bit** entry field.

c. Select Target Logic Bits, and then double-click on TRGTR to copy the TRGTR name into the **Relay Word Bit** field. This also copies TRGTR to the Alias Name field.

d. Type **Target Reset PB** in the **Reporting Name** field.

e. Type **TEST** in the **Set State Name** field.

f. Type **OFF** in the **Clear State Name** field.

g. Click **OK**.

Step 6. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 7. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the first dialog box of *Figure 4.44*.

b. Click the **Report** check box.

c. Click **OK**.

ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.44*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.44 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

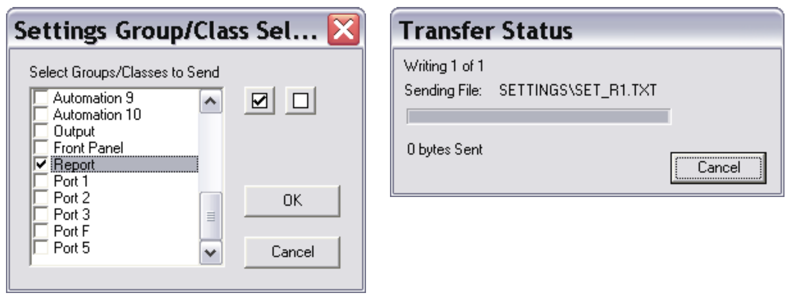


Figure 4.44 Uploading Report Settings to the SEL-421

Step 8. Press and release the front-panel {TARGET RESET} pushbutton to generate an SER record.

Step 9. View the SER report.

a. Start the ACSELERATOR QuickSet operator interface.

b. In the top toolbar HMI menu, click **Meter and Control**.

c. Click the **SER** button of the HMI tree view (see *Figure 4.45*).

ACSELERATOR QuickSet displays the SER records with a display similar to *Figure 4.46*.

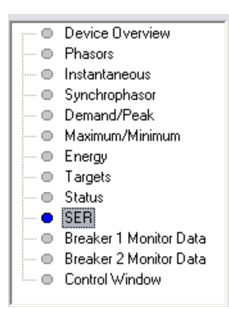


Figure 4.45 Retrieving SER Records With ACSELERATOR QuickSet

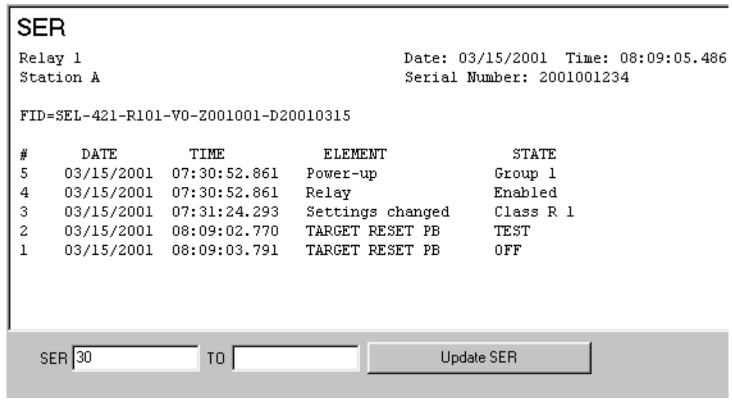


Figure 4.46 SER Records in the ACSELERATOR QuickSet HMI

The relay lists the SER records in chronological order from top to bottom as shown in *Figure 4.46*. In addition, the relay numbers each record with the most recent record as number 1; new events are usually more important for determining the effects of recently occurring power system events.

For each application of power to the relay, the SER reports a “Power-up” indication and the active settings group (**Group 1** in *Figure 4.46*). A properly operating relay immediately goes to the enabled state, an event that causes the SER to report another SER record. The SER reports the **TARGET RESET** button when you first press the pushbutton. When you release the pushbutton, the SER records the pushbutton release. For more information on the Sequential Events Recorder, see *SER (Sequential Events Recorder) on page A.3.34*.

Setting the SER and Examining the SER Record: Terminal

The procedure in the following steps shows how to use a terminal connected to an SEL-421 communications port to set an element in the SER. Use text edit mode line editing to enter the SER settings (see *Text-Edit Mode Line Editing on page U.4.18*). Also included is a procedure for viewing the SER report with a terminal. For more information on the SER, see *SER (Sequential Events Recorder) on page A.3.34*.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Enter SER trigger data.

a. Type **SET R TERSE <Enter>** to access the **Report** settings (see *Figure 4.47*).

b. Type **<Enter>** to move past the **SER Chatter Criteria** setting.

c. At the **SER Points and Aliases** prompt line, type the following:

TRGTR,"TARGET RESET PB",TEST,OFF,N <Enter>.

At the next line, type **END <Enter>**.

d. The relay prompts you to save the new setting; type **Y <Enter>**.

```
=>>SET R TERSE <Enter>

Report
SER Chatter Criteria
Automatic Removal of Chattering SER Points (Y,N)   ESERDEL := N   ? <Enter>


SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1:
? TRGTR,"TARGET RESET PB",TEST,OFF
2:
? END <Enter>

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.47 Setting an SER Element: Terminal

Step 3. Press and release the front-panel {TARGET RESET} pushbutton to generate an SER record.

Step 4. Type **SER <Enter>** (at the Access Level 1 prompt or higher) to view the SER report.

The relay presents a screen similar to the SER display of *Figure 4.46*.

Downloading an SER Report File

The procedure in the following steps shows you how to retrieve the SER report stored in the relay as a file. For this procedure, you must use a terminal emulation program with file transfer capability. For more information on the SER, see *SER (Sequential Events Recorder) on page A.3.34*.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR REPORTS <Enter>** to view the events file directory.

The terminal lists the file names for standard reports as shown in *Figure 4.48*.

Step 3. Prepare the relay to download the SER report.

a. Type **FILE READ REPORTS SER.TXT <Enter>**.

b. If you want the Compressed ASCII file, type the following:

FILE READ REPORTS CSER.TXT <Enter>

```
=>FILE DIR REPORTS <Enter>

BRE_1.TXT                         R
BRE_2.TXT                         R
BRE_S1.TXT                        R
BRE_S2.TXT                        R
CBRE.TXT                          R
CHISTORY.TXT                      R
CSER.TXT                          R
HISTORY.TXT                       R
SER.TXT                           R
=>
```

Figure 4.48 Reports File Structure

Step 4. Download the SER report. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

- ➢ Specify the destination file location in your computer file storage system and file name.
- ➢ Select the transfer type as **Y-Modem** (if not already enabled).
- ➢ Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

NOTE: Transferring SER files (or CSER files) with the **FILE READ REPORTS SER.TXT** command, performs an **SER CV** command as part of the transfer. **SER CV** clears the SER information from the present port. With the SER information cleared, there is no data available for subsequent SER or CSER transfers from the same port.

Step 5. When the SER.TXT file has transferred successfully, use a word-processing program to view the contents of the file.

You will see the SER records in a format similar to *Figure 4.46*.

The CSER.TXT file viewed with a word-processing program is similar to the example in CSER, SER (Sequential Events Recorder), in *CSER on page A.3.35*.

Operating the Relay Inputs and Outputs

The SEL-421 gives you great ability to perform control actions at bay and substation locations via the relay control outputs. The control outputs close and open circuit breakers, switch disconnects, and operate auxiliary station equipment such as fans and lights. The relay reads data from the power system and interfaces with external signals (contact closures and data) through the control inputs. This subsection is an introduction to operating the SEL-421 control outputs and control inputs. For more information on connecting and applying the control outputs and control inputs, see *Section 2: Installation*.

Control Output

The SEL-421 features Standard, Hybrid (High-Current Interrupting), and Fast Hybrid (Fast High-Current Interrupting) control outputs that you can use to control circuit breakers and other devices in an equipment bay or substation control house. See *Control Outputs on page U.2.7* for more information on control outputs.

Pulsing a Control Output: Terminal

When first connecting the relay, or at any time that you want to test relay control outputs, perform the following procedure. The procedure in the following steps shows how to use a communications terminal to pulse the control output contacts. Perform the steps in this example to become familiar with relay control and serial communication. For more information on the **PULSE** command, see *PULSE on page R.9.37*.

This example assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

NOTE: To PULSE an output, the circuit breaker control enable jumper, J18C, must be installed on the main board.

Step 1. Prepare to control the relay at Access Level B.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type the **BAC <Enter>** command.

d. Type the correct password to go to Access Level B.

You will see the Access Level 1 => prompt.

Step 2. Attach an indicating device (ohmmeter with a beep sounder or a test set) to the terminals for control output OUT104.

This output is a Standard control output and is not polarity sensitive.

For more information on connecting control outputs, see *Control Outputs on page U.2.7*.

Step 3. Perform the pulse operation.

a. Type **PULSE OUT104 <Enter>**.

The relay confirms your request to pulse an output with a prompt such as that shown in *Figure 4.49*.

b. Type **Y <Enter>** at the prompt.

You will see or hear the indicating device turn on for a second and then turn off.

```
==>PULSE OUT104 <Enter>

Pulse contact OUT104 for 1 seconds(Y/N)       ? Y <Enter>
==>
```

Figure 4.49 Terminal Display for PULSE Command

You can also pulse an output for longer than the default 1-second period. If you enter a number after the **PULSE** command, that number specifies the duration in seconds for the pulse. For example, if you enter **PULSE OUT104 3 <Enter>**, the relay pulses OUT104 for 3 seconds.

Pulsing a Control Output: Front Panel

The procedure in the following steps shows you how to use the front-panel display and navigation pushbuttons to check for proper operation of the SEL-421 control outputs. See *Section 5: Front-Panel Operations* for information on using the relay front panel.

Step 1. Attach an indicating device (an ohmmeter with a beep sounder or a test set) to the terminals for control output **OUT104**.

This output is a Standard control output and is not polarity sensitive.

For more information on connecting control outputs, see *Control Outputs on page U.2.7*.

Step 2. View the front-panel display.

After applying power to the relay, note that the LCD shows a sequence of screens called the ROTATING DISPLAY.

(Also, if you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 3. Press the **{ENT}** pushbutton to view the MAIN MENU, similar to that at the top of *Figure 4.50*.

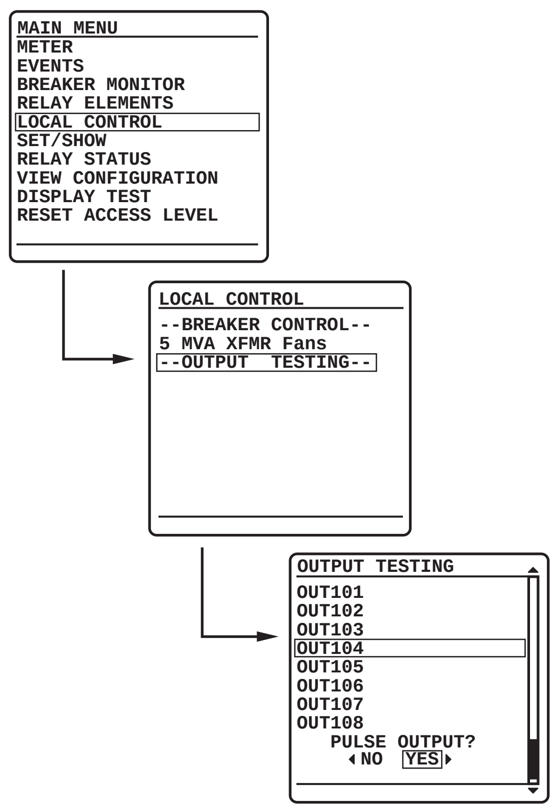


Figure 4.50 Front-Panel Menus for Pulsing OUT104

Step 4. View the local control screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the LOCAL CONTROL action item (see *Figure 4.50*).

b. Press the **{ENT}** pushbutton.

You will see the `LOCAL CONTROL` submenu (the middle screen in *Figure 4.50*).

Step 5. View the output testing screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the `--OUTPUT TESTING--` action item (see *Figure 4.50*, middle screen).

b. Press the **{ENT}** pushbutton.

The relay next displays the `OUTPUT TESTING` submenu (the last screen of *Figure 4.50*).

Step 6. Command the relay to pulse the control output.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight `OUT104` (see *Figure 4.50*, last screen).

b. Press the **{Right Arrow}** navigation pushbutton to highlight `YES` under `PULSE OUTPUT?`

c. Press the **{ENT}** pushbutton.

The relay detects your request for a function at an access level for which you do not yet have authorization. Whenever this condition occurs, the relay displays the password access screen of *Figure 4.51*.

```
PASSWORD REQUIRED
█
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 0 1 2 3
4 5 6 7 8 9 _ .
ACCEPT  BACKSPACE
```

Figure 4.51 Password Entry Screen

Step 7. Input a password and pulse the output.

a. Enter a valid Access Level B, P, A, O, or 2 password.

(The front panel is always at Access Level 1, so you do not enter the Access Level 1 password.)

Enter a valid password by using the navigation pushbuttons to select, in sequence, the alphanumeric characters that correspond to your password.

b. Press the **{ENT}** pushbutton at each password character.

(If you make a mistake, highlight the `BACKSPACE` option and press **{ENT}** to reenter a character or characters.)

c. After entering all password characters, press the **{Up Arrow}** or **{Down Arrow}** pushbuttons to highlight `ACCEPT`, and press **{ENT}**.

The relay pulses the output, and you will see the indicating device turn on for a second and then turn off.

Controlling a Relay Control Output With a Local Bit: Terminal

In this example, you set Local Bit 3 to start the transformer cooling fans near the breaker bay where you have installed the SEL-421. Thus, you can use the LCD screen and navigation pushbuttons to toggle relay Local Bit 3 to control the state of the cooling fans. Relay Word bit LB_SP03 provides supervision for local bit 3. Relay Word bit LB_SP03 must be asserted for successful Local Bit 3 operations. For more information on local bits, see *LOCAL CONTROL BITS on page U.5.24*.

The procedure in the following steps proposes connecting the transformer bank fan control to relay output OUT105. You can choose any relay output that conforms to your requirements. See *Control Outputs on page U.2.7* for more information on SEL-421 control outputs.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 1 =>> prompt.

Step 2. Access the local control settings.

a. Type **SET F <Enter>** command.

b. Repeatedly type **>** and then **<Enter>** to advance through the front-panel settings until you reach the **Display Points and Aliases** category.

c. Press **<Enter>** to access the **Control Points and Aliases Category**.

Figure 4.52 shows a representative terminal screen.

```
Control Points and Aliases
(Local Bit, Alias Name, Alias for Set State, Alias for Clear State,
Pulse Enable)
 1:
? LIST <Enter>

1:
? LB03,"5 MVA XFMR Fans",ON,OFF,N <Enter>
2:
? END <Enter>
              .
              .
              .

Control Points and Aliases
(Local Bit, Alias Name, Alias for Set State, Alias for Clear State,
Pulse Enable)

1: LB03,"5 MVA XMFR Fans","ON","OFF",N

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.52 Using Text-Edit Mode Line Editing to Set Local Bit 3

NOTE: Use quotation marks when entering alias strings that contain spaces or punctuation marks, as shown in the LB03 example, Step 4.

Step 3. Type **LIST <Enter>** at the **Local Control and Aliases** prompt to list the active control points.

This example assumes that you are using no local bits, so the relay returns you to line `1:` followed by the settings `?` prompt.

Step 4. Type **LB03,“5 MVA XFMR Fans”,ON,OFF,N <Enter>** at the line 1 prompt:

1: LB03,“5 MVA XFMR Fans”,ON,OFF,N <Enter>

The relay checks that this is a valid entry and responds with the next line prompt `2:` followed by the settings `?` prompt.

Step 5. End the settings session.

a. Type **END <Enter>**.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (In *Figure 4.52* a vertical ellipsis represents the readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can see the new local bit information.

b. Answer **Y <Enter>** to save your new settings.

Step 6. Set OUT105 to respond to Local Bit 3.

a. Type **SET O OUT105 <Enter>** (see *Figure 4.53*).

b. At the `?` prompt, type **LB03 <Enter>**.

c. At the next `?` prompt, type **END <Enter>**.

d. When prompted to save settings, answer **Y <Enter>**.

```
=>>SET O OUT105 <Enter>
Output

Main Board

OUT105 :== NA
? LB03 <Enter>

OUT106 := NA

? END <Enter>
Output

Main Board

OUT101 := 3PT AND NOT PLT04
OUT102 := 3PT AND NOT PLT04
OUT103 := BK1 CL AND NOT PLT04
OUT104 := KEY AND PLT02 AND NOT PLT04
OUT105 := LB03
OUT106 := NA
OUT107 := PLT04
OUT108 := NOT (HALARM OR SALARM)

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 4.53 Setting Control Output OUT105: Terminal

Step 7. Test the connection and programming.

a. Use the appropriate interface hardware to connect the fan control start circuit to OUT105.

b. At the relay front-panel `MAIN MENU`, select `LOCAL CONTROL` and press the **{ENT}** pushbutton (see *Figure 4.54*).

c. Select `5 MVA XFMR Fans` on the `LOCAL CONTROL` screen as shown in *Figure 4.54*.

d. Press **{ENT}** to see the last screen of *Figure 4.54*.

e. Highlight `1 ON` and press **{ENT}**.

The graphical local control handle moves to the 1 position. At this time, the transformer fans will begin running.

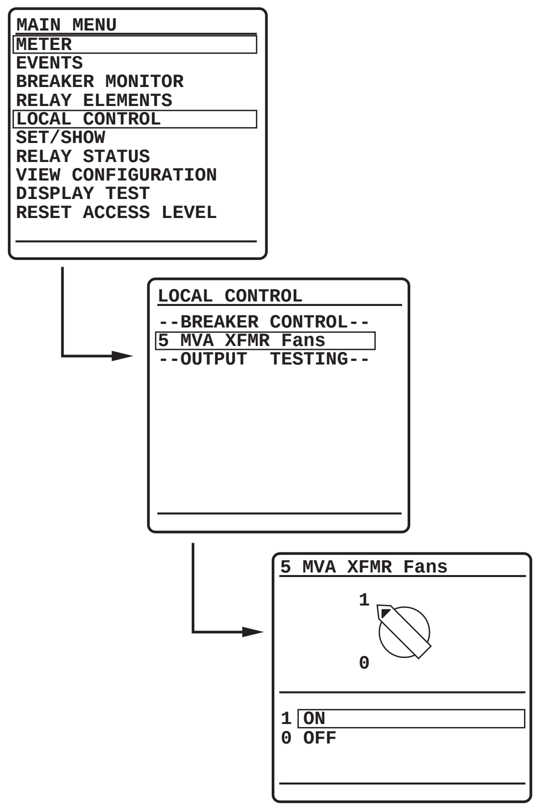


Figure 4.54 Front-Panel LOCAL CONTROL Screens

Setting Outputs for Tripping and Closing

To actuate power system circuit breakers, you must configure the SEL-421 control outputs to operate the trip bus and close bus. The relay uses internal logic and SELOGIC control equations to activate the control outputs.

Trip Output Signals

The SEL-421 is capable of single-pole tripping and three-pole tripping. There are many Relay Word bits (e.g., TPA1, TPA2, RTA1, and 3PT) that you can program to drive control outputs to trip circuit breakers. See *Section 1: Protection Functions in the Reference Manual* for complete information on tripping equations and settings. For target illumination at tripping, see *Section 5: Front-Panel Operations*.

Close Output Signals

The SEL-421 features an automatic recloser for single circuit breaker and two circuit breaker applications. The relay provides as many as two single-pole and four three-pole reclose shots. See *Section 2: Auto-Reclosing and Synchronism Check in the Reference Manual* for more information.

Close the circuit breakers using Relay Word bits BK1CLS and BK2CLS for Circuit Breaker 1 and Circuit Breaker 2, respectively.

Assigning Control Outputs for Tripping and Closing

The procedure in the following steps shows a method for setting the relay to operate the trip bus and the close bus at a typical substation. Relay factory defaults assign control outputs OUT101 and OUT102 to the trip bus and OUT103 to the close bus for a three-pole tripping circuit breaker. This procedure assigns an additional close output at OUT106.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Click **Settings > Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Access the **Main Board** output settings.

a. Expand the **Outputs** branch of the **Settings** tree view.

b. Click **Main Board** (see *Figure 4.55*).

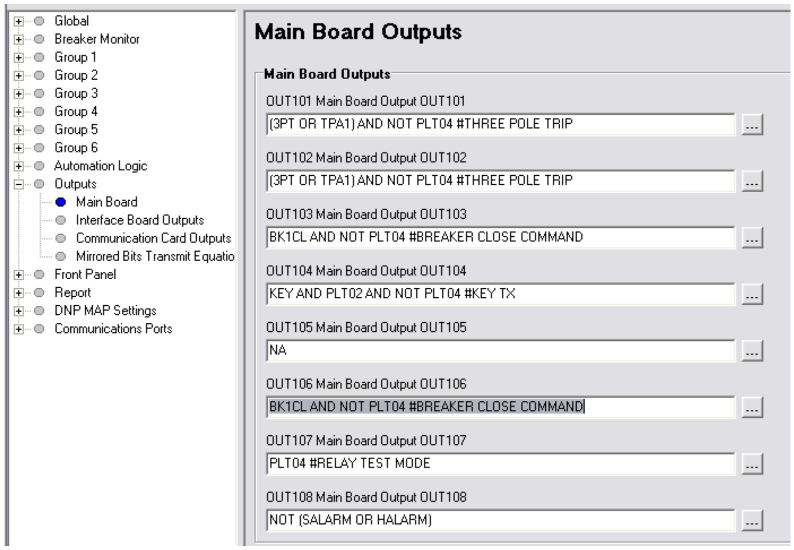


Figure 4.55 Assigning an Additional Close Output: ACSELERATOR QuickSet

Step 5. Assign a control output for the close bus.

a. In the **Main Board Outputs** dialog box, click the **OUT106** text box and type the following:

BK1CL AND NOT PLT04 #BREAKER CLOSE COMMAND

(The # indicates that a comment follows.)

b. Click or tab to another text box.

ACSELERATOR QuickSet checks that your entry is valid.

Step 6. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 7. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Click the check box for **Outputs** as shown in the first dialog box of *Figure 4.56*.

c. Click **OK**.

ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.56*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.56 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

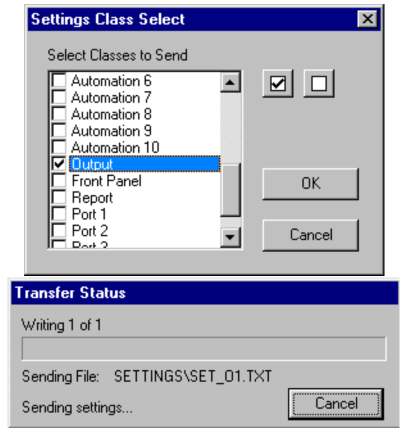


Figure 4.56 Uploading Output Settings to the SEL-421

Control Input Assignment

The SEL-421 relay has control inputs on the main board (IN101–IN107), and on one or two optional I/O interface boards (IN201–IN2xx, IN301–IN3xx), if so equipped. See *Control Inputs on page U.2.5* for detailed information.

There are two types of input circuitry: Direct Coupled and Optoisolated. *Table 4.8* lists the main differences between the two types of control inputs.

Table 4.8 Control Inputs in the SEL-421

	Direct-Coupled	Optoisolated
Pickup characteristics:	Pickup voltage can be selected via Global settings. Can have different pickup voltages on each input.	Pickup voltage is determined by hardware: one of six voltage levels determined at time of factory order. All pickup voltages are the same on each I/O interface board.
Polarity-sensitive:	Yes (will not respond to reverse polarity signals). A + polarity mark is printed over the positive terminals.	No (will respond to signals of either polarity). No polarity mark. AC signal detection is possible.[a]
Where found:·	➤ SEL-421 Main Board A (IN101–IN107) ➤ INT1, INT5, and INT6 I/O Interface Boards (IN201–IN208; IN301–IN308)	➤ SEL-421 Main Board B (IN101–IN107) ➤ INT2, INT7, and INT8 I/O Interface Boards (IN201–IN208; IN301–IN308) ➤ INT4 I/O Interface Board (IN201–IN224; IN301–IN324)

[a] With appropriate debounce settings—see Table 2.4.

The default value for Global setting EICIS (Enable Independent Control Input Settings) is N, which hides all individual control input settings, and only presents some overall settings that will apply to all control inputs. Set EICIS := Y to gain full access to the individual control input settings. For information on the Global settings related to control inputs, see *Table 9.3 on page R.9.2*, and *Table 9.5 on page R.9.2* through *Table 9.10 on page R.9.4*.

The following exercises use Direct-Coupled control inputs on Main Board A.

Setting a Control Input: Circuit Breaker Auxiliary Contacts (52A): Terminal

This is a step-by-step procedure to configure a control input that reflects the state of the circuit breaker auxiliary (52A) NO (normally open) contact. A common relay input is from circuit breaker auxiliary contacts; the relay monitors the 52A contacts to detect the closed/open status of the circuit breaker. Perform the following steps to connect three-pole circuit breaker auxiliary contacts to the SEL-421. This example is for a 125 Vdc system; the open state of the auxiliary contacts is 0 Vdc (circuit breaker open), and the closed state of the auxiliary contacts is approximately 125 Vdc (circuit breaker closed). The voltage drop in the connecting wires from the auxiliary contacts through the station battery to the relay gives a slightly lower voltage than the station battery at the relay control input terminals. Make the control input pickup, dropout, and debounce timer settings as explained in *Control Inputs on page U.2.5*.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

- a. Using a communications terminal, type **ACC <Enter>**.
- b. Type the Access Level 1 password and press **<Enter>**.

  You will see the => action prompt.
- c. Type the **2AC <Enter>** command.
- d. Type the correct password to go to Access Level 2.

  You will see the Access Level 2 =>> prompt.

Step 2. Configure the relay to read the circuit breaker auxiliary contact.

- a. Type **SET M <Enter>** (see *Figure 4.57*).

  These settings are the breaker monitor settings.
- b. Type **<Enter>** to bypass the Breaker 1 Monitoring enable, and **<Enter>** again to bypass the Breaker 2 Monitoring enable (NUMBK := 2 in this example).
- c. At the BK1TYP setting, type **3 <Enter>** for a three-pole circuit breaker for this particular example.

  (Use the setting BK1TYP appropriate for your circuit breaker(s).)
- d. At the BK2TYP setting, type **3 <Enter>** for a three-pole circuit breaker for this example.

  The relay displays the 52AA1 SELOGIC control equation action prompt.
- e. Type **IN101 <Enter>** at the ? prompt to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

  The relay next displays the 52AA2 SELOGIC control equation action prompt.
- f. Type **IN102 <Enter>** at the ? prompt to specify input IN102 as the control input that represents the close/open state of Circuit Breaker 2.

Step 3. End the settings process. The relay next scrolls a readback of all the Global settings, eventually displaying the `Save settings (Y,N) ?` prompt.

a. In the readback information, just before the `Save settings (Y,N) ?` prompt, confirm the new control input information.

b. Answer **Y <Enter>** to save your new settings.

```
=>>SET M <Enter>
Breaker Monitor

Breaker Configuration

Breaker 1 Monitoring (Y,N) EB1MON  := N ? <Enter>
Breaker 2 Monitoring (Y,N) EB2MON  := N ? <Enter>
Breaker 1 Trip Type (Single Pole=1,Three Pole=3) BK1TYP  := 1 ? 3 <Enter>
Breaker 2 Trip Type (Single Pole=1,Three Pole=3) BK2TYP  := 1 ? 3 <Enter>

Breaker 1 Inputs

N/O Contact Input -BK1 (SELogic Equation)
52AA1 := NA
?  IN101 <Enter>

Breaker 2 Inputs

A-Phase N/O Contact Input -BK2 (SELogic Equation)
52AA2 := NA
?  IN102 <Enter>
Breaker Monitor

Breaker Configuration

EB1MON  := N       EB2MON  := N       BK1TYP  := 3       BK2TYP  := 3

Breaker 1 Inputs

52AA1   := IN101

Breaker 2 Inputs

52AA2   := IN102

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 4.57 Setting 52AA1: Terminal

Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A): ACSELERATOR QuickSet

The procedure in the following steps shows how to program the SEL-421 control input IN101 to read the state of circuit breaker auxiliary contacts. This example uses a single three-pole tripping breaker. Modify the procedure listed here for your application.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. On the **Settings** menu, click **Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Access the **Control Inputs** settings.

a. Click the **+** mark next to the **Global** branch of the **Settings** tree view.

b. Click the + mark next to the **Control Inputs** branch of the **Settings** tree view, and click the **Control Inputs** branch (see *Figure 4.58*).

Step 5. Set **EICIS Independent Control Input Settings** to **Y**.

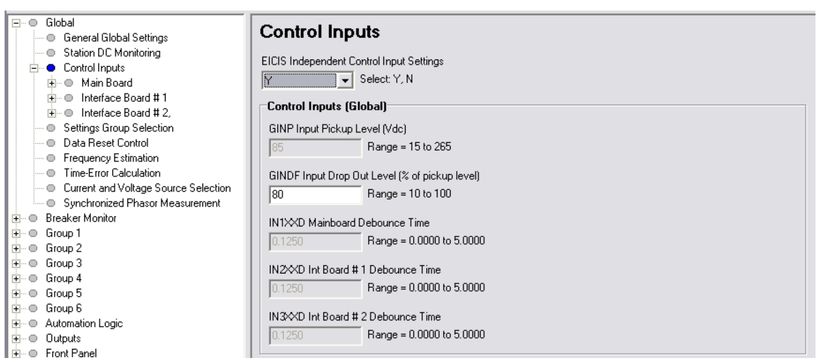


Figure 4.58 Accessing Global Enable Setting EICIS in ACSELERATOR QuickSet

Step 6. Access the **Control Inputs** settings.

a. Expand the **Main Board** branch by clicking the **+** button next to **Main Board**.

b. Click **Mainboard Pickup Levels**. You will see the input window similar to that in *Figure 4.59*.

c. Click **Mainboard Pickup and Dropout Delays**. You will see the input window similar to that in *Figure 4.60*.

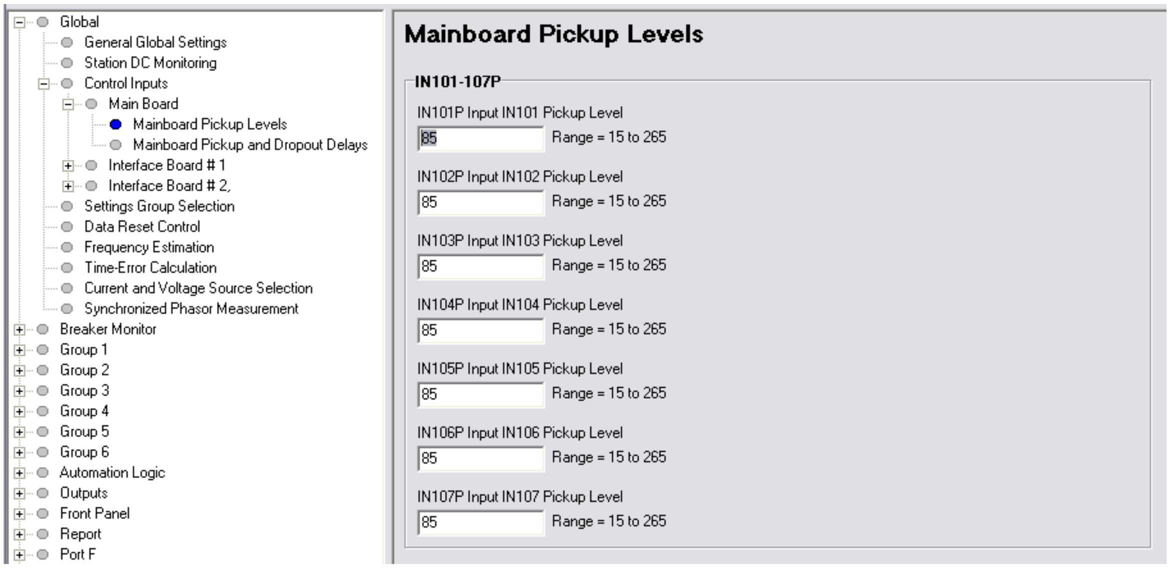


Figure 4.59 Control Input Pickup Level Settings in ACSELERATOR Quickset SEL-5030 Software

Step 7. Set the control input IN101 pickup threshold.

For this example, a 125 Vdc station battery is providing the control voltage. Referring to *Table 2.1 on page U.2.5*, the appropriate pickup voltage settings is 100 Vdc. Click the mouse cursor (or press <**Tab**>) to highlight **IN101P Main Board Input 101 Assertion Level**.

a. Delete the present setting by pressing <**Delete**>.

b. Type **100**, and then click or <**Tab**> to another value.

The relay checks the new value and enters the value in the ACSELERATOR QuickSet database.

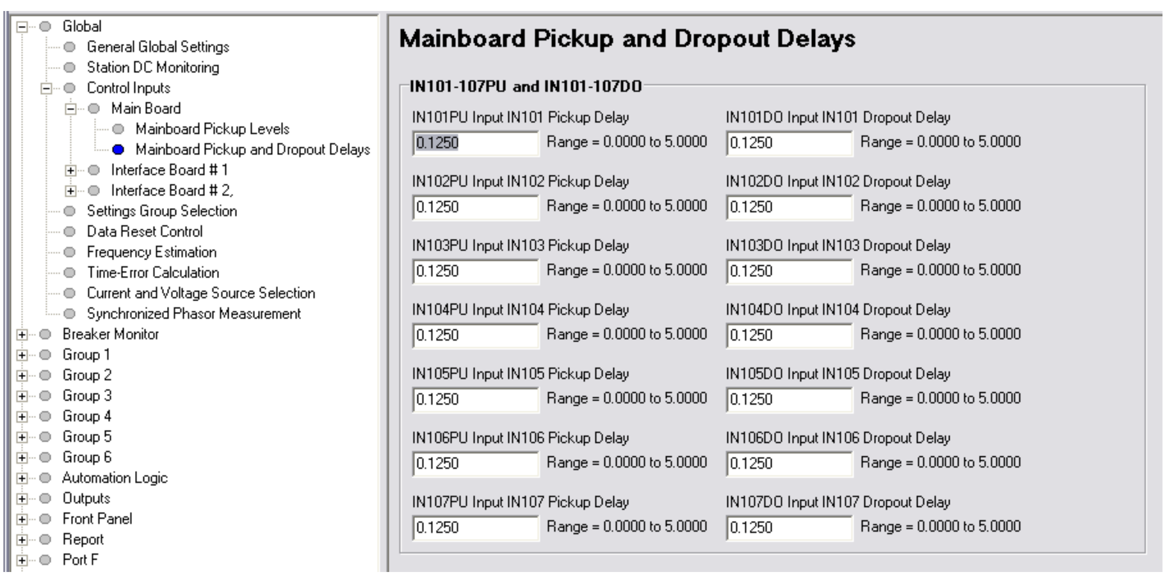


Figure 4.60 Control Input Pickup and Dropout Delay Settings in ACSELERATOR QuickSet

Step 8. Set the control input IN101 debounce time.

For this example, assume that the auxiliary contacts are slow and noisy; you must provide a slightly longer debounce time for these contacts.

a. Double-click the mouse cursor (or press **<Tab>**) to highlight **IN101PU Input IN101 pickup delay**.

b. Delete the present setting by pressing **<Delete>**.

c. Type **0.25 <Enter>**.

d. Similarly change the **IN101DO Input IN101 Dropout Delay** to **0.25**.

The relay checks the new value and enters the value in the ACSELERATOR QuickSet database.

Step 9. Configure the relay to read the circuit breaker auxiliary contact.

a. Expand the **Breaker Monitor** branch of the **Settings** tree view by clicking the **+** button (see *Figure 4.61*).

b. In the tree view, click **Breaker 1** to select circuit breaker monitor settings for Circuit Breaker 1.

c. At the **BK1TYP** setting, click **3** for the three-pole circuit breaker of this particular example.

(Use the setting BK1TYP appropriate for your circuit breaker(s).)

d. Set the 52AA1 SELOGIC control equation by clicking in the text box labeled **N/O Contact Input -BK1**.

e. Type **IN101**, and then click or **<Tab>** to another field to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

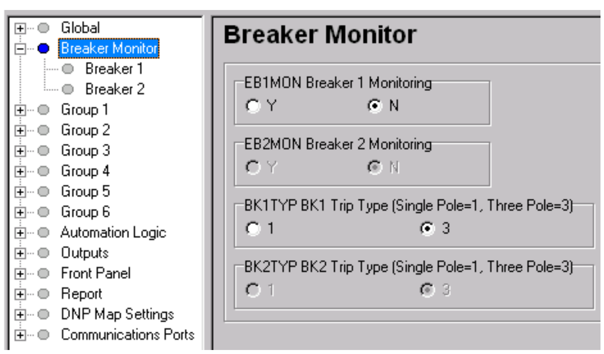


Figure 4.61 Setting BK1TYP in ACSELERATOR QuickSet

Step 10. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 11. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay

b. Click the **Global** check box and the **Breaker Monitor** check box, as shown in the first dialog box of *Figure 4.62*.

c. Click **OK**.

d. ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.62*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.62 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

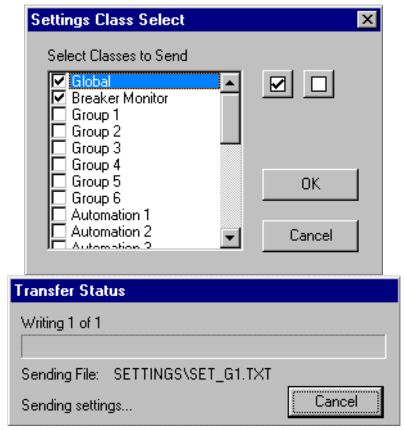


Figure 4.62 Uploading Global and Breaker Monitor Settings to the SEL-421

Configuring High-Accuracy Timekeeping

The SEL-421 features high-accuracy timekeeping when supplied with an IRIG-B signal. When the supplied clock signal is sufficiently accurate, the SEL-421 can act as a Phasor Measurement Unit (PMU) and transmit synchrophasor data representative of the power system at fixed time periods to an external data processor. The relay can also record COMTRADE event report data using the high-accuracy time stamp. See *Synchrophasors on page R.7.1*, *Oscillography on page A.3.7*, and *Time-Synchronized Measurements on page A.4.1* for details on these applications.

IRIG-B

The SEL-421 has two input connectors that accept IRIG-B (Inter-Range Instrumentation Group-B) demodulated time-code format: the IRIG-B pins of Serial Port 1, and the IRIG-B BNC connector—see *TIME Input Connections on page U.2.45*.

NOTE: The SEL-2407 Satellite Synchronized Clock meets both the SEL-421 accuracy and IEEE C37.118 requirements for a high-accuracy time source.

The IRIG-B BNC connector can be used for high-accuracy timekeeping purposes, with up to 1 µs accuracy with an appropriate time source. Either input can be used for general-purpose timekeeping, and the relay will have up to 500 µs accuracy. See *Table 4.9* for SEL-421 timekeeping mode details.

Table 4.9 SEL-421 Timekeeping Modes (Sheet 1 of 2)

Item	Internal Clock	IRIG	HIRIG (or High-Accuracy IRIG)
Best accuracy (condition)	Depends on last method of setting, or synchronization[a]	500 µs (when time source jitter is less than 3 ms)	1 µs (when time source jitter is less than 500 ns, and time-error is less than 1 µs)[b]

Table 4.9 SEL-421 Timekeeping Modes (Sheet 2 of 2)

Item	Internal Clock	IRIG	HIRIG (or High-Accuracy IRIG)
IRIG-B Connection Required	None	BNC connector (preferred), or Serial Port 1	BNC connector
Relay Word bits	TIRIG = logical 0 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 1

[a] The SEL-421 internal clock can be synchronized via DNP3, Ethernet card, SEL-2030 Communications Processor, or MIRRORED BITS communications.
[b] The time source must include the IEEE C37.118 IRIG-B control bit assignments to provide the Time Error estimate for the clock.

NOTE: If the time-code signal connected to the BNC connector degrades in quality, the SEL-421 will *not* switch-over to the IRIG-B pins of serial port 1. The SEL-421 will only switch to Serial Port 1 if the signal on the BNC connector completely fails (e.g. the cable is un-plugged).

Only one IRIG-B time source can be used by the SEL-421, and the signal connected to the IRIG-B BNC connector (shown in *Figure 4.64*) takes priority over the Serial Port 1 IRIG-B pins. If a signal is detected on the IRIG-B BNC input, the IRIG-B pins of Serial Port 1 will be ignored.

The SEL-421 determines the suitability of the IRIG-B signal connected to the BNC connector for high-accuracy timekeeping by applying two tests:

- Measuring whether the jitter between positive-transitions (rising edges) of the clock signal is less than 500 ns.
- Decoding the time-error information contained in the IRIG-B control field and determining that Analog Quantity TQUAL is less than 10^{-6} seconds (1 µs).

The SEL-421 will assert Relay Word bit TSOK only when these two tests are met, indicating HIRIG mode. The TQUAL Analog Quantity can be viewed with the **MET PM** command, and is shown beside the label

`Time Quality   Maximum time synchronization error:`. See *Figure 7.13 on page R.7.25* for a sample.

The IRIG-B control field is defined in the IEEE C37.118 standard. The SEL-421 places the raw time quality information in Relay Word bits TQUAL1, TQUAL2, TQUAL4, and TQUAL8; and the decoded maximum clock error in Analog Quantity TQUAL, in seconds.

If the clock signal is determined to be of low quality, with more than 500 ns of jitter, the SEL-421 will not assert the TIRIG Relay Word bit.

1k PPS Connection Not Required

SEL-421 Relays Changed

Previous versions of the SEL-421 Relay required a 1k PPS clock signal in addition to the IRIG-B signal to allow HIRIG mode (high-accuracy IRIG timekeeping). The previous SEL-421 hardware included two BNC connectors for timekeeping: 1k PPS and IRIG-B (see *Figure 4.64*). On newer SEL-421 relays, there is only one BNC connector, IRIG-B, as shown in *Figure 4.63*.

Starting with SEL-421 firmware version R112, HIRIG mode is available if a sufficiently accurate IRIG-B time source is connected to the IRIG-B BNC connector (see *Table 4.9*). A 1k PPS time source *cannot be used.*

Firmware version R112 redefines the meaning of the BNC connectors on the rear panel of the SEL-421. Pay close attention to the following instructions if you are upgrading your SEL-421 firmware.

Using New SEL-421 Firmware in an Existing Relay

In new SEL-421 relays, the IRIG-B BNC connector is in the same location as the 1k PPS BNC connector on previous relays. If you upgrade a previously installed SEL-421 relay to firmware version R112 or later, you will be provided with a retrofit kit that includes a new rear-panel label for the TIME inputs (see *Figure 4.65*). Follow the instructions included in the firmware upgrade package, and be sure to remove any 1k PPS time source cables that were previously connected.

Additionally, if the IRIG-B signal was previously supplied to the SEL-421 via Serial Port 1, and HIRIG mode operation is desired, connect the IRIG-B source to the IRIG-B BNC connector instead.

Time and Date Management Settings Not Required

SEL-421 Relays Changed

Previous firmware versions (R111 and earlier) of the SEL-421 relay provided Global Settings ETPPS and ETIRIG to enable or disable the 1k PPS and IRIG-B time sources. Beginning in firmware version R112, these settings are no longer part of Global Settings, because there is no 1k PPS input connector. Relay Word bit TPPS has also been removed from the relay.

Connecting High-Accuracy Timekeeping

The procedure in the following steps assumes that you have a modern high-accuracy GPS receiver with a BNC connector output for an IRIG-B signal. Use a communications terminal to send commands and receive data from the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*).

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Confirm that the relay is operating (see *Connecting and Applying Power on page U.4.3*).

Step 2. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Connect the cable.

Attach the IRIG-B signal with a BNC-to-BNC coaxial jumper cable from the GPS receiver IRIG-B output to the SEL-421 **TIME IRIG-B** BNC connector (see *Figure 4.63*).

NOTE: Consult the specific GPS Clock (IRIG-B time source) instruction manual for the IRIG-B cable requirements, termination resistor requirements, antenna installation, and clock configuration details.

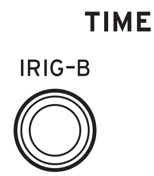


Figure 4.63 TIME BNC Connector, new hardware

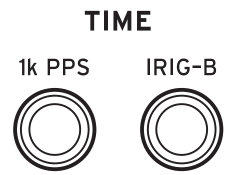


Figure 4.64 TIME BNC Connectors, old hardware

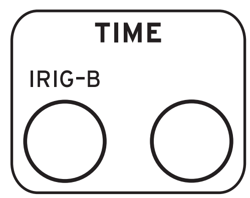


Figure 4.65 Retrofit Sticker

Step 4. Confirm/Enable automatic detection of high-accuracy timekeeping.

a. Wait at least 20 seconds for the SEL-421 to acquire the clock signal, and then, at a communications terminal, type **TAR TIRIG <Enter>**

The relay will return one row from the Relay Word, as shown in *Figure 4.66*. Only the state of the TIRIG and TSOK Relay Word bits are discussed in the troubleshooting steps below. The other Relay Word bits of interest to this discussion are TUPDH, which indicates that the SEL-421 internal clock is presently being updated by the HIRIG source, and TSYNCA, which acts as an alarm bit that asserts when the SEL-421 is not synchronized to either an internal or an external source. TSYNCA will only assert briefly when the HIRIG time source is connected or disconnected.

```
=>TAR TIRIG <Enter>

*       *       TIRIG   TUPDH   TSYNCA  TSOK    PMDOK   FREQOK
0       0       1       1       0       1       1       0
=>
```

Figure 4.66 Confirming the High-Accuracy Timekeeping Relay Word Bits

b. The TIRIG and TSOK Relay Word bits should be asserted (logical 1), indicating that the relay is in the High-Accuracy IRIG timekeeping mode (HIRIG).

If TSOK is not asserted, but TIRIG is asserted, the relay is in regular IRIG timekeeping mode. Here is a list of possible reasons for not entering HIRIG mode:

- ➢ The IRIG-B clock does not use the IEEE C37.118 Control Bit assignments, or the IRIG-B signal is not of sufficient accuracy.
- ➢ The termination resistor, required by some IRIG clocks, is not installed.
- ➢ If the time-source clock is reporting that its time error is greater than 1 µs.
- ➢ The IRIG-B clock source is connected via Serial Port 1 instead of the IRIG-B BNC connector.
- ➢ The IRIG-B clock source is connected to the unlabeled BNC connector on older relay hardware (the previous location of the IRIG-B BNC connector).

NOTE: If the firmware in an already installed SEL-421 is upgraded to version R112 or later, and the previous IRIG-B BNC cable is not moved to the new location (see Figure 4.63), the SEL-421 cannot enter High-Accuracy mode.

If neither TSOK nor TIRIG are asserted, the relay is not in an IRIG time-source mode. Here is a list of possible reasons for not entering IRIG mode:

- ➢ The IRIG-B clock signal is not of sufficient accuracy or is improperly configured.
- ➢ The termination resistor, required by some IRIG clocks, is not installed.
- ➢ The time source clock is not connected to an antenna.
- ➢ An IRIG-B clock source is connected both to serial port 1 and the unlabeled BNC connector on older relay hardware (the previous location of the IRIG-B BNC connector).
- ➢ A 1k PPS cable is still connected to the relay.

NOTE: If the firmware in an already installed SEL-421 is upgraded to version R112 or later, and the previous 1k PPS BNC cable is not removed (see Figure 4.63), the SEL-421 cannot use the IRIG time inputs.

Step 5. Type **TIME Q <Enter>** to confirm that the relay is operating in the high-accuracy IRIG (HIRIG) mode.

The relay displays information similar to *Figure 4.67*.

The Time Source will be HIRIG, indicating that the relay internal clock is locked to the high-accuracy IRIG input signal.

```
=>TIME Q <Enter>

Relay 1                                            Date: 10/06/2004  Time: 15:44:30.840
Station A                                          Serial Number: 0000000000

Time Source: HIRIG
Last Update Source: HIRIG

IRIG Time Mark Period:  1000.000000 ms

Internal Clock Period:  24.999995 ns

=>
```

Figure 4.67 Results of the TIME Q Command

TIME Q Descriptions

The **TIME Q** command provides details about relay timekeeping (see *Figure 4.67*). The SEL-421 internal clock is initially calibrated at the SEL factory. An external IRIG source is required to eliminate clock drift. For high-accuracy timekeeping functions such as synchrophasor measurement, the connected clock must support IEEE C37.118—Annex F, IRIG-B Control Bit assignments. The Time Source field provides the present high-accuracy timing input source; entries for this line are HIRIG and OTHER. The Last Update Source reports the source from which the relay referenced the last time value measurement. Entries for this line can be high-priority or low-priority sources. *Table 4.10* lists the possible Last Update Source values for the SEL-421.

NOTE: When EPMU := Y, the relay year is updated automatically from the connected clock IEEE C37.118–Annex F, IRIG-B Control Bit information.

Table 4.10 Date/Time Last Update Sources

Time Input Source Mode (QQQQQ)	Priority	Time Source	Front Panel Editing?
HIRIG	High	Time/date from the high-accuracy IRIG-B input.	No
IRIG	High	Time/date from the IRIG-B format time base signal	No
COMM CARD	Low	Time/date signal from the communications card	Date and Time
DNP	Low	Time/date from the DNP communications port	Date and Time
MIRRORED BITS	Low	Time/date from the MIRRORED BIT port	Date and Time
ASCII TIME	Low	Time from the relay serial ports	Time only
ASCII DATE	Low	Date from the relay serial ports	Date only
NONV CLK	Low	Time/date from the nonvolatile memory clock	Date and Time
FRONT PANEL TIME	Low	Time from the front-panel TIME entry screen	Time only
FRONT PANEL DATE	Low	Time from the front-panel DATE entry screen	Date only

The IRIG Time Mark Period value indicates the instantaneous period in which the relay measures the time-source inputs. The relay displays the time mark periods showing the present time precision derived from the applied time-source signals.

The **TIME Q** command is also helpful for troubleshooting IRIG problems. If the IRIG Time Mark Period value changes significantly between successive **TIME Q** commands, there may be too much noise in the signal for the relay timekeeping function.

Adaptive Internal Clock Period Adjustment

The Internal Clock Period is the internal relay timekeeping period. The relay adjusts this master internal clock when you apply HIRIG mode timekeeping, adapting the internal relay clock for your installation temperature conditions. If you lose the HIRIG timing lock, the relay internal clock operates at this precisely adapted clock period until HIRIG mode is restored. Time tags for event reports during a loss of HIRIG mode timekeeping remain very accurate. Lower accuracy time sources do not adaptively adjust the internal relay clock period.

Monitoring High-Accuracy Time Source Status

The purpose of the procedure in the following steps is to show one method for deriving the TIME Q Time Source information from Relay Word bits TSOK and TIRIG. The TSOK Relay Word bit is at logical 1 when the relay is in HIRIG time mode. For this application example, use a PSV (Protection SELOGIC Variable) to monitor time keeping status.

PSV01 asserts when the relay is synchronized to the HIRIG source. A departure from this condition asserts the relay alarm output (OUT108 for this application example).

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). Also, you should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

The defaults are **9600**, **8**, **1**, **None**, and **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Read the present configuration in the SEL-421. Click **Settings > Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Access the protection free-form SELOGIC settings.

a. Click the **+** mark next to **Group 1** in the **Settings** tree view.

b. Click the **Protection Logic 1** settings (see *Figure 4.68*).

Step 5. Enter the two lines of SELOGIC control equation programming in the **Protection Free-Form Logic Settings** shown in *Figure 4.68*.

Comments begin with the **#** character (see *Fixed SELOGIC Control Equations on page R.3.4*).

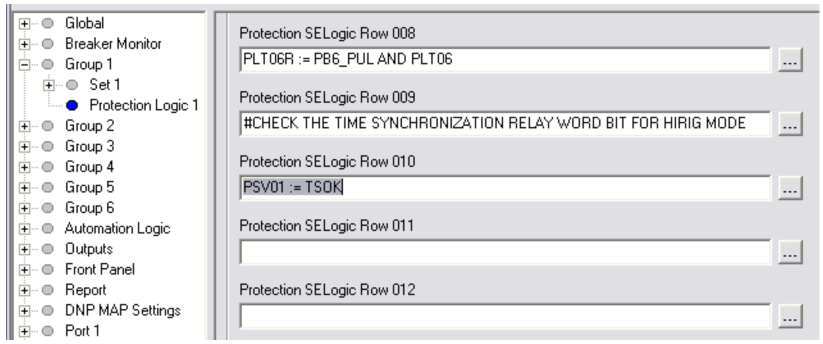


Figure 4.68 Programming a PSV in ACSELERATOR QuickSet

Step 6. Configure a control output to alarm a loss of HIRIG mode.

a. In the **Settings** tree view, double-click **Outputs** and then click **Main Board** (see *Figure 4.69*).

b. In the **OUT108 Main Board Outputs** text box, enter the OR NOT PSV01 condition to the preexisting OUT108 := NOT (SALARM OR HALARM) equation, as shown in *Figure 4.69*.

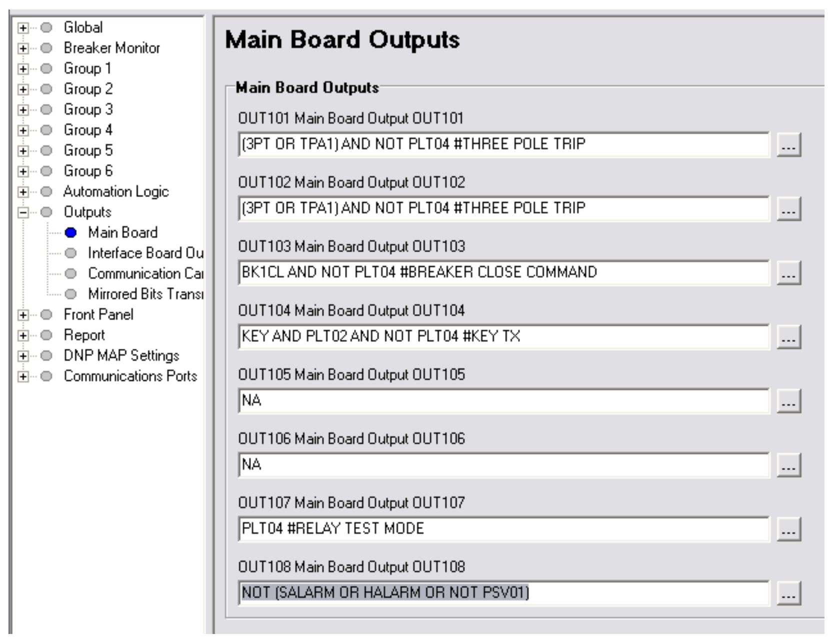


Figure 4.69 Setting OUT108 in ACSELERATOR QuickSet

Step 7. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 8. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Click the check box for **Group 1** check box and the **Output** check box, as shown in the first dialog box of *Figure 4.56*.

c. Click **OK**.

ACSELERATOR QuickSet responds with a display similar to the second dialog box of *Figure 4.56*.

If you see no error message, the new settings are loaded in the relay.

To confirm that you have prepared an out-of synchronization/loss of HIRIG mode alarm, disconnect the IRIG-B input. The relay alarm will activate.

Readying the Relay for Field Application

Before applying the SEL-421 in your power system, set the relay for your particular field application. Be sure to modify the relay factory default settings for your power system conditions to enable relay features to help you protect and control your system.

This procedure is a guide to help you ready the relay for field application. If you are unfamiliar with the steps in this procedure, see the many relay usage examples presented in this section. This is a suggested procedure; modify the procedure as necessary to conform to your standard company practices.

Step 1. Open the appropriate low-voltage breaker(s) and remove fuses to verify removal of control power and ac signals from the SEL-421.

Step 2. Isolate the relay TRIP control output.

Step 3. Perform point-to-point continuity checks on the circuits associated with the SEL-421 to verify the accuracy and correctness of the ac and dc connections.

Step 4. Apply power to the relay (see *Connecting and Applying Power on page U.4.3*).

The green **ENABLED** LED on the front panel will illuminate.

Step 5. Use an SEL Cable C234A to connect a serial terminal to the relay.

Step 6. Start the terminal (usually a PC with terminal emulation software).

Step 7. Establish communication with the relay at Access Level 0.

Step 8. Proceed to Access Level 2 (see *Changing the Default Passwords on page U.4.6*).

Step 9. Change the default passwords (see *Changing the Default Passwords on page U.4.6*).

Step 10. Set the DATE and TIME (see *Making Simple Settings Changes on page U.4.13*).

Step 11. Use test sources to verify relay ac connections (see *Examining Metering Quantities on page U.4.33*).

Step 12. Verify control input connections (see *Operating the Relay Inputs and Outputs on page U.4.56* and *Control Inputs on page U.2.5*).

Step 13. Verify control output connections (see *Operating the Relay Inputs and Outputs on page U.4.56* and *Control Outputs on page U.2.7*).

Step 14. Perform protection element tests (see *Checking Relay Operation on page U.6.24*).

Step 15. Set the relay (see *Making Simple Settings Changes on page U.4.13*, *Section 1: Protection Application Examples in the Applications Handbook*, and *Section 1: Protection Functions in the Reference Manual*).

Step 16. Connect the relay for tripping/closing duty (see *AC/DC Connection Diagrams on page U.2.50*).

Step 17. From Access Level 2, use a communications terminal to issue the commands to clear the relay data buffers (listed in *Table 4.11*).

Table 4.11 Communications Port Commands That Clear Relay Buffers

Communications Port Command	Task Performed
MET RD	Reset demand meter data
MET RP	Reset peak demand meter data
MET RE	Reset energy meter data
MET RM	Reset maximum/minimum meter data
HIS CA	Reset event report and history buffers
SER CA	Reset Sequential Events Recorder data

Step 18. Connect the secondary voltage and current inputs (see *User's Guide Section 2: Installation*).

Step 19. Use the **MET** command or the ACSELERATOR QuickSet HMI to view relay metering to confirm secondary connections (see *Examining Metering Quantities on page U.4.33*).

Section 5

Front-Panel Operations

The SEL-421 Relay front panel makes power system data collection and system control quick and efficient. Using the front panel, you can analyze power system operating information, view and change relay settings, and perform relay control functions. The relay features a straightforward menu-driven control structure presented on the front-panel liquid crystal display (LCD). Front-panel targets and other LED indicators give a quick look at SEL-421 operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include:

- Reading metering
- Inspecting targets
- Accessing settings
- Controlling relay operations

This section includes the following:

Front-Panel Layout

The front panel for the horizontal 3U (3 rack unit) SEL-421 configuration is shown in *Figure 5.1* (other configurations are similar).

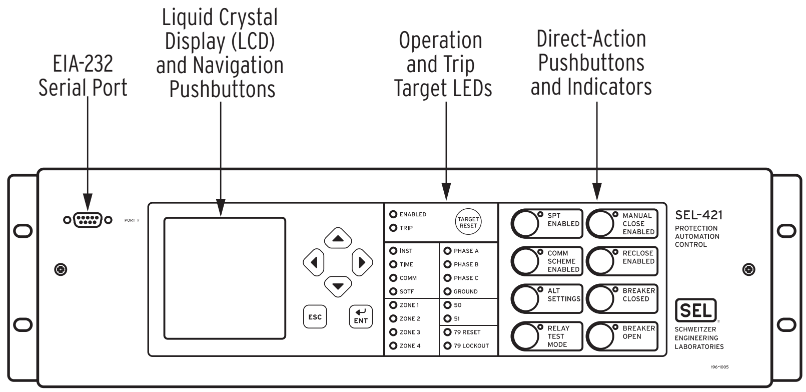


Figure 5.1 SEL-421 Front Panel (8 pushbutton model)

The front panel for the horizontal 5U (5-rack unit) SEL-421 configured with auxiliary **{TRIP}/{CLOSE}** pushbuttons is shown in *Figure 5.2*.

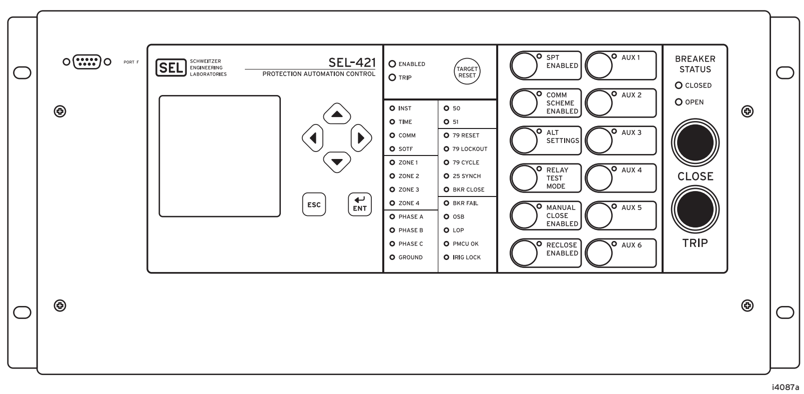


Figure 5.2 SEL-421 Front Panel (12 pushbutton model)

A 128 x 128 pixel LCD (liquid crystal display) shows relay operating data including event summaries, metering, settings, and relay self-test information.

Six navigation pushbuttons adjacent to the LCD window control the relay menus and information screens. Sequentially rotating display screens relate important power system metering parameters; you can easily change this ROTATING DISPLAY to suit your particular on-site monitoring needs. Use a simple and efficient menu structure to operate the relay from the front panel. With these menus you can quickly access SEL-421 metering, control, and settings.

Front-panel LEDs (light emitting diodes) indicate the relay operating status. You can confirm that the SEL-421 is operational by viewing the **ENABLED** LED. The relay illuminates the **TRIP** LED target to indicate a tripping incident. The relay is factory programmed for particular relay elements to illuminate the other target LEDs. You can program these target LEDs to show the results of the most recent relay trip event. The asserted and deasserted colors for the LEDs are programmable.

Select SEL-421 models feature auxiliary **{TRIP}/{CLOSE}** pushbuttons. These pushbuttons are electrically isolated from the rest of the relay. See *Auxiliary {TRIP}/{CLOSE} Pushbutton and Breaker Status LED Jumpers (select models only) on page U.2.29* for more information about this feature.

The SEL-421 front panel features large operator control pushbutton switches with annunciator LEDs that facilitate local control. Factory default settings associate specific relay functions with these direct-action pushbuttons and LEDs. Using SELOGIC® control equations or front-panel settings PB*n*_HMI, you can readily change the default direct-action pushbutton functions and LED indications to fit your specific control and operational needs. Change the pushbutton and pushbutton LED labels with the slide-in labels adjacent to the pushbuttons. The asserted and deasserted colors for the LEDs are programmable.

The SEL-421 front panel includes an EIA-232 serial port (labeled **PORT F**) for connecting a communications terminal or using the ACSELERATOR QuickSet® SEL-5030 software program. Use the common EIA-232 open ASCII communications protocol to communicate with the relay via front-panel **PORT F**. Other communications protocols available with the front-panel port are MIRRORED BITS® communications, and DNP3. For more information on communications protocols and **PORT F**, see *Communications Ports Connections on page U.2.47* and *Serial Communication on page R.4.2*.

Front-Panel LCD

The LCD is the prominent feature of the SEL-421 front panel. *Figure 5.3* shows the areas contained in the LCD:

- ➤ Title area
- ➤ Main area
- ➤ Message area
- ➤ Scroll bars

The scroll bars are present only when a display has multiple screens.

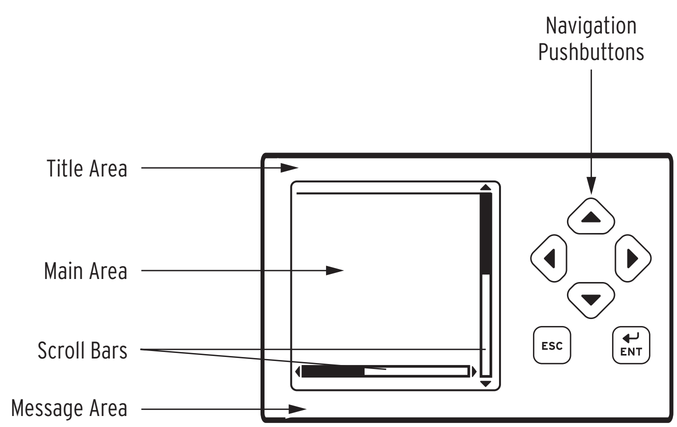


Figure 5.3 LCD Display and Navigation Pushbuttons

Front-Panel Inactivity Time Out

An LCD backlight illuminates the screen when you press any front-panel pushbutton. This backlight extinguishes after a front-panel inactivity time out. You can control the duration of the time out with relay setting FP_TO, listed in *Table 5.1*.

To set FP_TO, use the **SET F** (set front panel) settings from any communications port or use the Front Panel branch of the ACSELERATOR QuickSet **Settings** tree view. The maximum backlight time is one hour. Obtain this 60-minute maximum backlight time by setting FP_TO to 60 or to OFF. When the front-panel times out, the relay displays an automatic ROTATING DISPLAY, described later in this section under *Screen Scrolling on page U.5.5*.

Table 5.1 Front-Panel Inactivity Time-Out Setting

Name	Description	Range	Default
FP_TO	Front-panel display time-out	OFF, 1–60 minutes	15 minutes

Navigating the Menus

The SEL-421 front panel presents a menu system for accessing metering, settings, and control functions. Use the LCD and the six pushbuttons adjacent to the display (see *Figure 5.3*) to navigate these front-panel menus.

The navigation pushbutton names and functions are the following:

- {ESC}—Escape pushbutton
- {ENT}—Enter pushbutton
- {Left Arrow}, {Right Arrow}, {Up Arrow}, and {Down Arrow}—Navigation pushbuttons

Menus show lists of items that display information or control the relay. A rectangular box around an action or choice indicates the menu item you have selected. This rectangular box is the menu item highlight.

Figure 5.4 shows an example of the highlighted item RELAY ELEMENTS in the MAIN MENU. When you highlight a menu item, pressing the {ENT} pushbutton selects the highlighted item.

```
MAIN MENU
METER
EVENTS
BREAKER MONITOR
RELAY ELEMENTS
LOCAL CONTROL
SET/SHOW
RELAY STATUS
VIEW CONFIGURATION
DISPLAY TEST
RESET ACCESS LEVEL
```

Figure 5.4 RELAY ELEMENTS Highlighted in MAIN MENU

The {Up Arrow} pushbutton and {Down Arrow} pushbutton scroll the highlight box to the previous or next menu selection, respectively. When there is more than one screen of menu items, pressing {Up Arrow} while at the first menu item causes the display to show the previous set of full-screen menu items, with the last menu item highlighted. Pressing {Down Arrow} while at the bottom menu item causes the display to show the next set of full-screen menu items, with the first menu item highlighted.

Pressing the {ESC} pushbutton reverts the LCD display to the previous screen. Pressing {ESC} repeatedly returns you to the MAIN MENU. If a status warning, alarm condition, or event condition is active (not acknowledged or reset), the relay displays the full-screen status warning, alarm screen, or trip event screen in place of the MAIN MENU.

Screen Scrolling

The SEL-421 has two screen scrolling modes: autoscrolling mode and manual-scrolling mode. After front-panel time out, the LCD presents each of the display screens in this sequence:

- ➤ Any active (filled) alarm points screens
- ➤ Any active (filled) display points screens
- ➤ Enabled metering screens

The relay displays enabled metering screens in the order listed in *Table 5.2*. (see *Figure 5.19* for samples of the metering screens.) This sequence comprises the ROTATING DISPLAY.

NOTE: The initial display can present only the RMS_I line current screen. This can occur when you have not enabled any of the metering screens, alarm points, and display points.

Table 5.2 Metering Screens Enable Settings

Name	Description	Range	Default
RMS_V	RMS Line Voltage Screen	Y, N	N
RMS_I	RMS Line Current Screen[a]	Y, N	Y
RMS_VPP	RMS Line Voltage Phase-to-Phase Screen	Y, N	N
RMS_W	RMS Active Power Screen	Y, N	N
FUNDVAR	Fundamental Reactive Power Screen	Y, N	N
RMS_VA	RMS Apparent Power Screen	Y, N	N
RMS_PF	RMS Power Factor Screen	Y, N	N
RMS_BK1	RMS Breaker 1 Currents Screen	Y, N	N
RMS_BK2	RMS Breaker 2 Currents Screen	Y, N	N
STA_BAT	Station Battery Screen	Y, N	N
FUND_VI	Fundamental Voltage and Current Screen[a]	Y, N	Y
FUNDSEQ	Fundamental Sequence Quantities Screen	Y, N	N
FUND_BK	Fundamental Breaker Currents Screen	Y, N	N

[a] The default displays are RMS_I and FUND_VI.

Use the front-panel settings (the **SET F** command from a communications port or the Front Panel settings in ACSELERATOR QuickSet) to access the metering screen enables. Entering a **Y** (Yes) for a metering screen enable setting causes the corresponding metering screen to appear in the ROTATING DISPLAY. Entering an **N** (No) hides the metering screen from presentation in the ROTATING DISPLAY. *Figure 5.5* shows a sample ROTATING DISPLAY consisting of an example alarm points screen, an example display points screen, and the two factory-default metering screens, RMS_I and FUND_VI (the screen values in *Figure 5.5* are representative values).

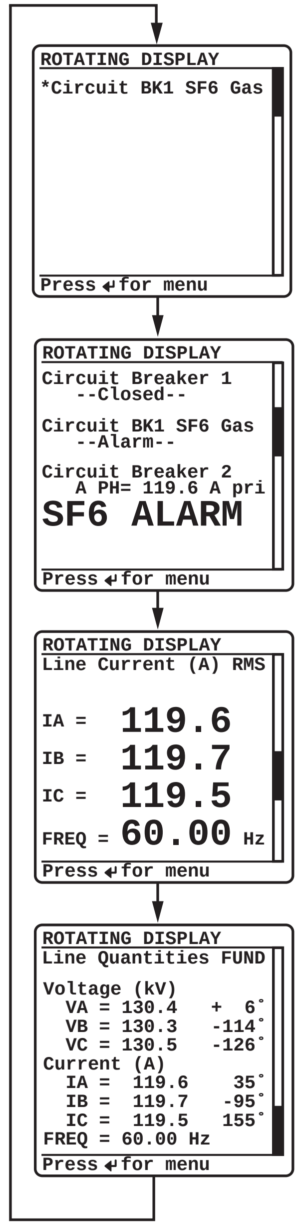


Figure 5.5 Sample ROTATING DISPLAY

The active alarm points are the first set of screens displayed in the ROTATING DISPLAY (see *Alarm Points on page U.5.7*). Each alarm points screen shows as many as 11 alarm conditions. The SEL-421 can present a maximum of 6 alarm points screens.

The active display points are the second set of screens in the ROTATING DISPLAY (see *Display Points on page U.5.10*). Each display points screen shows as many as 11 enabled display points. (With 96 display points, the SEL-421 can present a maximum of 9 display points screens.) If a display point does not have text to display, the screen space for that display point is maintained.

Autoscrolling Mode

Autoscrolling mode shows each screen for a user-settable period of time. Front-panel setting SCROLD defines the period of time each screen is shown. When you first apply power to the relay, the LCD shows the autoscrolling ROTATING DISPLAY. With SCROLD := OFF the screen remains on the first screen in the rotating display order, automatic rotation of additional screens is disabled.

The autoscrolling ROTATING DISPLAY also appears after a front-panel inactivity time out (see *Front-Panel Inactivity Time Out on page U.5.3*). The relay retrieves data prior to displaying each new screen. The relay does not update screen information during the display interval. At any time during autoscrolling mode, pressing **{ENT}** takes you to the MAIN MENU. Pressing any of the four navigation pushbuttons switches the display to manual-scrolling mode.

Manual-Scrolling Mode

In the manual-scrolling mode you can use the directional navigation arrow pushbuttons to select the next or previous screen. Pressing the **{Down Arrow}** or **{Right Arrow}** pushbuttons switches the display to the next screen; pressing the **{Up Arrow}** or **{Left Arrow}** pushbuttons switches the display to the previous screen.

In manual-scrolling mode, the display shows arrows at the top and bottom of the vertical scroll bar. The screen arrows indicate that you can navigate between the different screens at will. The relay retrieves data prior to displaying each new screen. Unlike the autoscrolling mode, the relay continues to update screen information while you view it in the manual-scrolling mode. To return to autoscrolling mode, press **{ESC}** or wait for a front-panel time out.

Alarm Points

You can display messages on the SEL-421 front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 5.6 shows a sample alarm points screen. The relay is capable of displaying up to 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. While you navigate the HMI menu structure, the relay does not automatically display the alarm points. Instead, ALARM EVENT displays in the footer. When you escape the HMI menu structure, the relay will display the alarm points screen.

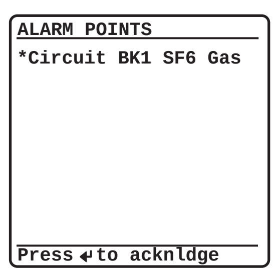


Figure 5.6 Sample Alarm Points Screen

The alarm point setting is an element of the SER settings. To enable an alarm point, enable the HMI alarm parameter of the SER Point Settings listed in *Table 5.3*. The format for entering the SER point data is the following comma-delimited string:

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Names can contain any valid ASCII character. Enclose the name within double quotation marks. See *Example 5.1* for particular information on the format for entering SER point data.

Table 5.3 SER Point Settings

Description	Range
Relay Word Bit	Any valid relay element
Reporting Name	20-character maximum ASCII string
Set State Name (logical 1)	20-character maximum ASCII string
Clear State Name (logical 0)	20-character maximum ASCII string
HMI Alarm	Y,N

If you enter a Relay Word bit that does not match a valid relay element, the relay displays: `Unknown relay word reference`. If you enter an alias or name that is too long, the relay displays: `Alias label too long`.

The relay displays alarm points in a similar fashion as the SER. Up to 19 characters of the given alias are displayed, with a character reserved for the "*." The asterisk denotes if the element is asserted. Initially, an alarm point must be asserted in order to be displayed; after the corresponding element deasserts, the asterisk is removed, but the alias is not. The relay displays alarm points in reverse chronological order, just as in the SER, with the most recently asserted alarm displayed on the top. Deasserted alarms may be removed from the display with user acknowledgement, as shown in *Example 5.1*.

EXAMPLE 5.1 Creating an Alarm Point

Alarm points screens provide operator feedback about the status of system conditions. An alarm points screen contains 11 alarm points; this example demonstrates a method to set the alarm point message that is shown in Figure 5.6. This example is based on the Relay Word bit IN101 asserting when circuit breaker 1 is in an alarm condition.

In the Report settings (**SET R**), enter the following after the SER Points line 1 prompt:

1: **IN101,"Circuit BK1 SF6 Gas","Alarm","Normal","Y"**

The circuit breaker alarm condition is indicated by the set state, "Alarm," and the circuit breaker normal condition is indicated by the clear state "Normal." The HMI Alarm parameter is set to "Y" in order to enable alarm points screen display of this element.

While in the scrolling mode, the assertion of IN101 will cause Figure 5.6 to automatically display. Upon the deassertion of IN101, the asterisk will disappear, as in Figure 5.7.

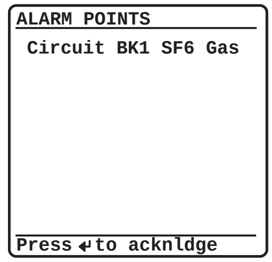


Figure 5.7 Deasserted Alarm Point

Pressing the **{ENT}** pushbutton will allow the user to acknowledge and clear deasserted alarms. Before clearing, you will be prompted to confirm that this is the intended action, as shown in Figure 5.8.

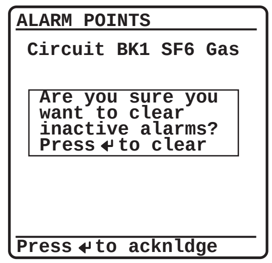


Figure 5.8 Clear Alarm Point Confirmation Screen

In the case that all alarms are deasserted, pressing the **{ENT}** pushbutton will allow the user to acknowledge and clear all alarms. After clearing, you will see a screen showing the results of the action, as depicted in Figure 5.9.

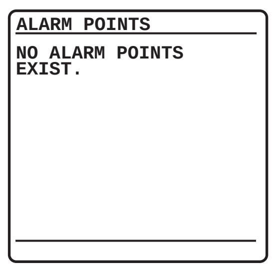


Figure 5.9 No Alarm Points Screen

Alarm points are not updated for a particular element if it has been deleted from the SER due to chatter criteria (see Automatic Deletion and Reinsertion on page A.3.36). Upon reinsertion, the element state will be updated on the alarm point display. If the relay enters a period of SER data loss, the status of alarm points cannot be determined. The screen shown in Figure 5.10 will appear until you exit the data loss condition, at which point the alarm point elements will be polled and displayed if asserted. Subsequent alarm point assertions will be displayed above the data loss message.

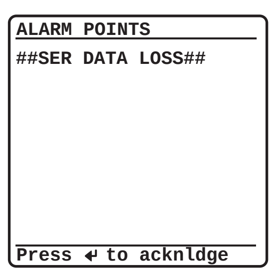


Figure 5.10 Alarm Points Data Loss Screen

Display Points

You can display messages on the SEL-421 front-panel LCD that indicate conditions in the power system. The relay uses display points to place these messages on the LCD.

Figure 5.11 shows a sample display points screen. Display points can show the status of Relay Word bits or display the value of analog quantities. The relay has 96 possible display points; *Table 5.4* and *Table 5.5* list the display points settings. The relay updates the display points data once per second if you are viewing the display points in manual-scrolling mode; in autoscrolling mode the relay updates the display points information each time the screen appears in the ROTATING DISPLAY sequence.

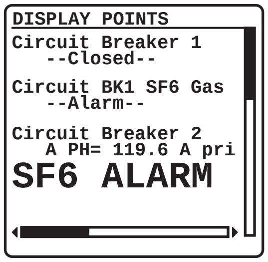


Figure 5.11 Sample Display Points Screen

To enable a display point, enter the display point settings listed in *Table 5.4* or *Table 5.5*. All display points occupy one, and only one, line on the display at all times. The height of the line is determined by the "Text Size" setting parameter. Display points of single-line height span one screen in total width. Display points of double-line height span two screens in total width. You can use multiple display points to simulate multiple lines.

Use the following syntax to display the given Relay Word bit exactly as seen in the navigational menu (name and value).

DPxx := **Name**

Use the following syntax to display the given Relay Word bit as seen in the navigational menu, replacing the name of the value with the given alias string. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Text Size"**

Use the following syntax to display the given Relay Word bit with the given alias. If the Relay Word bit is asserted (logical 1), the LCD displays the set string in the place of the value. If the Relay Word bit is deasserted (logical 0), the LCD displays the clear string in the place of the value. One or all of Alias, Set String, or Clear String can be empty. If Alias is empty, then the LCD displays only the Set or Clear Strings. If either Set String or Clear String is empty, then an empty line is displayed when the bit matches that state. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Set String", "Clear String", "Text Size"**

Use the following syntax to display the given analog quantity with the given text and formatting. Formatting must be in the form {Width.Decimal,Scale} with the value of Name, scaled by "Scale," formatted with total width "Width" and "Decimal" decimal places. The width value includes the decimal point and sign character, if applicable. The "Scale" value is optional; if omitted, the scale factor is processed as 1. If the numeric value is smaller than the field size requested, the field is padded with spaces to the left of the number. If the numeric value will not fit within the field width given, "$" characters are displayed. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Text1 {Width.Decimal,Scale} Text2", "Text Size"**

Table 5.4 Display Point Settings—Boolean

Description	Range
Relay Word Bit Name	Reference Manual, *Appendix A: Relay Word Bits*
Alias	ASCII string
Set String	ASCII string
Clear String	ASCII string
Text Size	S, D

Table 5.5 Display Point Settings—Analog

Description	Range
Analog Quantity Name	Reference Manual, *Appendix B: Analog Quantities*
User Text and Formatting	ASCII string
Text Size	S, D

Table 5.6 Display Point Settings—Boolean and Analog Examples

Example Display Point Setting Value	Example Display 12345678901234567890
IN101	`IN101=1` `IN101=0`
MWHAIN,"{7.2}"	`1234.56`
50P1,Overcurrent,,	`Overcurrent=1` `Overcurrent=0`
PSV01,Control,On,Off	`Control=On` `Control=Off`
PSV02,Breaker,Tripped,	`Breaker=Tripped` *Empty Line*
50P1,,,Overcurrent	*Empty Line* `Overcurrent`
MWHAIN,"A Ph Import={7.2}"	`A Ph Import=1234.56`
MWHAIN,"A Ph Import={7.3}"	`A Ph Import=$$$.$$$`
MWHAIN,"A Ph Imp {4}MWh"	`A Ph Imp 1234MWh`
PAD,"{7.2}"	`1234.56`
PAD,"A Ph Dem Pwr={4.1}"	`A Ph Dem Pwr=1234.5`
ICD,"C Demand={5}"	`C Demand= 1230`
ICD,"C Demand={4.2,0.001} kA"	`C Demand=1.23 kA`
MWHAOUT,"A Phase Out={3, 1000}"	`A Phase Out=1234`
MWHAOUT,"A Phase Out={3, 1000} kWh"	`A Phase Out=$$$ kWh`
1,"Fixed Text"	`Fixed Text`
0,"Fixed Text"	`Fixed Text`
1,	*Empty Line*
0,	*Empty Line*
	Display Point is hidden

If you enter a Relay Word bit or analog quantity that does not match a valid relay element, the relay displays `Invalid element`. If you enter a display point that exceeds the allowable length, the relay displays: `Too many characters`. If you enter an invalid scale factor, invalid width, too many parameters, or omit necessary quotation marks or brackets, the relay displays an error message. If a display point was used previously and you want to remove the display point, you can delete the display point. In the Front Panel settings (**SET F**), at the Display Points and Aliases prompt, use the text-edit mode line editing commands to set the display points (see *Text-Edit Mode Line Editing on page U.4.18* for information on text-edit mode line editing). To delete Display Point 1, type **DELETE <Enter>** at the Front Panel settings Line 1 prompt.

EXAMPLE 5.2 Creating a Display Point

Display points screens provide operator feedback about the readiness of equipment connected to the SEL-421. A display points screen contains 11 display points; this example demonstrates a method to set the display point messages that are shown in Figure 5.11. The SEL-421 in this example has an additional I/O interface board.

This example is based on a three-pole circuit breaker, with breaker input settings entered as shown in Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A): ACSELERATOR QuickSet on page U.4.67. The Relay Word bit 52AA1 will assert when Circuit Breaker 1 is in the closed position.

IN109 will assert when Circuit Breaker 1 is in an alarm condition. B2IAFIM is the filtered instantaneous magnitude for the A-Phase current through Circuit Breaker 2.

In the Front Panel settings (**SET F**), enter the following after the Display Points and Aliases line 1 prompt:

1: **1,"Circuit Breaker 1"**

2: **52AA1,," --Closed--"," --Open--"**

3: **0**

4: **0,"Circuit BK1 SF6 Gas"**

5: **IN109,," --Alarm--"," --Normal--"**

6: **1**

7: **1,"Circuit Breaker 2"**

8: **B2IAFIM," A PH={6.1,1} A pri"**

9: **IN109,,"SF6 ALARM", D**

Fixed text is set by assigning an alias to a "1" or "0." Blank lines are set by assigning a blank alias to a "1" or "0." The circuit breaker closed condition is indicated by the set state, " --Closed--" where leading spaces are added to center the set state message. Add a clear state named " --Open--" to show that the circuit breaker is open. The circuit breaker alarm condition is indicated by the set state, " --Alarm--" where leading spaces are added to center the set state message. Add a clear state named " --Normal--" to show that the circuit breaker is not in alarm. User text " A PH=" and "A pri" allows for customized display of the Circuit Breaker 2 A-Phase current, which has been formatted to display numerically as XXXX.X. Double font display is used to give greater visibility to the SF6 Alarm. A horizontal scroll appears while in manual-scrolling mode regardless of whether or not the display point label width requires two full screens to display.

EXAMPLE 5.3 Monitoring Test Modes With Display Points

This example uses the Relay Word bit TESTFM (Fast Meter test running) to activate a front-panel display point that alerts an on-site operator that the relay is in Fast Meter test mode.

In the Front Panel settings (**SET F**), enter the following after the line 10 prompt:

10: **TESTFM,,"FAST METER TEST!!!!"**

The LCD displays the screen shown in Figure 5.12 as a part of the ROTATING DISPLAY if the Fast Meter test is running. (Instruct the operator to view the relay front panel for messages or warnings as the last item on a "Leaving the Substation" checklist.)

Again, this display point application example does not require a clear state, so the clear state is blank. If the Fast Meter test is not running and no other display points are active, the relay shows a blank screen in the ROTATING DISPLAY.

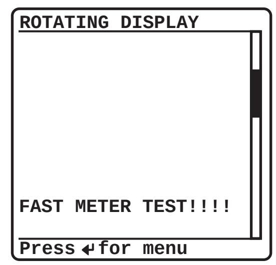


Figure 5.12 Fast Meter Display Points Sample Screen

Front-Panel Menus and Screens

Operate the SEL-421 front panel through a sequence of menus that you view on the front-panel display. The MAIN MENU is the introductory menu for other front-panel menus (see *Figure 5.4*). These additional menus allow you on-site access to metering, control, and settings for configuring the SEL-421 to your specific application needs. Use the following menus and screens to set the relay, perform local control actions, and read metering:

- Support Screens
  - Contrast
  - Password
- MAIN MENU
  - METER
  - EVENTS
  - BREAKER MONITOR
  - RELAY ELEMENTS
  - LOCAL CONTROL
  - SET/SHOW
  - RELAY STATUS
  - VIEW CONFIGURATION
  - DISPLAY TEST
  - RESET ACCESS LEVEL

Support Screens

The relay displays special screens over the top of the menu or screen that you are using to control the relay or view data. These screens are the contrast adjustment screen and the PASSWORD REQUIRED screen.

Contrast

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 one second. The relay displays a contrast adjustment box superimposed over the display.

Figure 5.13 shows the contrast adjustment box with the MAIN MENU screen in the background. Pressing the **{Right Arrow}** pushbutton increases the contrast. Pressing the **{Left Arrow}** pushbutton decreases the screen contrast. When finished adjusting the screen contrast, press the **{ENT}** pushbutton.

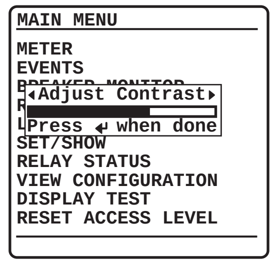


Figure 5.13 Contrast Adjustment

Password

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

The SEL-421 uses passwords to control access to settings and control menus. The relay has six access-level passwords. See *Changing the Default Passwords on page U.4.6* for more information on access levels and setting passwords. The SEL-421 front panel is at Access Level 1 upon initial power-up and after front-panel time out.

Password validation occurs only when you request a menu function that is at a higher access level than the presently authorized level. At this point, the relay displays a password entry screen, shown in *Figure 5.14*. This screen has a blank password field and an area containing alphabetic, numeric, and special password characters with a movable highlight box.

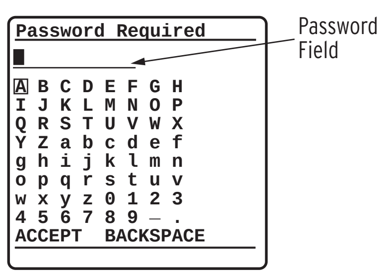


Figure 5.14 Enter Password Screen

Enter the password by pressing the navigation pushbuttons to move the highlight box through the alphanumeric field. When at the desired character, press **{ENT}**. The relay enters the selected character in the password field and moves the dark box cursor one space to the right. You can backspace at any time by highlighting the BACKSPACE character and then pressing **{ENT}**. When finished, enter the password by highlighting the ACCEPT option and then pressing **{ENT}**.

If you entered a valid password for an access level greater than or equal to the required access level, the relay authorizes front-panel access to the combination of access levels (new level and all lower levels) for which the password is valid. The relay replaces the password screen with the menu screen that was active before the password validation routine. When you enter Access Levels B, P, A, O, and 2, the Relay Word bit SALARM pulses for one second.

If you did not enter a valid password, the relay displays the error screen shown in *Figure 5.15*. Entering a valid password for an access level below the required access level also causes the relay to generate the error screen. In both password failure cases, the relay does not change the front-panel access level (it does not reset to Access Level 1 if at a higher access level). The relay displays the PASSWORD INVALID screen for five seconds. If you do not want to wait for the relay to remove the message, press any of the six navigational pushbuttons during the five-second error message to return to the previous screen in which you were working.

Figure 5.15 Invalid Password Screen

Main Menu

The MAIN MENU is the starting point for all other front-panel menus. The relay MAIN MENU is shown in *Figure 5.16*. When the front-panel LCD is in the ROTATING DISPLAY, press the **{ENT}** pushbutton to show the MAIN MENU.

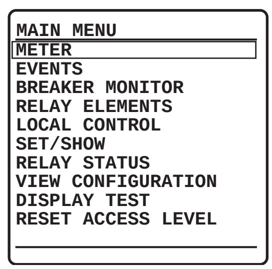


Figure 5.16 MAIN MENU

Meter

The SEL-421 displays metering screens on the LCD. Highlight METER on the MAIN MENU screen to select these screens. The METER MENU, shown in *Figure 5.17*, allows you to choose the following metering screens corresponding to the relay metering modes:

- RMS METER
- FUNDAMENTAL METER
- DEMAND METER (if enabled)
- ENERGY METER
- MAX/MIN
- SYNCHRONISM CHECK (if enabled)

```
METER MENU
RMS METER
FUNDAMENTAL METER
DEMAND METER
ENERGY METER
MAX/MIN
SYNCHRONISM CHECK
```

Demand Meter Enabled
(EDEM := ROL or
EDEM := THM)
Synchronism Check Enabled
(E25BK1 := Y or
E25BK2 := Y)

```
METER MENU
RMS METER
FUNDAMENTAL METER
ENERGY METER
MAX/MIN
```

No Synchronism Check
No Demand Metering
(E25BK1 := N)
(E25BK2 := N)
(EDEM := OFF)

Figure 5.17 METER MENU Screens

NOTE: Global settings ESS (Enable Source Selection) and NUMBK (Number of Circuit Breakers) affect how the SEL-421 determines the line current and the voltage source for protection functions (directional elements, load encroachment, out-of-step logic, distance element, and loss-of-potential).

Combinations of relay Global settings ESS and NUMBK give you metering data for Line, Circuit Breaker 1, and Circuit Breaker 2 when you view RMS METER, FUNDAMENTAL METER, and MAX/MIN metering screens. The relay shows the METER SUBMENU of *Figure 5.18* so you can choose the line or circuit breaker data that you want to display.

For example, if you have two sources feeding a transmission line through two circuit breakers and you set ESS := 3, NUMBK := 2, then the SEL-421 measures BREAKER 1 currents, BREAKER 2 currents, and combined (Circuit Breakers 1 and 2) currents for LINE. The relay displays the METER SUBMENU screen when you make this settings configuration.

Other combinations of settings ESS and NUMBK do not require separate circuit breaker metering screens; for these configurations, the relay does not present the METER SUBMENU screen. See *Current and Voltage Source Selection on page R.1.2* and *Global Settings on page R.10.4* for information on configuring global settings ESS, NUMBK, LINEI, BK1I, and BK2I.

```
METER SUBMENU
LINE
BREAKER 1
BREAKER 2
```

Figure 5.18 METER SUBMENU

The relay presents the meter screens in the order shown in each column of *Figure 5.19* and *Figure 5.20*. Once you have selected the type of metering data to display (RMS METER, FUNDAMENTAL METER, DEMAND METER, ENERGY METER, MAX/MIN, or SYNCHRONISM CHECK), you can scroll through the particular display column by pressing the **{Down Arrow}** pushbutton. Return to a previously viewed screen in each column by pressing the **{Up Arrow}** pushbutton. Press **{ESC}** to revert the LCD screen to the METER SUBMENU and METER MENU screens.

The metering screens show reset options for the MAX/MIN, ENERGY METER, PEAK DEMAND METER, and DEMAND METER metering quantities at the end of each screen column. Use the **{Left Arrow}** and **{Right Arrow}** pushbuttons to select a NO or YES response to the reset prompt, and then press **{ENT}** to reset the metering quantity.

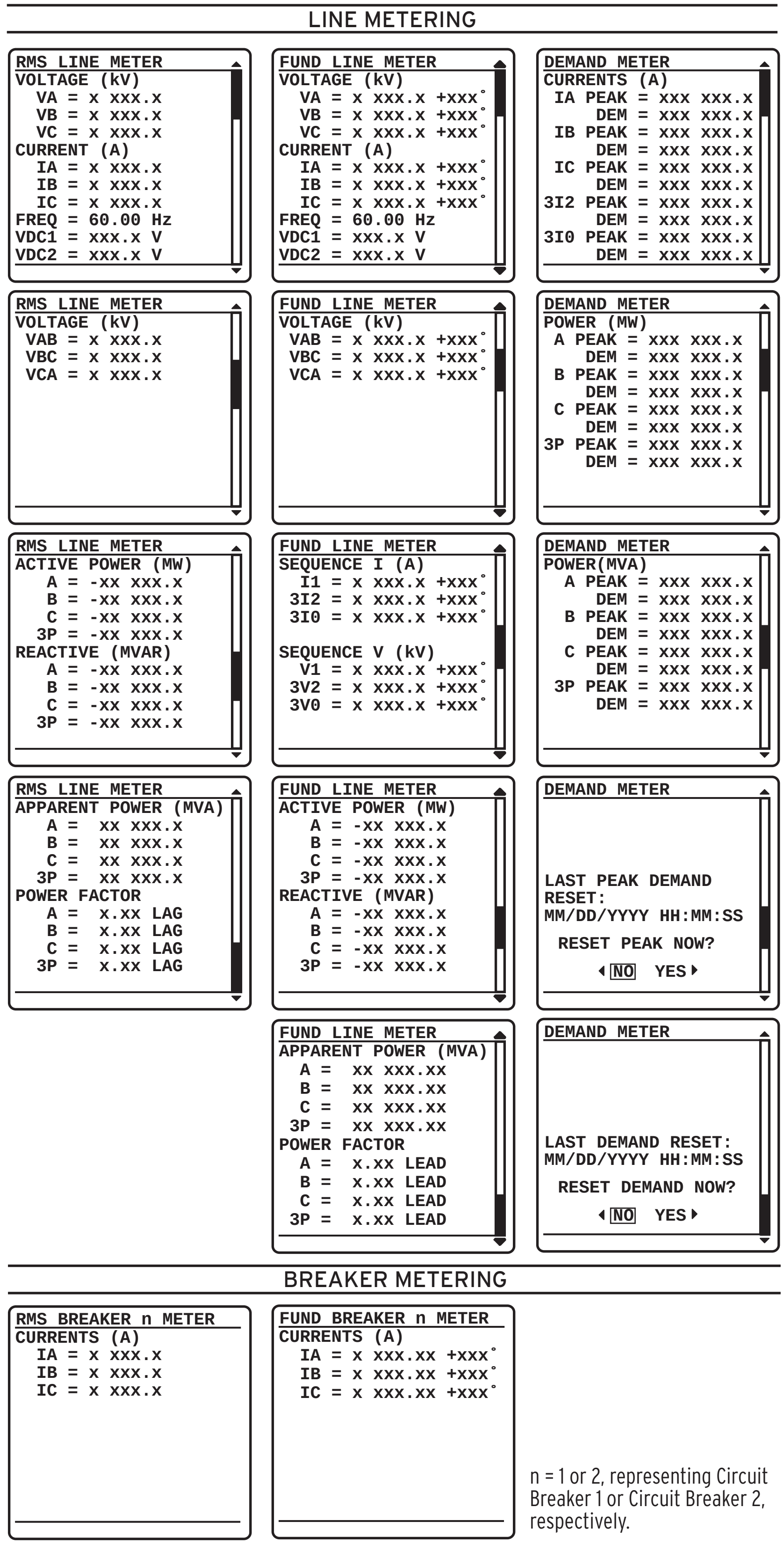


Figure 5.19 RMS, FUND, and DEMAND Metering Screens

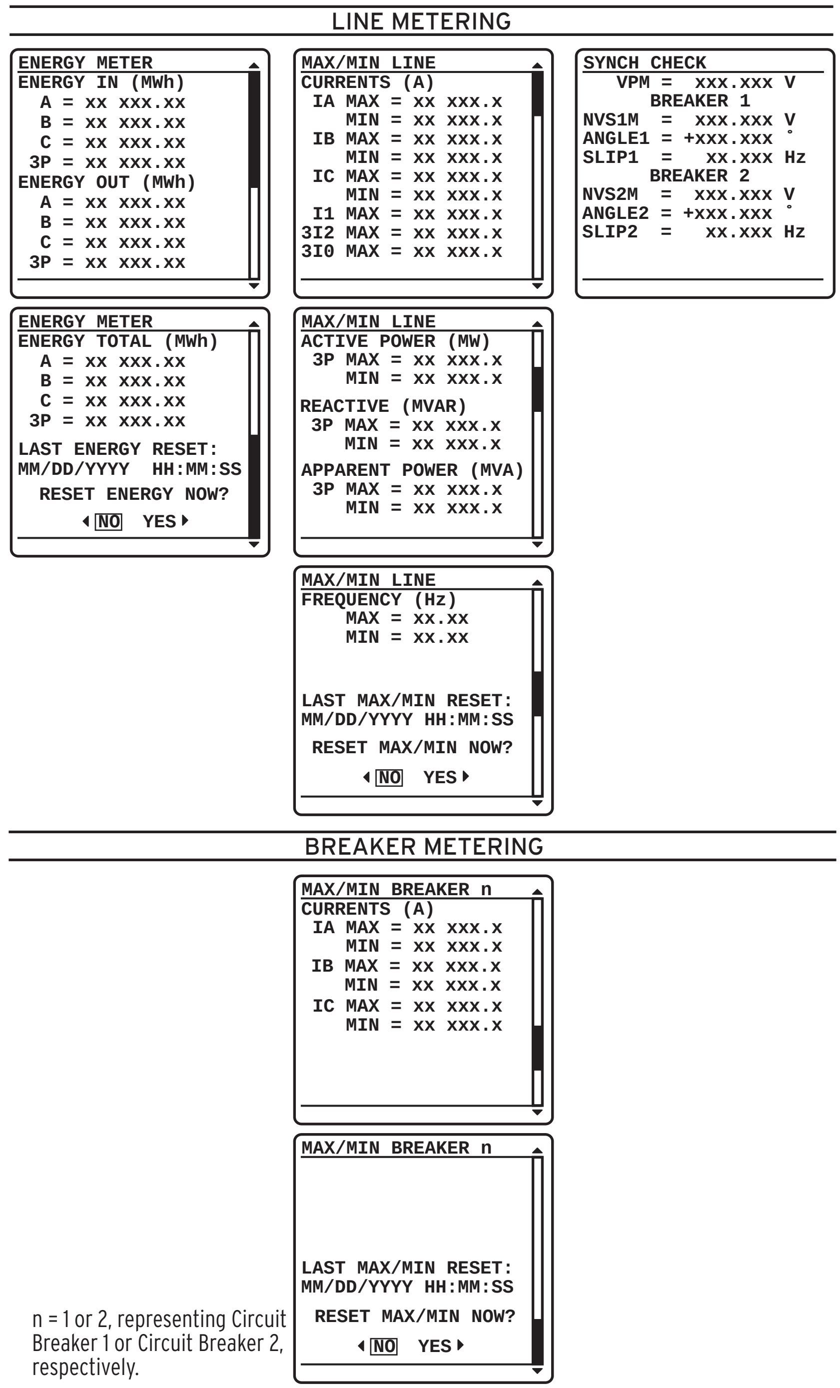


Figure 5.20 ENERGY, MAX/MIN, and SYNCH CHECK Metering Screens

Events

The SEL-421 front panel features summary event reporting, which simplifies post-fault analysis. These summary event reports include all trip events, event and data capture triggering (via the ER SELOGIC control equation), and manual triggers. The relay displays event reports based on the Relay Word bit elements in the ER (event report trigger) SELOGIC control equation. See *Event Report on page A.3.12* for more information on event reports.

The front-panel event buffer size is 100 summaries. The relay numbers summary events in order from 10000 through 42767 and displays the most recent summaries on the LCD.

You can view summary event reports from the relay front-panel display by selecting EVENTS from the MAIN MENU. *Figure 5.21* shows sample EVENT SUMMARY screens for a phase-to-phase-to-ground fault. Use the **{Right Arrow}** and **{Left Arrow}** pushbuttons to show each of the summary screens for the event. Event reports can also be viewed via a front-panel automatic message (*Front-Panel Automatic Messages on page U.5.34*) or programmable front-panel operator control pushbutton (*Front-Panel Operator Control Pushbuttons on page U.5.40*).

The horizontal scroll bar indicates that you can view other event 10002 screens. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to move among the events in the summary buffer. Press **{ESC}** to return to the MAIN MENU.

```
EVENT SUMMARY 10002
03/15/2001   GROUP 1
00:00:05.387

EVENT:         BCG T
LOCATION:      48.47
FREQ:          60.00
SHOT:      1P=0 3P=1
BK1    OPEN
BK2 CLOSED
```

```
EVENT SUMMARY 10002
TARGETS:
COMM
ZONE 2
PHASE B
PHASE C
GROUND
50
```

```
EVENT SUMMARY 10002
FAULT QUANTITIES
(kV/A)
VA =     131     0.7°
VB =     113  -123.4°
VC =     113   124.7°

IA =     200    -0.5°
IB =    2478   172.3°
IC =    2480     6.7°
IG =     212   -11.3°
```

Figure 5.21 EVENT SUMMARY Screens

SER

The Sequential Events Recorder records state changes of user-programmable Relay Word bits. State changes are time-tagged for future analysis of relay operations during an event. See *SER (Sequential Events Recorder) on page A.3.34* for more information on SER events. To view SER events from the front panel, select EVENTS from the MAIN MENU and SER Events from the Events Menu as shown in *Figure 5.22*. SER events are also viewable using programmable front-panel operator-control pushbuttons; see *Front-Panel Operations on page U.5.1*.

Figure 5.22 illustrates the SER Events display screen. Data reported in this screen for each event are the SER number, SER Point Alias Name, Asserted or Deasserted state, and the Date and Time of the event. When in the SER Events screen, three SER records are displayed. Using the navigation pushbuttons, the most recent 200 SER events are viewable on the front-panel display. The topmost event is the most recent event and the bottommost event is the oldest. The upper right of the screen displays the number of the SER events currently being viewed. If a new event occurs while viewing the SER events, the display does not update with the new event automatically. To include the new SER event in the display, exit the SER screen by pressing **{ESC}** and re-enter the SER Events screen by pressing **{ENT}** with the SER Events selection highlighted. This rebuilds the SER Events display and contains the latest SER events triggered.

```
SER Events   001-003
Local
Disabled
02/16/06 11:11:01.993

Local
Enabled
02/16/06 10:11:19.090

IN101
Asserted
02/16/06 03:22:01.988
```

Figure 5.22 SER Events Screen

If no SER events are available, *Figure 5.23* is displayed.

Figure 5.23 No SER Events Screen

While viewing the SER events, front-panel pushbuttons provide navigation and control functions as indicated in *Table 5.7*.

Table 5.7 Front-Panel Pushbutton Functions While Viewing SER Events

Pushbutton	Description
{Up Arrow}, {Down Arrow}	Navigates one screen at a time up or down. Each screen contains three SER events. Accelerated scrolling is obtained when the pushbutton remains pressed (see accelerated scrolling behavior below).
{Left Arrow}, {Right Arrow}	Navigates between SER events to allow adjacent SER events to be displayed on one screen. For example, if events 1, 2, and 3 are displayed, press the **{Right Arrow}** once to display events 2, 3, and 4 in the same screen. No accelerated scrolling is provided with the **{Left Arrow}** and **{Right Arrow}** pushbuttons.
{ESC}	Returns to the Events Menu
{ENT}	Does nothing

Hold down either the **{Up Arrow}** or **{Down Arrow}** to achieve accelerated scrolling. Holding down the **{Up Arrow}** or **{Down Arrow}** navigates one screen at a time for the first five screens, and then increases to five screens at a time if the button remains pressed. Accelerated scrolling stops at the newest or oldest SER event record available, depending on the direction of the scrolling.

When the upper limit of the SER events is reached, press the **{Down Arrow}** one more time and the report will wrap around to display the screen containing the first SER event. Similarly, when the lower limit of the SER events is reached, press the **{Up Arrow}** one more time and the report will wrap around to display the screen containing the last SER event.

Breaker Monitor

The SEL-421 features an advanced circuit breaker monitor. Select BREAKER MONITOR screens from the MAIN MENU to view circuit breaker monitor alarm data on the front-panel display.

Figure 5.24 shows sample breaker monitor display screens. The BKR n ALARM COUNTER screen displays the number of times the circuit breaker exceeded certain alarm thresholds (see *Circuit Breaker Monitor on page A.2.1*).

If you have two circuit breakers and have set NUMBK := 2, the alarm submenu in *Figure 5.24* appears first. Use the navigation pushbuttons to choose either Circuit Breaker 1 or Circuit Breaker 2. Press **{ENT}** to view the selected circuit breaker monitor information. An example of the Circuit Breaker 1 ALARM COUNTER screen for a single-pole tripping circuit breaker is shown on the right side of *Figure 5.24*.

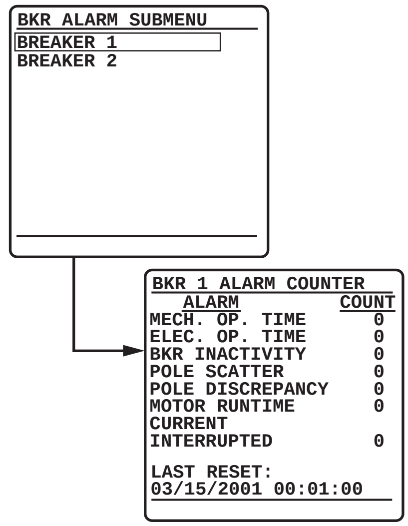


Figure 5.24 BREAKER MONITOR Report Screens

Relay Elements (Relay Word Bits)

You can view the RELAY ELEMENTS screen to check the state of the Relay Word bits in the SEL-421. The relay has two unique manual-scrolling features for viewing these elements:

➤ Accelerated navigation

➤ Search

These Relay Word bit scrolling features make selecting elements from among the many relay targets easy and efficient. *Figure 5.25* shows an example of the RELAY ELEMENTS screen. If an alias exists for an element, the alias name is displayed instead of the element name. The asterisk (*) in *Figure 5.25* indicates that this Relay Word bit position is reserved for future use.

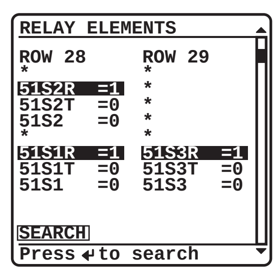


Figure 5.25 RELAY ELEMENTS Screen

When you move item by item through the Relay Word bit table, pressing the {Up Arrow} or {Down Arrow} pushbuttons shows each previous or next screen in turn.

Accelerated navigation occurs when you press and hold the {Up Arrow} or {Down Arrow} pushbuttons. Holding the {Up Arrow} or {Down Arrow} pushbuttons repeats the regular pushbutton action at 2 rows every second for the first 10 rows. Continue pressing the {Up Arrow} or {Down Arrow} pushbutton to cause the relay screen scrolling to accelerate to 20 rows per second. When you are scrolling up in accelerated scrolling, scrolling will stop at the first relay elements screen. When you are scrolling down, scrolling will stop at the last screen.

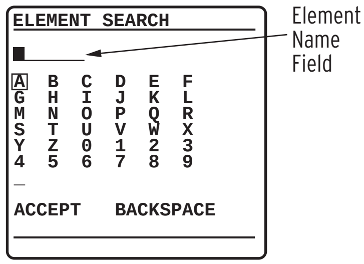


Figure 5.26 ELEMENT SEARCH Screen

Search mode allows you to find a specific relay target element quickly. *Figure 5.26* shows the menu screen that the relay displays when you select the SEARCH option of the RELAY ELEMENTS initial menu.

When you first enter this search menu, the block cursor is at the beginning of the element name field and the highlight box in the alphanumeric field is around the letter A. Use the navigation pushbuttons to move through the alphanumeric characters. If the highlight is on one of the characters, pressing **{ENT}** enters the character at the block cursor location in the element name field. Next, the block cursor moves automatically to the character placeholder to the right. If the block cursor was already at the first character position on the left, the block cursor remains at the end of the name field. To backspace the cursor in the element name field, move the highlight to BACKSPACE and press **{ENT}**. When you have finished entering an element name, move the highlight to ACCEPT and press **{ENT}**. At any time, pressing **{ESC}** returns the display to the RELAY ELEMENTS screen.

If the highlight is on ACCEPT, the relay finds the matching relay element when you press **{ENT}**. The relay first searches for alias names, seeking an exact match. If the relay does not find an exact alias name match, it searches for an exact primitive name match. If there is no exact primitive name match, the relay initiates a partial alias name string search, followed by a partial primitive name string search. If the relay finds no match, the screen displays an error message and stays in the ELEMENT SEARCH screen. If the relay finds a match, the screen displays the element row containing the matching element.

Local Control

The SEL-421 provides great flexibility in power system control through the LOCAL CONTROL menus. You can use the front-panel LOCAL CONTROL menus to perform these relay functions:

- ➤ Trip and close circuit breakers (password required)
- ➤ Assert, deassert, and pulse relay control outputs to command station control actions
- ➤ Test relay outputs (password required)

In the first LOCAL CONTROL submenu of *Figure 5.27*, you can choose BREAKER CONTROL, LOCAL BITS CONTROL, or OUTPUT TESTING. You must install the circuit breaker control enable jumper to enable circuit breaker control and output testing capability (see *Operating the Relay Inputs and Outputs on page U.4.56* and *Password and Circuit Breaker Jumpers on page U.2.18*). The submenu will not display the --BREAKER CONTROL-- option and the --OUTPUT TESTING-- option if the breaker jumper is not installed. (The relay checks the status of the breaker jumper whenever you activate the front-panel settings and at power-up.) If the breaker jumper is not installed, and there are no local bits enabled, the relay displays an information message when you attempt to enter LOCAL CONTROL and the screen returns to the MAIN MENU after a short delay.

Local bit names that you have programmed (see *Example 5.4*) appear in the local control bit names field between --BREAKER CONTROL-- and --OUTPUT TESTING--, as shown in *Figure 5.27*. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the local control action you want to perform. Pressing **{ENT}** takes you to the specific LOCAL CONTROL screen.

```
LOCAL CONTROL
--BREAKER CONTROL--
Enable Bus Switching
North Bus MOD
South Bus MOD
Bus Tie Interlock
Alternate Settings 3
--OUTPUT TESTING--
```

Figure 5.27 LOCAL CONTROL Initial Menu

BREAKER CONTROL

The BREAKER CONTROL option presents a circuit breaker selection submenu if NUMBK := 2. Use the navigation pushbuttons and **{ENT}** to select the circuit breaker you want to control.

Figure 5.28 shows the BREAKER CONTROL submenu and sample circuit breaker control screens for BREAKER 1. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the TRIP BREAKER 1 or CLOSE BREAKER 1 control actions.

When you highlight the trip option and press **{ENT}**, the relay displays the confirmation message OPEN COMMAND ISSUED and trips Circuit Breaker 1. The BREAKER 1 STATUS changes to OPEN.

When you highlight the close option and press **{ENT}**, the relay displays the confirmation message CLOSE COMMAND ISSUED and closes Circuit Breaker 1. The BREAKER 1 STATUS changes to CLOSED.

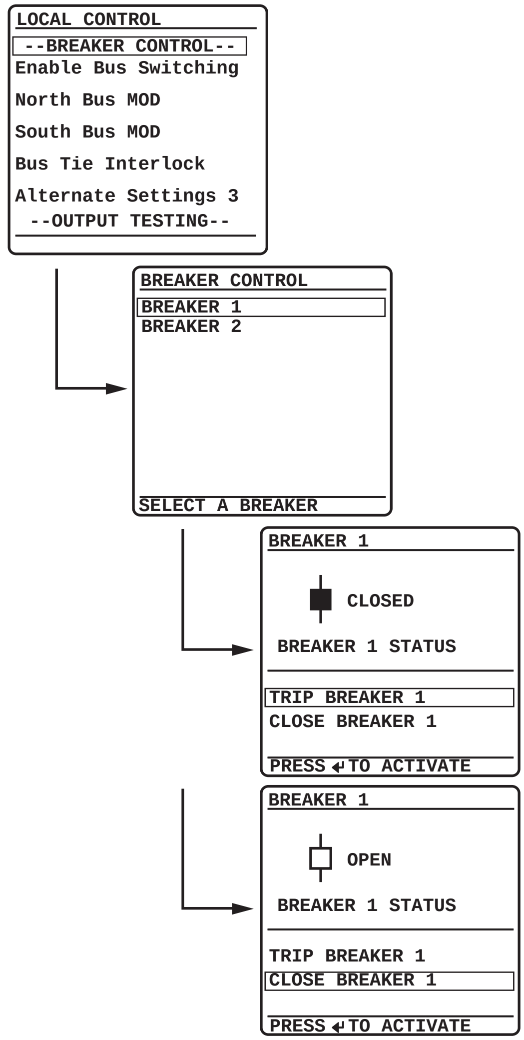


Figure 5.28 BREAKER CONTROL Screens

LOCAL CONTROL BITS

The relay provides 32 local control bits with SELOGIC control equation supervision. These local bits replace substation control handles to perform switching functions such as bus transfer switching. The SEL-421 saves the states of the local bits in nonvolatile memory and restores the local bit states at relay power-up.

NOTE: The default settings for LB_SPnn are "1". The default settings satisfy the local bit supervision logic so that local bit operations can take place.

Local control bit supervision is available through a SELOGIC control equation provided in the Front Panel settings (LB_SP*nn*). For local bit operations to take place, the corresponding LB_SP*nn* must be asserted. *Table 5.9* defines the local bit SELOGIC settings available in the Front Panel settings class. *Figure 5.30* illustrates the logic that supervises all local bit operations (Set, Clear, Pulse).

NOTE: The default settings for LB_DPnn are LBnn. The default settings cause the local bit switch to move to the corresponding state of the local bit (asserted = 1, deasserted = 0).

The SELOGIC control equation local bit status (LB_DP*nn*) is provided to return the status of a device that is being controlled by the local bit. The LB_DP*nn* Relay Word bit drives the state of the graphical switch on the display, i.e., with LB_DP*nn* deasserted, the switch points to 0.

Any unused local control bits default to the clear (logical 0) state. Also, any reconfigured local bit retains the existing bit state after you change the bit setting. Deleting a local bit sets that bit to the clear (logical 0) state.

In the top part of *Figure 5.29*, the custom labeled functions are those controlled by local control bit operation.

- Enable Bus Switching
- North Bus MOD
- South bus MOD
- Bus Tie Interlock
- Alternate Settings 3

In addition, *Figure 5.29* gives an example of a custom-labeled function, Bus Tie Interlock. The LCD shows a graphic representation of a substation control handle. The LB_DP*nn* SELOGIC control equation determines the state of the switch position on the LCD. If the LB_DP*nn* Relay Word bit is deasserted, the graphic control handle points to 0; if the LB_DP*nn* Relay Word bit is asserted, the switch points to 1.

You can program names or aliases for the local bit clear and set states; these appear next to logical 0 and logical 1, respectively, in the lower portion of the sample Bus Tie Interlock screens of *Figure 5.29*. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the set (1) or clear (0) control actions. Highlighting the set option (shown in *Figure 5.29* as `Closed (OK to TIE)`) and pressing **{ENT}** changes the local control bit and performs the required control action. If the LB_DP*nn* Relay Word bit asserts, the graphical switch moves to 1 to indicate the asserted local bit status.

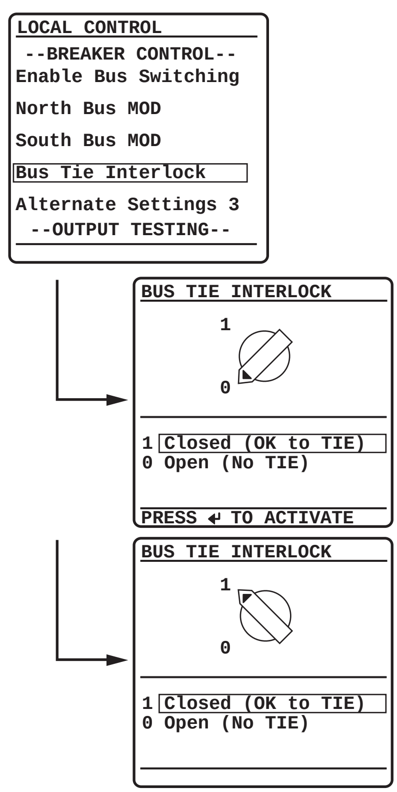


Figure 5.29 LOCAL CONTROL Example Menus

To enable a local bit, enter the local bit settings in *Table 5.8* (*n* = 1–32). The format for entering the local bit data is the comma-delimited string:

> *local bit,control function name,alias for the set state,alias for the clear state,pulse enable*

Names or aliases can contain any printable ASCII character except double quotation marks. Use double quotation marks to enclose the name or alias. See *Example 5.4* for particular information on enabling a local control bit.

Table 5.8 Local Bit Control Settings[a]

Description	Range	Default
Local Bit *n*	1–32	1
Local Bit *n* Name	20-character maximum ASCII string	(blank)
Local Bit *n* Set Alias (1 state)	20-character maximum ASCII string	(blank)
Local Bit *n* Clear Alias (0 state)	20-character maximum ASCII string	(blank)
Pulse Local Bit *n*	Y, N	N

[a] n = 1–32

The pulse state enable setting at the end of the setting string is optional. If your application requires a pulsed or momentary output, you can activate an output pulse by setting the option at the end of the local bit command string to `Y` (for Yes). The default for the pulse state is `N` (for No); if you do not specify `Y`, the local bit defaults at `N` and gives a continuous set or clear switch level.

If you enter an invalid setting, the relay displays an error message prompting you to correct your input. If you do not enter a valid local bit number, the relay displays `A local bit element must be entered`. If you enter a local bit number and that local bit is already in use, the relay displays `The local bit element is already in use`. Likewise, if you do not enter valid local bit name, set alias, and clear alias, the relay returns an error message. If an alias is too long, the relay displays `Too many characters`.

Table 5.9 Local Bit SELogic[a]

Description	Range	Default
Local Bit Supervision *n*	SELogic Equation, NA	1
Local Bit Status Display *n*	SELogic Equation, NA	LB*n*

[a] n = 1–32, only available if the corresponding local bit is defined.

Local Bit Supervision SELogic control equation provides supervision of Local Bit Set, Clear, and Pulse operations

Local Bit Status Display SELogic control equation returns the status of the local bit switch state.

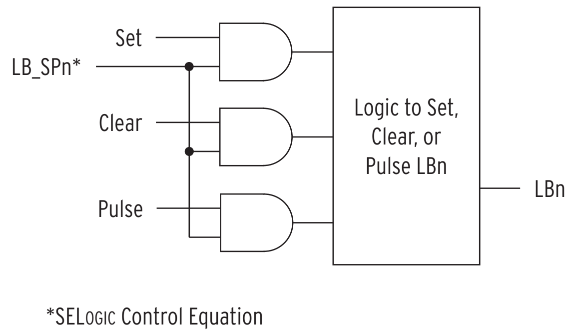


Figure 5.30 Local Bit Supervision Logic

EXAMPLE 5.4 Enabling Local Bit Control

This application example demonstrates a method to create one of the control points in the LOCAL CONTROL screens of Figure 5.29 to control the interlock on a power bus tie circuit breaker. Perform the following actions to create a local control bit:

- ➤ Eliminate previous usage of the local bit and condition the state of the local bit
- ➤ Set the local bit
- ➤ Assign the local bit to a relay output

If you are using a previously used local bit, delete all references to the local bit from the SELogic control equations already programmed in the relay. A good safety practice would be to disconnect any relay output that was programmed to that local bit.

To change the local bit state, select the bit and set it to the state you want. In addition, you can delete the local bit, which changes the state of this local bit to logical 0 when you save the settings. To delete, use the front-panel settings. When using a communications port and terminal, use the text-edit mode line setting editing commands at the Local Bits and Aliases prompt to go to the line that lists Local Bit 9. (See Text-Edit Mode Line Editing on page U.4.18 for information on text-edit mode line editing.) To delete Local Bit 9, type **DELETE <Enter>** after the line that displays Local Bit 9 information. For example, if a previously programmed Local Bit 9 appears in the **SET F** line numbered listings on Line 1, then typing **DELETE <Enter>** at Line 1 deletes Local Bit 9.

Next, set the local bit. In the Front Panel settings (**SET F**), enter the following:

1: **LB09,"Bus Tie Interlock","Closed (OK to TIE)","Open (No TIE)",N**

This sets Local Bit 9 to "Bus Tie Interlock" with the set state as "Closed (OK to TIE)" and the clear state as "Open (No TIE)."

Assign the local bit to a relay output. In the Output settings (**SET O**), set the SELogic control equation, OUT201, to respond to Local Bit 9.

OUT201 := **LB09**

Use the appropriate interface hardware to connect the circuit breaker interlock to OUT201.

OUTPUT TESTING

NOTE: The circuit breaker control enable jumper J18C must be installed to perform output testing (see Main Board Jumpers on page U.2.18).

You can check for proper operation of the SEL-421 control outputs by using the `OUTPUT TESTING` submenu of the `LOCAL CONTROL` menu. A menu screen similar to *Figure 5.31* displays a list of the control outputs available in your relay configuration. For more information on output testing, see *Control Output on page U.4.56*.

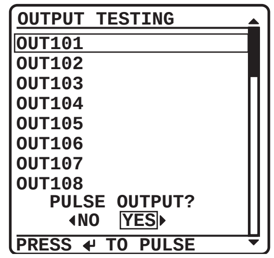


Figure 5.31 OUTPUT TESTING Screen

Set/Show

NOTE: You cannot use the front-panel SET/SHOW menus to change front-panel settings. To change front-panel settings, use a communications port interface and the **SET F** command or use the ACSELERATOR QuickSet Front Panel settings.

You can use the SET/SHOW menus to examine or modify SEL-421 port settings, global settings, active group settings, and date/time. From the front panel you can change only the settings classes and settings listed in *Table 5.10*.

Table 5.10 Settings Available From the Front Panel

Class/Setting	Description
PORT	Relay communications port settings
GLOBAL	Global relay settings
GROUP	Relay group settings
ACTIVE GROUP	Active settings group number 1–6
DATE/TIME	Date and time settings

Figure 5.32 shows how to enter the setting CTRW (Terminal W CT ratio) from the front panel. At the MAIN MENU, select the SET/SHOW item and press **{ENT}**. The LCD screen displays the SET/SHOW screen of *Figure 5.32*. Use the navigation pushbuttons to select the relay settings class (PORT, GROUP, and GLOBAL) or to change the ACTIVE GROUP or the DATE/TIME. Select the GROUP class.

Next, select the particular instance of the settings class. For the PORT settings class, the instances are PORT 1, PORT 2, PORT 3, PORT F, and PORT 5. For the GROUP class, the instances are the numbered groups from 1 through 6 and M, the breaker monitor (see the GROUP screen in *Figure 5.32*). The class GLOBAL, the setting ACTIVE GROUP = *n* (where n is a number from 1 to 6), and the settings for DATE/TIME have no settings instance screens. In the GROUP screen, move the highlight box to 3 and press **{ENT}**.

Proceed to selecting the settings category. The GROUP submenu in *Figure 5.32* is an example of settings Group 3 categories. Once you have highlighted the settings category, pressing **{ENT}** causes the relay to display the particular settings in that category. The LINE CONFIGURATION screen in *Figure 5.32* shows the settings that you can set in the line configuration settings category.

To edit or examine a setting, use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight that setting, then press **{ENT}**. The relay displays a settings entry screen with the existing setting value (see the SET CTRW screen in *Figure 5.32*). If the prompt for the selected setting does not fit on the line, the relay scrolls the setting prompt across the screen.

Enter the setting name using a method similar to the method described in *Relay Elements (Relay Word Bits) on page U.5.21*. Place characters in the element name field (with the block cursor) using the navigation pushbuttons.

If the data you entered is valid (within settings range checks), the front-panel display returns to the settings category screen that shows each setting and corresponding present value (see the LINE CONFIGURATION screen of

Figure 5.32). If the data you entered are invalid, the relay displays an error message screen, then returns to the particular settings entry screen so you can attempt a valid settings entry (see the `CTRW` screen of *Figure 5.32*).

When finished entering the new settings data, press **{ESC}**. The relay prompts you with a `Save Settings` screen. Using the navigation pushbuttons, answer `YES` to make the settings change(s), or `NO` to abort the settings change(s).

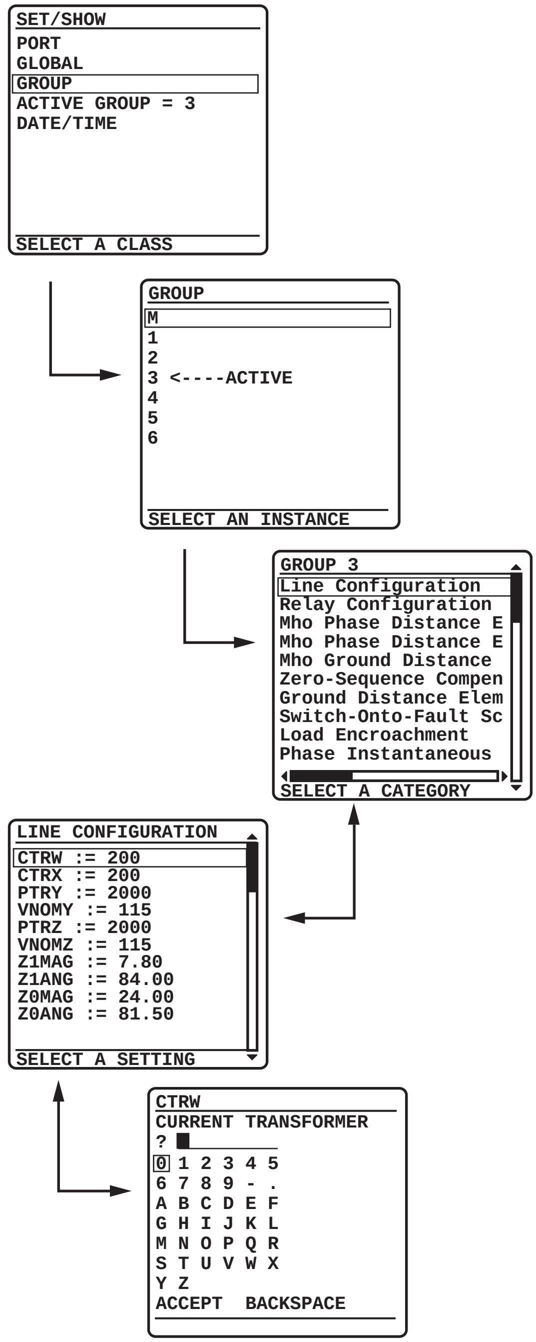


Figure 5.32 SET/SHOW Screens

The SEL-421 displays different settings entry screens depending on the settings type. For the CTRW setting in *Figure 5.32*, the relay requires basic alphanumeric input. Other settings can have other data input requirements. The front-panel settings input data types are the following:

- Basic alphanumeric
- Character or string or SELOGIC control equations
- Setting options

For alphanumeric settings, the relay presents the character or string input screen. Some settings have specific options; use the setting options screens to select these options. *Figure 5.33* shows examples of the settings input screens.

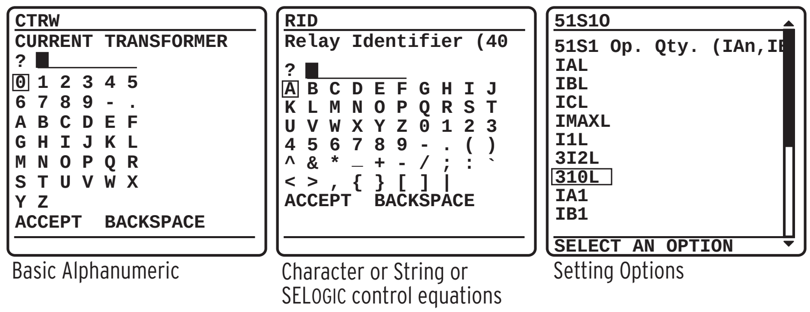


Figure 5.33 Sample Settings Input Screens

ACTIVE GROUP

Perform the following steps to change the active setting group:

Step 1. Select the ACTIVE GROUP option of the SET/SHOW submenu screen (shown in *Figure 5.32*) to change the settings group.

The relay performs a password validation test at this point to confirm that you have Breaker Access Level authorization or above.

Step 2. If access is allowed, and all the results of SELOGIC control equations SS1–SS6 are not logical 1 (asserted), then the relay displays the EDIT ACTIVE GROUP screen in *Figure 5.34*.

The relay shows the active group and underlines the group number after NEW GROUP =.

Step 3. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to increase or decrease the NEW GROUP number.

Step 4. Once you have selected the new active group, press **{ENT}** to change the relay settings to this new settings group.

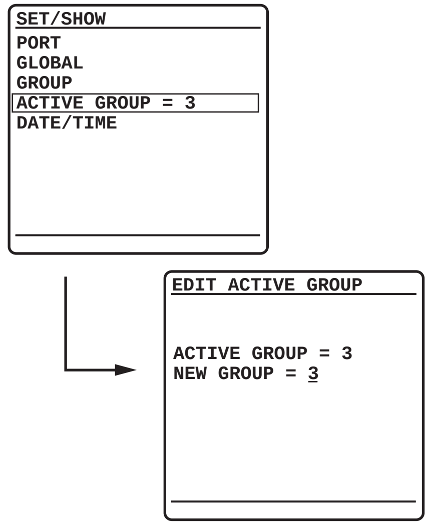


Figure 5.34 Changing the ACTIVE GROUP

DATE/TIME

Another submenu item of the SET/SHOW first screen (*Figure 5.32*) is the DATE/TIME screen shown in *Figure 5.35*. The SEL-421 generates date and time information internally, or you can use external high-accuracy time modes with time sources such as a GPS receiver.

Figure 5.35 is the relay date/time screen when a high accuracy source is in use. Possible time sources, qqqqq, are listed in *Table 4.10*. If you use a high-accuracy time source, edits are disabled, the DATE/TIME display does not show the highlight, and the screen does not show the help message on the bottom line.

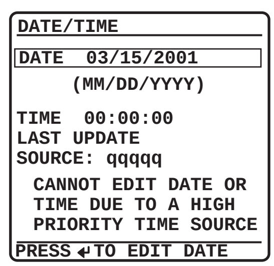


Figure 5.35 DATE/TIME Screen

When operating from a non-high-accuracy time source, you can use the front-panel DATE and TIME entry screens to set the date and time.

Figure 5.36 shows an example of these edit screens. Use the **{Left Arrow}** and **{Right Arrow}** navigation pushbuttons to move the underscore cursor; use the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to increment or decrement each date and time digit as appropriate to set the date and time. For a description of the LAST UPDATE SOURCE field, see *Configuring High-Accuracy Timekeeping on page U.4.71*.

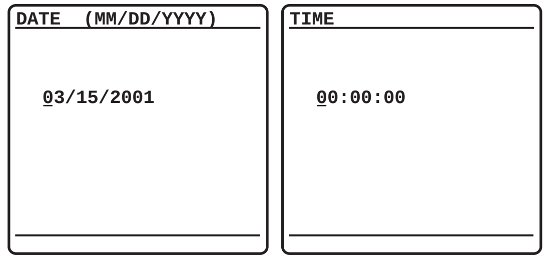


Figure 5.36 Edit DATE and Edit TIME Screens

To enable a high-accuracy external time source, connect an IRIG-B clock to the relay. For a discussion of the IRIG timing modes in the SEL-421 see *Configuring High-Accuracy Timekeeping on page U.4.71*. See *TIME Input Connections on page U.2.45* for more information on connecting time source inputs.

Relay Status

The SEL-421 performs continuous hardware and software self-checking. If any vital system in the relay approaches a failure condition, the relay issues a status warning. If the relay detects a failure, the relay displays the status failure RELAY STATUS screen immediately on the LCD.

For both warning and failure conditions, the relay shows the error message for the system or function that caused the warning or failure condition. You can access the RELAY STATUS screen via the MAIN MENU. The RELAY STATUS screen shows the firmware identification number (FID), serial number, whether the relay is enabled, and any status warnings.

Figure 5.37 shows examples of a normal RELAY STATUS screen, a status warning RELAY STATUS screen, and a status failure RELAY STATUS screen. For more information on status warning and status failure messages, see *Relay Self-Tests on page U.6.38*.

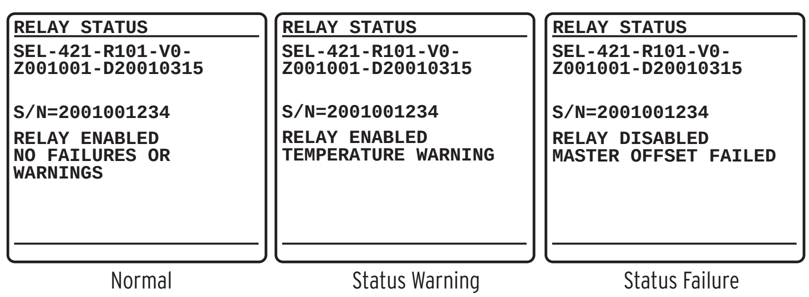


Figure 5.37 Relay STATUS Screens

View Configuration

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the SEL-421 Relay. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons. The relay presents five screens in the order shown in *Figure 5.38*. Use the navigation pushbuttons to scroll through these screens. When finished viewing these screens, press **{ESC}** to return to the MAIN MENU.

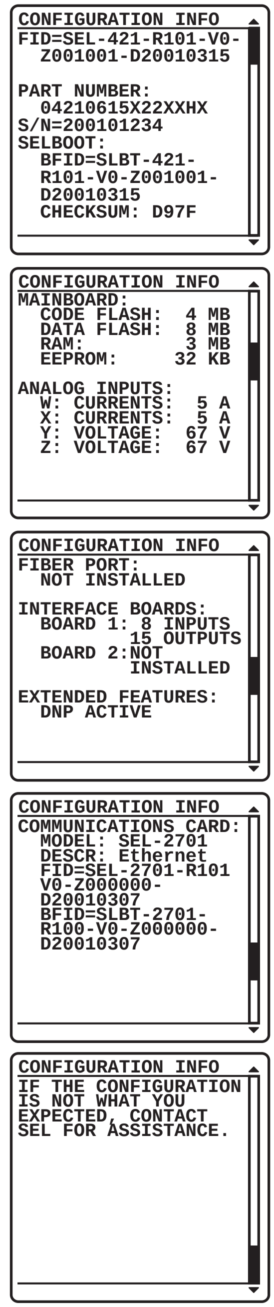


Figure 5.38 VIEW CONFIGURATION Sample Screens

Display Test

You can use the DISPLAY TEST option of the MAIN MENU to confirm operation of all of the LCD pixels. The LCD screen alternates the on/off state of the display pixels once every time you press **{ENT}**. *Figure 5.39* shows the resulting two screens. The DISPLAY TEST option also illuminates all of the front-panel LEDs. To exit the test mode, press **{ESC}**.

NOTE: The LCD DISPLAY TEST does NOT reset the front-panel LED targets.

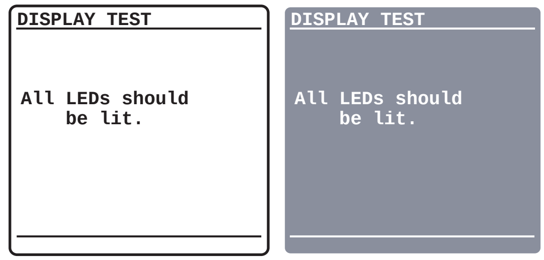


Figure 5.39 DISPLAY TEST Screens

Reset Access Level

The SEL-421 uses various passwords to control access to front-panel functions. As you progress through these menus, the relay detects the existing password level and prompts you for valid passwords before allowing you access to levels greater than Access Level 1 (see *Password on page U.5.14* in this section). When you want to return the front-panel to the lowest access level (Access Level 1), highlight RESET ACCESS LEVEL item on the MAIN MENU. Pressing **{ENT}** momentarily displays the screen of *Figure 5.40* and places the front panel at Access Level 1.

The relay automatically resets the access level to Access Level 1 upon front-panel timeout (setting FP_TO is not set to OFF). Use this feature to reduce the front-panel access level before the timeout occurs.

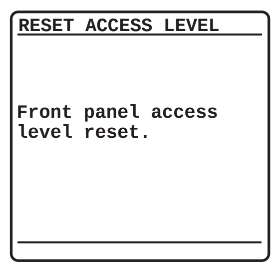


Figure 5.40 RESET ACCESS LEVEL Screen

Front-Panel Automatic Messages

The SEL-421 automatically displays alert messages. Any message generated due to an alert condition takes precedence over the normal ROTATING DISPLAY and the MAIN MENU. Alert conditions include these significant events:

- ➤ Alarm Point assertions
- ➤ Event reports and trips (user defined)
- ➤ Status warnings
- ➤ Status failures

In order to display event reports automatically from the ROTATING DISPLAY, you must set front-panel setting DISP_ER to Y. Front-panel setting TYPE_ER allows the user to define which types of event reports will be automatically displayed from the normal ROTATING DISPLAY; ALL will display all event types described in *Table 3.6 on page A.3.29* and TRIP will display only the event types that include the assertion of the TRIP Relay Word bit.

For alarm point assertions, qualified event reports (including trip events), and status warnings, the relay displays the corresponding full-screen automatic message, only if the front-panel display is in the time-out or standby condition (the relay is scrolling through the default display points/enabled metering screens of the ROTATING DISPLAY or is displaying the MAIN MENU). When a status warning, alarm, or event is triggered, the relay full-screen presentation is similar to the screens of *Figure 5.41*.

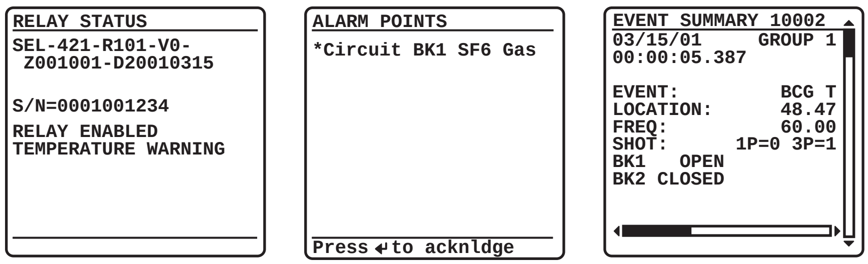


Figure 5.41 Sample Status Warning, Alarm Point Assertion, and Trip EVENT SUMMARY Screens

If you are on site using the SEL-421 front panel in menus and screens other than the MAIN MENU and a status warning occurs, alarm point asserts, or an event report triggers, the relay shows automatic messages at the bottom of the active screen in the message area.

For example, the message area shows RELAY STATUS WARNING for a status warning. *Figure 5.42* is an example of a status warning notification that appears in the message area of a LOCAL CONTROL (local bit) screen. If an alarm point asserts while you are using a front-panel screen, the message area notification reads: ALARM EVENT. If a trip event occurs while you are using a front-panel screen, the message area notification reads RELAY EVENT. When you repeatedly press **{ESC}** (as if returning to the MAIN MENU) during this warning or trip alert situation, the relay displays the corresponding full-screen automatic message concerning the warning or trip in place of the MAIN MENU. If the front-panel display is at the MAIN MENU and a status warning occurs, the full-screen warning replaces the MAIN MENU. After you view the warning, alarm, or trip screen, pressing **{ESC}** returns the LCD to the MAIN MENU.

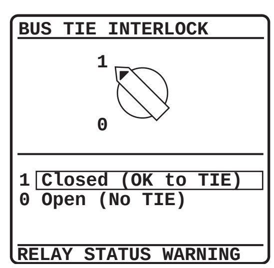


Figure 5.42 Sample Status Warning in the LCD Message Area

For a status failure, the relay immediately displays the full-screen status alert regardless of the present front-panel operating state. The relay displays no further LCD screens until the status failure clears. Should an unlikely status failure event occur, contact your local Technical Service Center or an SEL factory representative (see *Factory Assistance on page U.6.45*).

Operation and Target LEDs

The SEL-421 gives you at-a-glance confirmation of relay conditions via operation and target LEDs. These LEDs are located in the middle of the relay front panel. The SEL-421 provides either 16 or 24 LEDs depending on ordering option.

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect other operating conditions than the factory default programming described in this subsection. Settings T*n*_LED are SELOGIC control equations that, when asserted during a relay trip event, light the corresponding LED. Parameter *n* is a number from 1 through 24 that indicates each LED. LED positions are described in parenthesis next to each LED in *Figure 5.43*.

Program settings T*n*LEDL := Y to latch the LEDs during trip events; when you set T*n*LEDL := N, the trip latch supervision has no effect and the LED follows the state of the T*n*_LED SELOGIC control equation. The relay reports these targets in event reports; set the alias name listed in the report (up to eight characters) with settings T*n*LEDA. The asserted and deasserted colors for the LED are determined with settings T*n*LEDC. Options include red, green, amber, or off.

After setting the target LEDs, issue the **TAR R** command to reset the target LEDs. For a concise listing of the default programming on the front-panel LEDs, see *Front-Panel Settings on page R.10.37*.

Use the slide-in labels to mark the LEDs with custom names. Included on the SEL-421 Product Literature CD are Customer Label Templates to print labels for the slide-in label carrier.

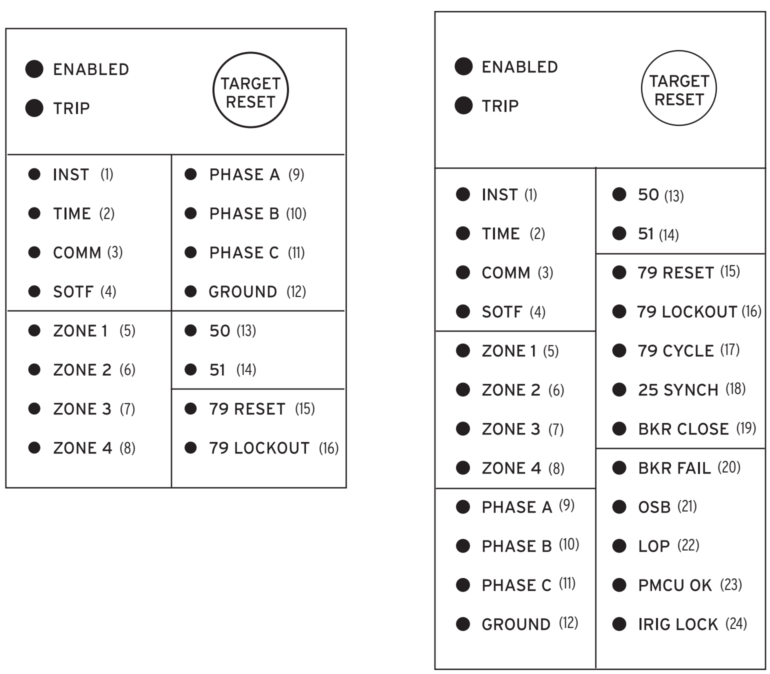


Figure 5.43 Factory Default Front-Panel Target Areas (16 or 24 LEDs)

Figure 5.43 shows the arrangement of the operation and target LEDs region into several areas as described in *Table 5.11*.

Table 5.11 Front-Panel Target LEDs

Label	Function
ENABLED, TRIP	Operational
INST, TIME, COMM, SOTF	Trip Type
ZONE 1, ZONE 2, ZONE 3, ZONE 4	Zone Activated
PHASE A, PHASE B, PHASE C, GROUND	Phase(s) or Ground
50, 51	Instantaneous and Time-Delayed Overcurrent
79 RESET, 79 LOCKOUT, 79 CYCLE[a]	Recloser Status
25 SYNCH[a], BKR CLOSE[a], BKR FAIL[a], OSB[a], LOP[a]	Miscellaneous Status
PMCU OK[a], IRIG LOCKED[a]	Synchrophasor Status

[a] Only available in 24 LED models..

Operational

The ENABLED LED indicates that the relay is active. Trip events illuminate the TRIP LED. The prominent location of the TRIP LED in the top target area helps you recognize a trip event quickly. Program settings EN_LEDc and TR_LEDc to determine the color of the respective LED. Options include red or green.

TARGET RESET and Lamp Test

For a trip event, the relay latches the trip-involved target LEDs (except for the ENABLED LED and the Recloser Status area LEDs). Press the {TARGET RESET} pushbutton to reset the latched target LEDs. When a new trip event occurs and you have not reset the previously latched trip targets, the relay clears the latched targets and displays the new trip targets.

Pressing the {TARGET RESET} pushbutton illuminates all the LEDs. Upon releasing 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.

Lamp Test Function With TARGET RESET

The {TARGET RESET} pushbutton also provides a front-panel lamp test. Pressing {TARGET RESET} illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as you press {TARGET RESET}. The target LEDs return to a normal operational state after you release the {TARGET RESET} pushbutton.

Lamp Test Function With LCD DISPLAY TEST Menu

The LCD menus provide a front-panel `DISPLAY TEST` mode. This menu-activated lamp test, from the `DISPLAY TEST` menu, does not reset the target LEDs (see *Display Test on page U.5.33*).

Other Target Reset Options

You can reset the target LEDs with the ASCII command **TAR R**; see *TARGET on page R.9.50* for more information.

The **TAR R** command and the {TARGET RESET} pushbutton also control the TRGTR Relay Word bit, which can be used for other functions, as shown in *Figure 1.81 on page R.1.125*. TRGTR is the factory default setting for the unlatch trip SELOGIC control equation, ULTR, in group settings. See *Table 1.72 on page R.1.108*.

You can reset the targets from the ACSELERATOR QuickSet **Control** branch of the HMI tree view. Programming specific conditions in the SELOGIC control equation RSTTRGT is another method to reset the relay targets. Access RSTTRGT in the relay **Global** settings (**Data Reset Control**); to use RSTTRGT, you must enable data reset control with global setting EDRSTC := Y.

Trip Type

The SEL-421 indicates essential information about the most recent relay trip event with the LEDs of the Trip Type area. These trip types are INST, TIME, COMM, and SOTF. For information on setting the corresponding trip logic, see *Trip Logic on page R.1.105*.

The INST target LED illuminates, indicating operation of the SEL-421 instantaneous elements. This LED lights if elements M1P (the Zone 1 mho phase distance element) or Z1G (the Zone 1 mho ground distance element) pick up and the relay has not illuminated the COMM or SOTF targets.

The TIME target LED indicates that a timed relay element caused a relay trip. *Table 5.12* lists the elements that activate the TIME LED in the factory default settings.

Table 5.12 TIME Target LED Trigger Elements—Factory Defaults

Mho	Quadrilateral
M2PT	Z2GT
M3PT	Z3GT
M4PT	Z4GT
M5PT	Z5GT

The COMM LED illuminates, indicating that tripping resulted from a communications-assisted trip. The relay lights the COMM target when there is a relay tripping condition and the Relay Word bit COMPRM (communications-assisted trip permission) asserts.

The SOTF target LED indicates that the switch-onto-fault protection logic operated. The relay illuminates the SOTF target when there is a relay tripping condition and the Relay Word bit SOTFT (switch-onto-fault trip) asserts.

Zone Activated

The zone activated area target indicators are the ZONE 1, ZONE 2, ZONE 3, and ZONE 4 LEDs. These targets illuminate when the corresponding zone distance elements pick up and there is a relay tripping condition.

In factory default programming, the lowest zone LED has priority; only the LED corresponding to the closest protection zone latches for distance element pickups.

The ZONE 1 target illuminates if either the M1P or Z1G distance elements operated or if the high-speed Zone 1 elements operated.

The ZONE 2 target illuminates if either the M2P or Z2G distance elements operated or if the high-speed Zone 2 elements operated and the similar elements in Zone 1 did not operate.

The **ZONE 3** target illuminates if either the M3P or Z3G distance elements operated or if the high-speed Zone 3 elements operated and the similar elements in Zone 1 and Zone 2 did not operate.

The **ZONE 4** target illuminates if either the M4P or Z4G distance elements operated and the similar elements in Zone 1, Zone 2, and Zone 3 did not operate.

Phase(s) or Ground

The phase(s) or ground targets illuminate according to the SEL-421 special targeting logic. This logic accurately classifies which phase, phases, and/or ground were involved in a trip event.

The PHASE A target LED lights for faults on the power system A-phase. Single-phase-to-ground faults from A-phase to ground illuminate both the **PHASE A** and **GROUND** targets. A phase-to-phase fault between A-phase and B-phase illuminates the **PHASE A** target and the **PHASE B** target.

The relay displays faults involving other phase combinations similarly. If the phase-to-phase fault includes ground, the relay also lights the **GROUND** target. The relay lights the **PHASE A**, **PHASE B**, and **PHASE C** target LEDS for a three-phase fault.

Instantaneous and Time-Delayed Overcurrent

The **50** target LED indicates that an instantaneous overcurrent element picked up. These elements are the nondirectional 50Pn phase overcurrent elements, 50Qn negative-sequence overcurrent elements, and the 50Gn ground overcurrent elements, where *n* is the overcurrent level; $n = 1, 2, 3$, and 4.

The **51** target LED illuminates if a time-overcurrent element has timed out. The relay lights this LED if any of the selectable operating quantity inverse-time overcurrent elements 51S1T, 51S2T, and 51S3T assert.

Recloser Status

The **79 RESET**, **79 LOCKOUT**, and **79 CYCLE** target LEDs show the operating status of the SEL-421 reclosing function.

The **79 RESET** LED indicates that the relay recloser is in the reset or ready-to-reclose state for Circuit Breaker 1 (Relay Word bit BK1RS is asserted).

The **79 LOCKOUT** target illuminates when the relay has completed the reclose attempts unsuccessfully (a drive-to-lockout condition), or when other programmed lockout conditions exist.

The **79 CYCLE** target illuminates when the relay the relay is in the auto-reclose cycle state for Circuit Breaker 1.

Miscellaneous Status

The **25 SYNCH**, **BKR CLOSE**, **BKR FAIL**, **OSB**, and **LOP** target LEDs illuminate in the SEL-421 for miscellaneous status conditions.

The **25 SYNCH** LED illuminates when the relay detects that the Circuit Breaker 1 voltages are within Synchronism Angle 1 (Relay Word bit 25A1BK1 is asserted). See *Synchronism Check on page R.2.50* for complete details.

The **BKR CLOSE** LED illuminates when the relay detects a breaker close command for Circuit Breaker 1 (Relay Word bit BK1CL is asserted).

The **BKR FAIL** LED illuminates when the relay detects a breaker failure trip for Circuit Breaker 1 (Relay Word bit BFTRIP1 is asserted). See *Circuit Breaker Failure Trip Logic on page R.1.121* for complete details.

The OSB LED illuminates when the relay detects an out-of-step condition (Relay Word bit OSB is asserted). See *Out-of-Step Logic on page R.1.43* for complete details.

The LOP LED illuminates when the relay detects a loss-of-potential condition (Relay Word bit LOP is asserted). See *Loss-of-Potential Logic on page R.1.23* for complete details.

Synchrophasor Status

The PMCU OK target LED illuminates when the relay is enabled for synchrophasor measurement (Relay Word bits TSOK and PMDOK are asserted). See *Synchrophasor Relay Word Bits on page R.7.19* for complete details.

The IRIG LOCKED target LED illuminates when the relay detects synchronization to an external clock with less than 500 ns of jitter (Relay Word bit TIRIG is asserted). See *IRIG-B on page U.4.71* for complete details.

Front-Panel Operator Control Pushbuttons

The SEL-421 front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 5.44* shows this region of the relay front panel with factory default configurable front-panel label text. The SEL-421 provides either 8 or 12 pushbuttons depending on ordering option.

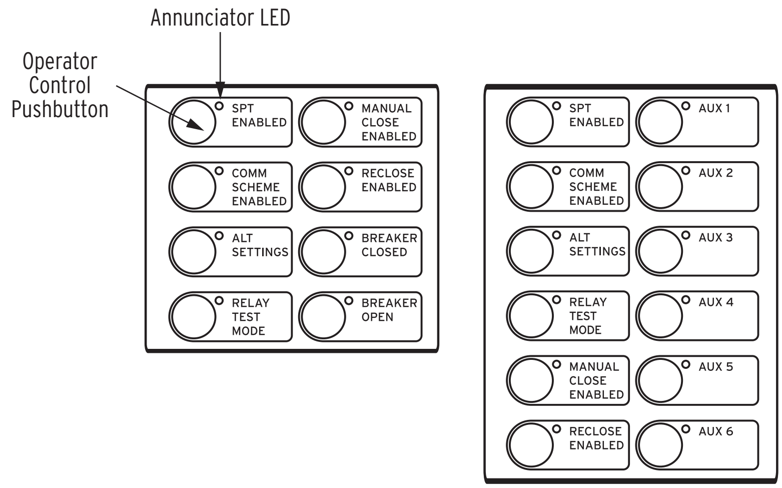


Figure 5.44 Operator Control Pushbuttons and LEDs (8 or 12 Pushbuttons)

Factory default programming associates specific relay functions with the eight pushbuttons and LEDs, as listed in *Table 5.13*. For a concise listing of the default programming for the front-panel pushbuttons and LEDs, see *Front-Panel Settings on page R.10.37*.

Table 5.13 Operator Control Pushbuttons and LEDs—Factory Defaults

Label	Function
SPT ENABLED	Enable single-pole tripping
COMM SCHEME ENABLED	Enable communications scheme
ALT SETTINGS	Switch between setting group 1 and setting group 2[a]. The LED is illuminated when group 1 is not the active setting group.
RELAY TEST MODE	Enter test mode
MANUAL CLOSE ENABLED	Enable manual closing
RECLOSE ENABLED	Enable automatic reclosing
AUX n[b]	Auxiliary
BREAKER CLOSED[c]	Close Circuit Breaker 1
BREAKER OPEN[c]	Open Circuit Breaker 1

[a] With factory settings, the {ALT SETTINGS} pushbutton must be pressed and held for three seconds before the SEL-421 will change setting groups.
[b] Available on 12-pushbutton models; n is the number of AUX buttons available depending on ordering option.
[c] Not available on model with auxiliary {TRIP/CLOSE} pushbuttons.

Press the operator control pushbuttons momentarily to toggle on and off the functions listed adjacent to each LED/pushbutton combination. The **CLOSE** and **TRIP** pushbuttons momentarily assert the close and trip relay outputs after a short delay.

The operator control pushbuttons and LEDs are programmable. *Figure 5.45* describes the factory defaults for the operator controls.

There are two ways to program the operator control pushbuttons. The first is through front-panel settings PB*n*_HMI. These settings allow any of the operator control pushbuttons to be programmed to display a particular HMI screen category. The HMI screen categories available are Alarm Points, Display Points, and Event Summaries, and SER. Front-panel setting NUM_ER allows the user to define the number of event summaries that are displayed via the operator control pushbutton; it has no effect on the event summaries automatically displayed or the event summaries available through the main menu. Each HMI screen category can be assigned to a single pushbutton. Attempting to program more than one pushbutton to a single HMI screen category will result in an error. After assigning a pushbutton to an HMI screen category, pressing the pushbutton will jump to the first available HMI screen in that particular category. If more than one screen is available, a navigation scroll bar will be displayed. Pressing the navigation arrows will scroll through the available screens. Subsequent pressing of the operator control pushbutton will advance through the available screens, behaving the same as the **{Right Arrow}** or the **{Down Arrow}** pushbutton. Pressing the **{ESC}** pushbutton will return the user to the ROTATING DISPLAY. The second way to program the operator control pushbutton is through SELOGIC control equations, using the pushbutton output as a programming element.

Using SELOGIC control equations, you can readily change the default LED functions. Use the slide-in labels to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. The labels are keyed; you can insert each Operator Control Label in only one position on the front of the relay. Included on the SEL-421 Relay 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.

The SEL-421 has two types of outputs for each of the front-panel pushbuttons. Relay Word bits represent the pushbutton presses. One set of Relay Word bits follows the pushbutton and another set pulses for one processing interval when the button is pressed. Relay Word bits PB1 through PB12 are the “follow” outputs of operator control pushbuttons. Relay Word bits PB1_PUL through PB12PUL are the pulsed outputs.

Annunciator LEDs for each operator control pushbutton are PB1_LED through PB12LED. The factory defaults programmed for these LEDs are protection latches (PLT01, for example), settings groups, Relay Word bits (NOT SG1), and the status of the circuit breaker auxiliary contacts (52AA1). The asserted and deasserted colors for the LED are determined with settings PB*n*COL. Options include red, green, amber, or off.

You can change the LED indications to fit your specific control and operational requirements. This programmability allows great flexibility and provides operator confidence and safety, especially in indicating the status of functions that are controlled both locally and remotely.

SELOGIC Factory Setting	Operator Control Pushbutton / LED	Description
PBn_LED = NOT E3PT #SPT ENABLED	SPT ENABLED	Press this operator control pushbutton to enable/disable single-pole tripping. The corresponding LED illuminates to indicate the SPT ENABLED state.
PBn_LED = PLT02 #COMM SCHEME ENABLED	COMM SCHEME ENABLED	Press this operator control pushbutton to enable/disable communications-assisted tripping. The corresponding LED illuminates to indicate the COMM SCHEME ENABLED state.
PBn_LED = NOT SG1 #ALT SETTINGS	ALT SETTINGS	Press this operator control pushbutton for three seconds to switch the active setting group between the main setting group (Setting Group 1) and the alternate setting group (Setting Group 2). The corresponding LED illuminates to indicate the ALT SETTINGS state.
PBn_LED = PLT04 #RELAY TEST MODE	RELAY TEST MODE	Press this operator control pushbutton to enable/disable the relay test mode. The corresponding LED illuminates to indicate the RELAY TEST MODE state.
PBn_LED = PLT05 #MANUAL CLOSE ENABLED	MANUAL CLOSE ENABLED	Press this operator control pushbutton to enable/disable local front-panel circuit breaker closing using the CLOSE pushbutton. The corresponding LED illuminates to indicate the MANUAL CLOSE ENABLED state.
PBn_LED = PLT06 #RECLOSE ENABLED	RECLOSE ENABLED	Press this operator control pushbutton to enable/disable the automatic recloser. The corresponding LED illuminates to indicate the RECLOSE ENABLED state.
PBn_LED = 0 #AUX	AUX	Press this operator control pushbutton to enable/disable user-programmed auxiliary control. Program the corresponding LED to indicate the required state. NOTE: This operator control does not perform any function with the factory settings.
PBn_LED = 52ACL1 and 52BCL1 and 52CCL1 #BREAKER CLOSED	BREAKER CLOSED	Press this operator control pushbutton to close Circuit Breaker 1. The corresponding BREAKER CLOSED LED illuminates indicating that Circuit Breaker 1 is closed. The MANUAL CLOSE ENABLED function above enables and disables the CLOSE pushbutton.
PBn_LED = NOT 52ACL1 and 52BCL1 and 52CCL1 #BREAKER OPEN	BREAKER OPEN	Press this operator control pushbutton to trip Circuit Breaker 1. The corresponding BREAKER OPEN LED illuminates, indicating that Circuit Breaker 1 is open.

Figure 5.45 Factory Default Operator Control Pushbuttons

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Section 6
Testing and Troubleshooting

This section contains guidelines for determining and establishing test routines for the SEL-421 Relay. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. The relay incorporates self-tests to help you diagnose potential difficulties should these occur. The subsection *Relay Troubleshooting on page U.6.42* contains a quick-reference table for common relay operation problems.

Topics, tests, and troubleshooting procedures presented in this section include the following:

The SEL-421 is factory calibrated; this section contains no calibration information. If you suspect that the relay is out of calibration, contact your Technical Service Center or the SEL factory.

Testing Philosophy

Protective relay testing generally consists of three categories: acceptance testing, commissioning testing, and maintenance testing. The categories differ in testing complexity and according to when these activities take place in the life of the relay.

Each testing category includes particular details as to when to perform the test, the testing goals at that time, and the relay functions that you need to test. This information is a guide to testing the SEL-421; be sure to follow the practices of your company for relay testing.

Acceptance Testing

SEL performs detailed acceptance testing on all new relay models and versions. We are certain that your SEL-421 meets published specifications. Even so, you can perform acceptance testing on a new relay model to become familiar with the relay operating theory and settings; this familiarity helps you apply the relay accurately and correctly. A summary of acceptance testing guidelines is presented in *Table 6.1*.

Table 6.1 Acceptance Testing

Details	Description
Time	Test when qualifying a relay model for use on the utility system.
Goals	a) Confirm that the relay meets published critical performance specifications such as operating speed and element accuracy.
	b) Confirm that the relay meets the requirements of the intended application.
	c) Gain familiarity with relay settings and capabilities.
Test	Test all protection elements and logic functions critical to your intended application.

Commissioning Testing

SEL performs a complete functional check and calibration of each SEL-421 before shipment so that your relay operates correctly and accurately. You should perform commissioning tests to verify proper connection of the relay to the power system and all auxiliary equipment. Check control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection test to verify that the relay current and voltage inputs are the proper magnitude and phase rotation.

Brief fault tests confirm that the relay settings and protection scheme logic are correct. You do not need to test every relay element, timer, and function in these tests.

At commissioning, use the relay **METER** command to verify the ac current and voltage magnitude and phase rotation (see *Examining Metering Quantities on page U.4.33*).

Use the **PUL** command to pulse relay control output operation. Use the **TAR** command to view relay targets and verify that control inputs are operational. Use **TEST FM**, **TEST DNP**, and **TEST DB** to check SCADA interfaces. (See *TEST DB on page R.9.52* for information on these relay commands.)

Table 6.2 lists guidelines for commissioning testing. For further discussion of these tests, see *Checking Relay Operation on page U.6.24*.

Table 6.2 Commissioning Testing

Details	Description
Time	Test when installing a new protection system.
Goals	a) Validate all system ac and dc connections.
	b) Confirm that the relay functions as intended using your settings.
	c) Check that all auxiliary equipment operates as intended.
	d) Check SCADA interface.
Tests	Test all connected/monitored inputs and outputs, and the polarity and phase rotation of ac connections. Make simple checks of protection elements. Test communications interfaces.

Maintenance Testing

The SEL-421 uses extensive self-testing routines and features detailed metering and event reporting functions. These features reduce your dependence on routine maintenance testing. When you want to perform maintenance testing, follow the recommendations in *Table 6.3*.

Table 6.3 Maintenance Testing

Details	Description
Time	Test at scheduled intervals or when there is an indication of a problem with the relay or power system.
Goals	a) Confirm that the relay is measuring ac quantities accurately.
	b) Check that scheme logic and protection elements function correctly.
	c) Verify that auxiliary equipment functions correctly.
Tests	Test all relay features/power system components that did not operate during an actual fault within the past maintenance interval.

You can use the SEL-421 reporting features as maintenance tools. Periodically compare the relay **METER** command output to other meter readings on a line to verify that the relay measures currents and voltages correctly and accurately. Use the circuit breaker monitor, for example, to detect slow breaker auxiliary contact operations and increasing or varying breaker pole operating times. For details on these features, see *Circuit Breaker Monitor on page A.2.1*.

Each occurrence of a fault tests the protection system and relay application. Review relay event reports in detail after each fault to determine the areas needing your attention. Use the event report current, voltage, and relay element data to determine that the relay protection elements and communications channels operate properly. Inspect event report input and output data to determine whether the relay asserts outputs at the correct times and whether auxiliary equipment operates properly.

At each maintenance interval, the only items to be tested are those that have not operated (via fault conditions and otherwise) during the maintenance interval. The basis for this testing philosophy is simple: you do not need to perform further maintenance testing for a correctly set and connected relay that measures the power system properly and for which no relay self-test has failed.

The SEL-421 is based on microprocessor technology; the relay internal processing characteristics do not change over time. For example, if time-overcurrent element operating times change, these changes occur because of alterations to relay settings and/or differences in the signals applied to the relay. You do not need to verify relay element operating characteristics as a part of maintenance checks.

SEL recommends that you limit maintenance tests on SEL relays according to the guidelines listed in *Table 6.3*. You will spend less time checking relay operations that function correctly. You can use the time you save to analyze event data and thoroughly test systems needing more attention.

Testing Features and Tools

The SEL-421 provides the following features to assist you during relay testing:

- Metering
- High-resolution oscillography
- Event reports
- Event summary reports
- SER (Sequential Events Recorder) reports

Certain relay commands are useful in confirming relay operation. The following commands, for example, aid you in testing the relay:

- **TAR**
- **PUL**
- **TEST DB**
- **TEST FM**
- **TEST DNP**

In addition, the SEL-421 incorporates a low-level test interface where you can interrupt the connection between the relay input transformers and the input processing module. Use the low-level test interface to apply reduced-scale test quantities from the SEL-4000 Relay Test System; you do not need to use large power amplifiers to perform relay testing.

Test Features

Metering

The metering data show the ac currents and voltages (magnitude and phase angle) connected to the relay in primary values. In addition, metering shows many other quantities including the power system frequency (FREQ) and the voltage input to the station dc battery monitors (Vdc1 and Vdc2). Compare these quantities against quantities from other devices of known accuracy. The metering data are available at the serial ports, from the ACSELERATOR QuickSet® SEL-5030 software HMI, and at the front-panel LCD METER menu. See *MET on page R.9.28*, *Meter on page U.5.15*, *HMI Meter and Control on page U.3.21*, and *Examining Metering Quantities on page U.4.33* for more information.

High-Resolution Oscillography

NOTE: Control Inputs are sampled 16 times per cycle, and the raw binary data (prior to debounce timer conditioning) is available in high-resolution oscillography—see Figure 3.1 on page A.3.3. The COMTRADE data labels for raw control input data are IN101–IN107, and optionally IN201–IN2nn, IN301–IN3nn, where nn = 01–08 or 01–24.

The SEL-421 takes an unfiltered data snapshot of the power system at each event trigger or trip. The relay samples power system data at high sample rates from 1 kHz to 8 kHz. You can use the SEL-5601 Analytic Assistant or other COMTRADE viewing program to export and view these raw data in a binary COMTRADE file format. Use high-resolution oscillography to capture fast power system transients or to examine low frequency anomalies in the power system. See *Raw Data Oscillography on page A.3.8* for more information.

Event Reports

NOTE: Control Inputs are sampled 16 times per cycle, and then conditioned by a debounce timer. The resulting Relay Word bits are updated 8 times per cycle and are available in standard event report files—see Figure 3.1 on page A.3.3.

The relay also generates a filtered-quantities event report in response to faults or disturbances. Each event report contains information on current and voltage, relay element states, control inputs, and control outputs. If you are unsure of the relay response or your test method, the event report provides you with information on the operating quantities that the relay used at the event trigger. The relay provides oscillographic displays of the filtered event report data, which give you a visual tool for testing relay operating quantities. You can use the serial ports and ACSELERATOR QuickSet to view event reports. See *Event Reports, Event Summaries, and Event Histories on page A.3.11* for a complete discussion of event reports.

Event Summary Reports

The relay generates an event summary for each event report; use these event summaries to quickly verify proper relay operation. With event summaries, you can quickly compare the reported fault current and voltage magnitudes and angles against the reported fault location and fault type. If you question the relay response or your test method, you can obtain the full event report and the high-resolution oscillographic report for a more detailed analysis. See *Event Summary on page A.3.28* for more information on the event summary.

SER Reports

The relay provides an SER report that time tags changes in relay elements, control inputs, and control outputs. Use the SER for convenient verification of the pickup and dropout of any relay element. For a complete discussion of the SER, see *SER (Sequential Events Recorder) on page A.3.34*.

Test Commands

TAR Command

Use the **TAR** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. You can see relay targets at the serial ports, and from the front-panel LCD (see *TARGET on page R.9.50* and *Operation and Target LEDs on page U.5.36*).

PUL Command

Use the **PUL** command to test the control output circuits. The specified output closes if open, or opens if closed. You can use the **PUL** command at the serial ports, in the ACSELERATOR QuickSet HMI, and from the front-panel LCD (see *PULSE on page R.9.37*, *HMI Meter and Control on page U.3.21*, and *Operation and Target LEDs on page U.5.36*).

TEST DB Command

Use the **TEST DB** command for testing the communications card relay database. The **TEST DB** command can be used to override any value in the relay database. Since the relay database provides data to the Ethernet card interfaces, the **TEST DB** command can also be used to test the data read operations of the DNP3 LAN/ WAN or IEC 61850 protocols on an installed Ethernet card. Use the **MAP 1** command and the **VIEW1** command to inspect the relay database (see *MAP on page R.9.27*). You must be familiar with the relay database structure to use the **TEST DB** command effectively; see *Communications Card Database on page R.4.18* for more information.

TEST DNP Command

Use the **TEST DNP** command to test the serial DNP3 interface. Values you enter in the DNP3 map are override values. Use the **TEST DNP** command to write override values in the serial DNP3 map. The **TEST DNP** command does not affect data on the DNP3 LAN/WAN interface. For more information on serial DNP3 and the SEL-421, see *DNP3 Communications on page R.6.1*.

TEST FM Command

Use the **TEST FM** command to override normal Fast Meter quantities for testing purposes. You can only override “reported” Fast Meter values (per-phase voltages and currents). You cannot directly test Fast Meter values that the relay derives from the reported values (power, sequence components, and so on). For more information on Fast Meter and the SEL-421, see *SEL Communications Protocols on page R.5.1*.

Low-Level Test Interface

The SEL-421 has a low-level test interface between the calibrated input module and the processing module. You can check the relay in two ways: by using secondary injection testing, or by applying low-magnitude ac voltage signals to the low-level test interface.

Connection

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can reuslt 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 top circuit board is the relay main board and the bottom circuit board is the input module board. At the right side of the relay main board (the top board) is the processing module. The input to the processing module is multipin connector J20, the analog or low-level test interface connection. Receptacle J20 is on the right side of the main board; for a locating diagram, see *Figure 2.19*.

Figure 6.1 shows the low-level interface connections. Note the nominal voltage levels, current levels, and scaling factors listed in *Figure 6.1* that you can apply to the relay. Never apply voltage signals greater than 6.6 Vp-p sinusoidal signal (2.33 Vrms) to the low-level test interface.

To use the low-level test interface, perform the following steps:

Step 1. Remove any cables connected to serial ports on the front panel.

Step 2. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 3. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

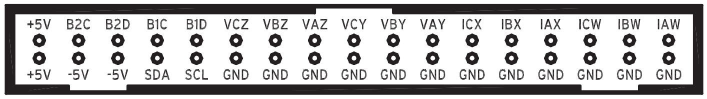
Step 4. Remove the ribbon cable from the main board J20 receptacle.

Step 5. Substitute a test cable with the signals specified in *Figure 6.1*.

Step 6. Reconnect the cables removed in *Step 4* and replace the relay front-panel cover.

Step 7. Replace any cables previously connected to serial ports on the front panel.

SEL-421 Relay
Low-Level Test Interface



Input Module Output (J3): 66.6 mV At Nominal Current (1 A or 5 A).
446 mV at Nominal Voltage (67 V_{LN}).

Processing Module Input (J20): 6.6 Vp-p Maximum.

U.S. Patent 5,479,315.

Figure 6.1 Low-Level Test Interface

Main Board Processing Module Tests

Use signals from the SEL-4000 Low-Level Relay Test System to test the relay processing module. Apply appropriate signals to the low-level test interface J20 from the SEL-4000 Relay Test System (see *Figure 6.1*). These signals simulate power system conditions, taking into account PT ratio and CT ratio scaling. Use relay metering to determine whether the applied test voltages and currents produce correct relay operating quantities.

The UUT Database entries for the SEL-421 in the SEL-5401 Relay Test System Software are shown in *Table 6.4* and *Table 6.5*.

Table 6.4 UUT Database Entries for SEL-5401 Relay Test System Software—5 A Relay

	Label	Scale Factor	Unit
1	IAW	75	A
2	IBW	75	A
3	ICW	75	A
4	IAX	75	A
5	IBX	75	A
6	ICX	75	A
7	VAY	150	V
8	VBY	150	V
9	VCY	150	V
10	VAZ	150	V
11	VBZ	150	V
12	VCZ	150	V

Table 6.5 UUT Database Entries for SEL-5401 Relay Test System Software—1 A Relay

	Label	Scale Factor	Unit
1	IAW	15	A
2	IBW	15	A
3	ICW	15	A
4	IAX	15	A
5	IBX	15	A
6	ICX	15	A
7	VAY	150	V
8	VBY	150	V
9	VCY	150	V
10	VAZ	150	V
11	VBZ	150	V
12	VCZ	150	V

Relay Test Connections

NOTE: The procedures specified in this subsection are for initial relay testing only. Follow your company policy for connecting the relay to the power system.

The SEL-421 is a flexible tool that you can use to implement many protection and control schemes. Although you can connect the relay to the power system in many ways, connecting basic bench test sources helps you model and understand more complex relay field connection schemes.

Test Setup

Test Source Connections

For each relay element test, you must apply ac voltage and current signals to the relay. The text and figures in this subsection describe the test source connections you need for relay protection element checks. You can use these connections to test protective elements and simulate all fault types.

Connections for Three Voltage Sources and Three Current Sources

Figure 6.2 shows the connections to use when you have three voltage sources and three current sources available.

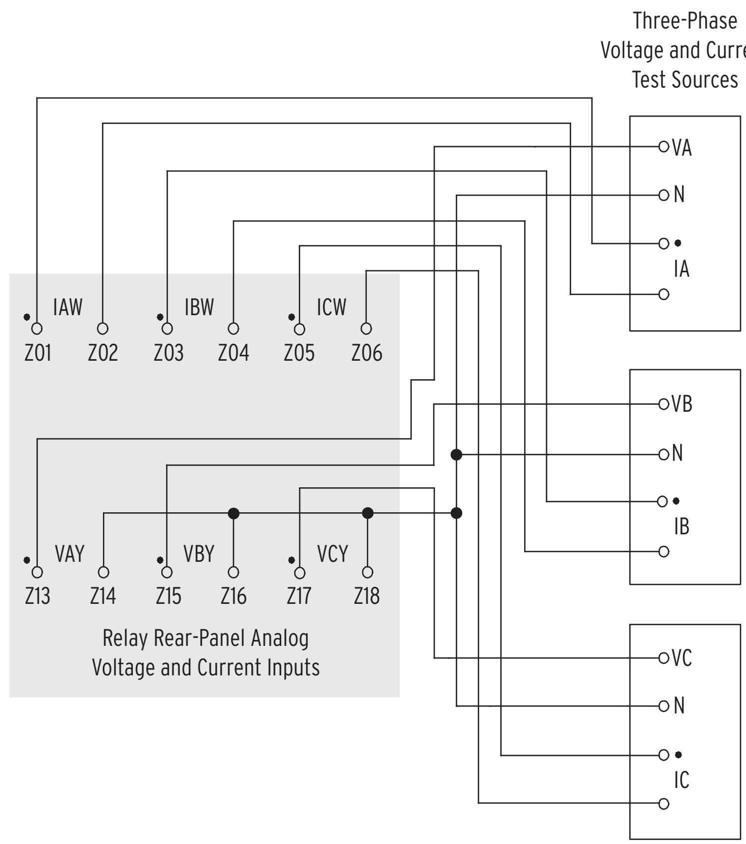


Figure 6.2 Test Connections Using Three Voltage and Three Current Sources

Connections for Three Voltage Sources and Two Current Sources

Figure 6.3 and *Figure 6.4* show connections to use when you have three voltage sources and two current sources. You can use the connections shown in *Figure 6.3* to simulate phase-to-phase, phase-to-ground, and two-phase-to-ground faults. Use the connections shown in *Figure 6.4* to simulate three-phase faults.

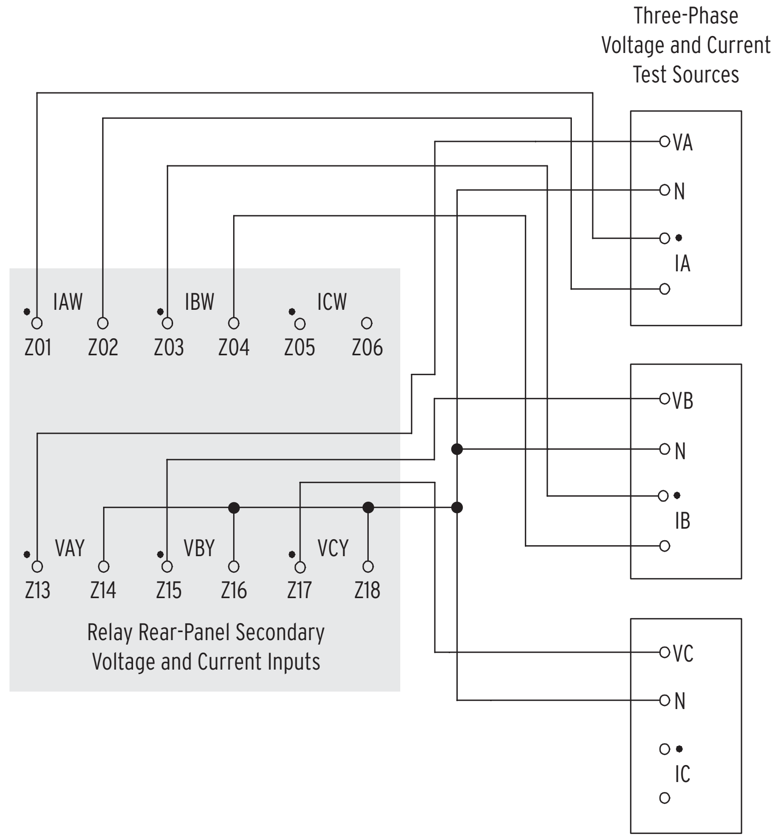


Figure 6.3 Test Connections Using Two Current Sources for Phase-to-Phase, Phase-to-Ground, and Two-Phase-to-Ground Faults

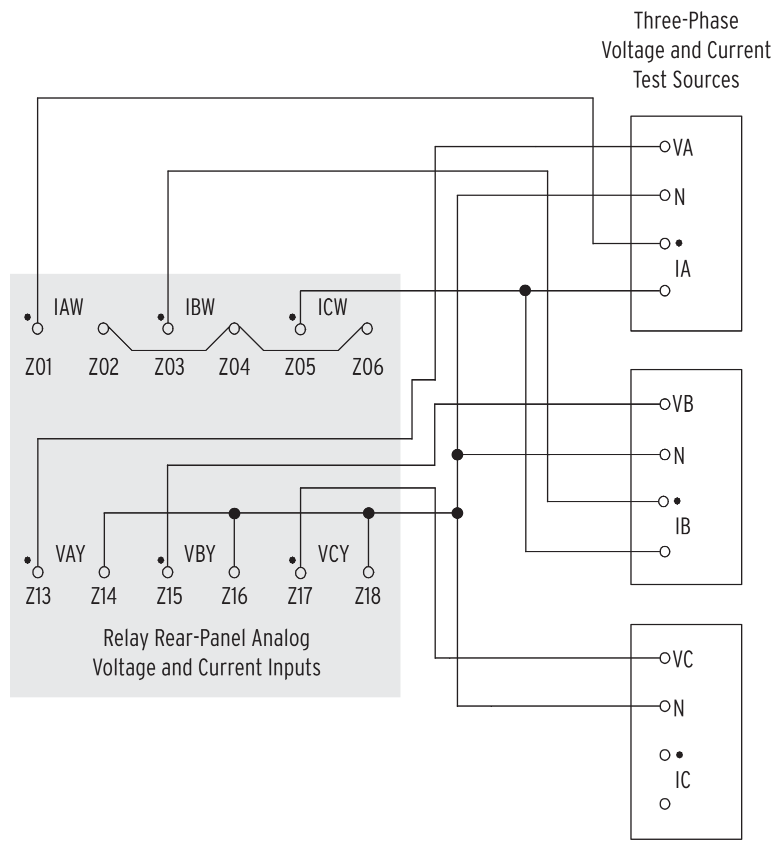


Figure 6.4 Test Connections Using Two Current Sources for Three-Phase Faults

Connections for Three Voltage Sources and One Current Source

Figure 6.5 and *Figure 6.6* show connections to use when you have three voltage sources and a single current source. You can use the connections shown in *Figure 6.5* to simulate phase-to-ground faults. Use the connections shown in *Figure 6.6* to simulate phase-to-phase faults.

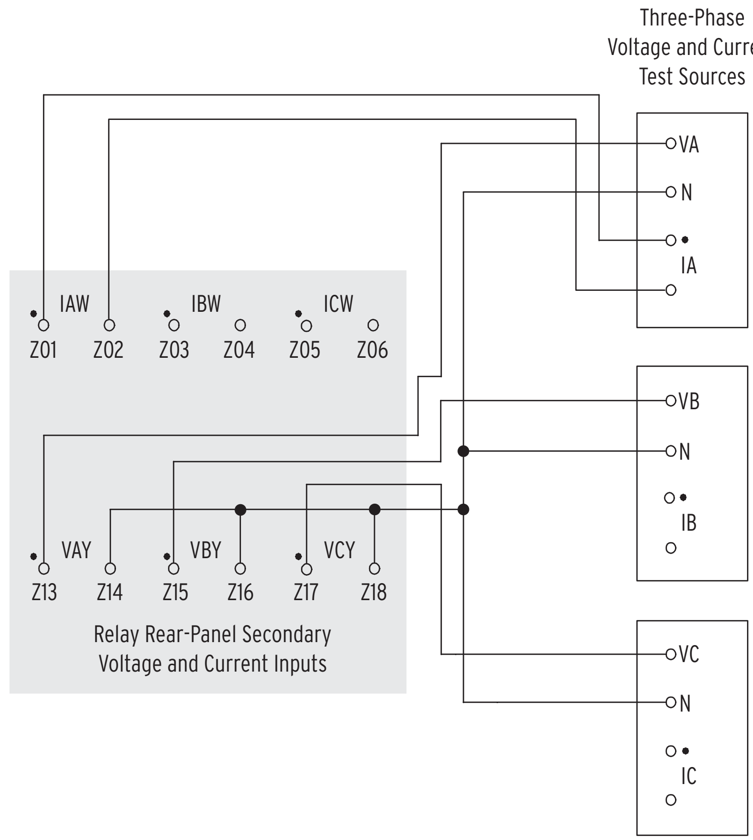


Figure 6.5 Test Connections Using a Single Current Source for a Phase-to-Ground Fault

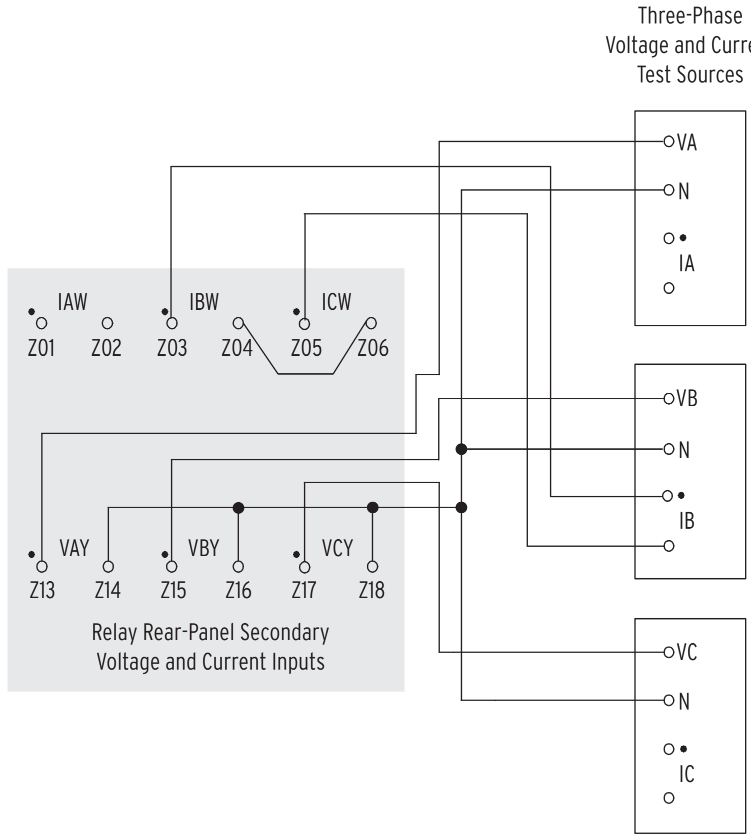


Figure 6.6 Test Connections Using a Single Current Source for a Phase-to-Phase Fault

Test Methods

Use the following methods to conveniently test the pickup and dropout of relay elements and other relay functions:

- Target indications (element pickup/dropout)
- Control output closures
- SER reports

The tests and procedures in the following subsections are for 5 A relays. Scale values appropriately for 1 A relays.

Once you have completed a test, return the relay settings that you modified for the test to default or operational values.

Testing With Targets

Use the communications port **TAR** command or the front panel to display the state of relay elements, control inputs, and control outputs. Viewing a change in relay element (Relay Word bit) status is a good way to verify the pickup settings you have entered for protection elements.

View Relay Elements With a Serial Terminal

The procedure in the following steps shows you how to view a change in state for the 50P1 Phase Instantaneous Overcurrent element from a communications port. Use the factory defaults for the pickup level (see *Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.64*.

Table 6.6 Phase Instantaneous Overcurrent Pickup

Setting	Description	Default (5A)
50P1P	Level 1 Pickup (OFF, 0.25–100 amps secondary)	10.00

For this procedure, you must have a serial terminal or computer with terminal emulation software and a variable current source for relay testing.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* to change the default access level passwords and enter higher relay access levels).

Step 1. Type **ACC <Enter>** at a communications terminal.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input (see *Figure 6.5* and *Section 2: Installation*).

Step 4. Type **TAR 50P1 <Enter>** to view the initial element status.

The relay returns a target terminal screen similar to *Figure 6.7*.

```
=>TAR 50P1 <Enter>

50P1 50P2 50P3 50P4 67P1 67P2 67P3 67P4

0    0    0    0    0    0    0    0
=>
```

Figure 6.7 Sample Targets Display on a Serial Terminal

Step 5. View the element status change.

a. Type **TAR 50P1 1000 <Enter>** (this command causes the relay to repeat the TAR 50P1 command 1000 times).

b. Increase the current source to produce a current magnitude greater than 10.00 A secondary in the relay.

You will see the 50P1 element status change to 1 when the input current exceeds the 50P1P setting threshold.

c. Type **<Ctrl+X>** to stop the relay from presenting the target display before completion of the 1000 target repeats.

View Relay Elements With the Front-Panel LCD

You can use the front-panel display and navigation pushbuttons to check Relay Word bit elements. See *Section 5: Front-Panel Operations* for more information on using the relay front panel.

This procedure uses the 50P1 Phase Instantaneous Overcurrent element. Use the factory defaults for the pickup level (*Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.64*.

Step 1. Display the MAIN MENU.

Step 1. If the relay LCD is in the ROTATING DISPLAY, press the **{ENT}** pushbutton to display the MAIN MENU similar to that in *Figure 6.8*.

Step 2. Press the **{Down Arrow}** navigation pushbutton to highlight the RELAY ELEMENTS action item (see the first screen of *Figure 6.8*).

Step 3. Press the **{ENT}** pushbutton.

You will see a RELAY ELEMENTS screen (the second screen of *Figure 6.8*).

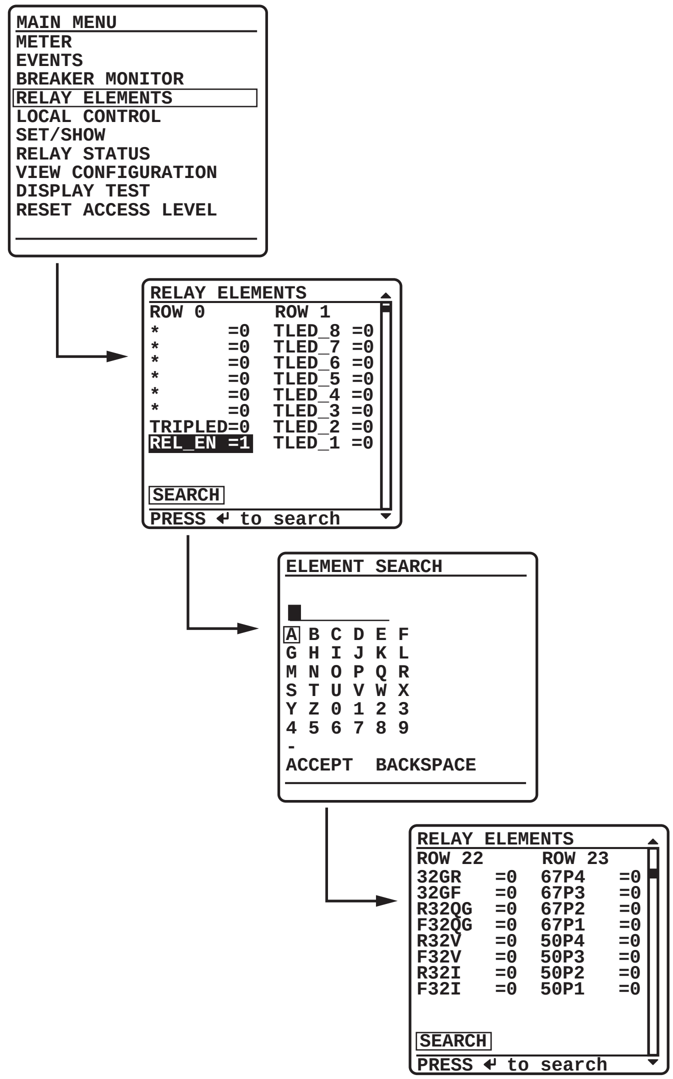


Figure 6.8 Viewing Relay Word Bits From the Front-Panel LCD

Step 4. Display the 50P1 Relay Word bit on the front-panel LCD screen.

a. Press **{ENT}** to go to the `ELEMENT SEARCH` submenu of *Figure 6.8*.

b. Use the navigation keys to highlight `5` and then press **{ENT}** to enter the character `5` in the text input field.

c. Enter the 0, P, and 1 characters in the same manner.

d. Highlight `ACCEPT` and press **{ENT}**.

The relay displays the LCD screen containing the 50P1 element, as shown in the last screen of *Figure 6.8*.

Step 5. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 6. View the target status change.

a. Increase the current source to produce a current magnitude greater than 10.00 A secondary in the relay.

b. Observe the 50P1 target on the front-panel display.

You will see the 50P1 element status change to 1 when the input current exceeds the 50P1P setting threshold.

Step 7. Press **{ESC}** to return to the MAIN MENU.

View Relay Elements With a Front-Panel LED

The procedure in the following steps shows you how to use a front-panel LED to view a change-in-state for the 50P1 Phase Instantaneous Overcurrent element. Use the factory defaults for the pickup level (see *Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.64*.

In this example, use ACSELERATOR QuickSet to configure the relay. You must have a computer that is communicating with the SEL-421 and running the ACSELERATOR QuickSet (see *Making Settings Changes: Initial Global Settings on page U.4.17*). In addition, you need a variable current source suitable for relay testing.

Step 1. Prepare to control the relay with ACSELERATOR QuickSet by establishing communication, checking passwords, and reading relay settings (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 2. Set a pushbutton LED SELOGIC control equation.

a. Expand the **Front Panel** branch of the **Settings** tree view and click **Pushbuttons** (see *Figure 6.9*).

ACSELERATOR QuickSet displays the **Pushbuttons** dialog box similar to *Figure 6.9*.

b. Click in the **PB4_LED** text box and type **50P1**.

c. Tab or click to any other text box.

ACSELERATOR QuickSet checks the validity of the setting.

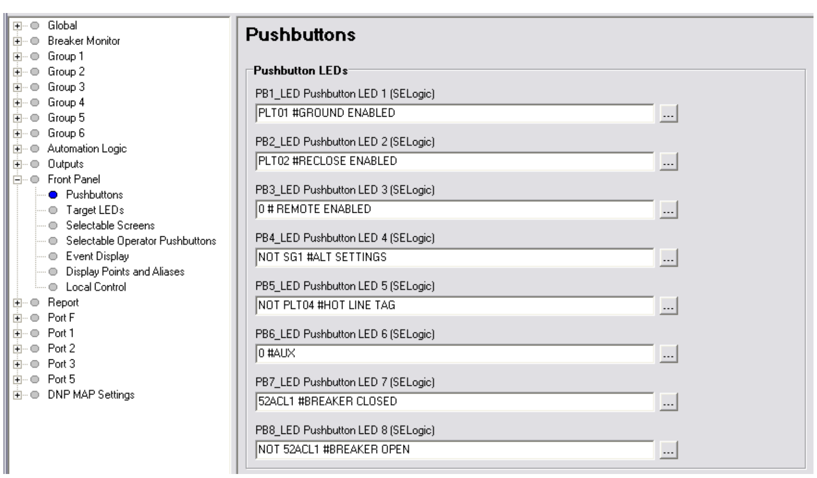


Figure 6.9 Setting Pushbutton LED Response: ACSELERATOR QuickSet

Step 3. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 4. Upload the new settings to the SEL-421.

a. Click **File > Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 6.10*.

b. Click the check box for **Front Panel**.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box of *Figure 6.10*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.10 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

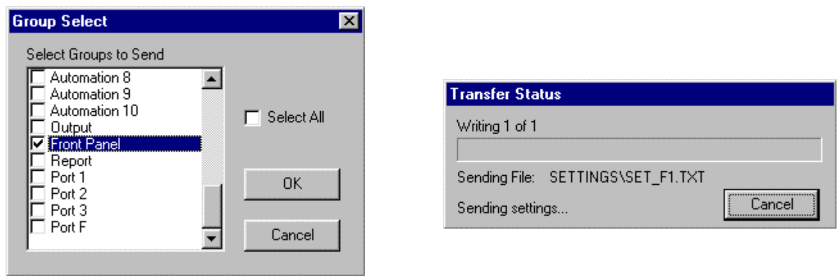


Figure 6.10 Uploading Front-Panel Settings to the SEL-421

Step 5. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 6. View the target status change.

a. Increase the current source to produce a current magnitude greater than 10.00 A secondary in the relay.

b. Observe the LED next to the **RELAY TEST MODE** pushbutton (PB4) on the SEL-421 front panel.

You will see the LED light when the input current exceeds the 50P1P setting threshold.

Testing With Control Outputs

You can set the relay to operate a control output to test a single element. Set the SELOGIC control equation for a particular output (OUT101 through OUT108, for example) to respond to the Relay Word bit for the element under test. See *Operating the Relay Inputs and Outputs on page U.4.56* for configuring control inputs and control outputs. *Appendix A: Relay Word Bits in the Reference Manual* lists the names of the relay element logic outputs.

Testing the 50P1 Element With a Control Output

This procedure shows how to set control output OUT105 to test the 50P1 Phase Instantaneous Overcurrent element. Use the factory defaults for the pickup level (see *Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.64*.

For this test, you must have a computer with ACSELERATOR QuickSet for the SEL-421, a variable current source for relay testing, and a control output closure indicating device such as a test set or a VOM (volt ohmmeter).

In this example, use ACSELERATOR QuickSet to configure the relay. You must have a computer that is communicating with the SEL-421 and running ACSELERATOR QuickSet (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 1. Prepare to control the relay with ACSELERATOR QuickSet by establishing communication, checking passwords, and reading relay settings (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 1. Click the **Outputs** > **Main Board** branch of the ACSELERATOR QuickSet **Settings** tree structure to view output settings (shown in *Figure 6.11*).

The **Main Board Outputs** dialog box appears.

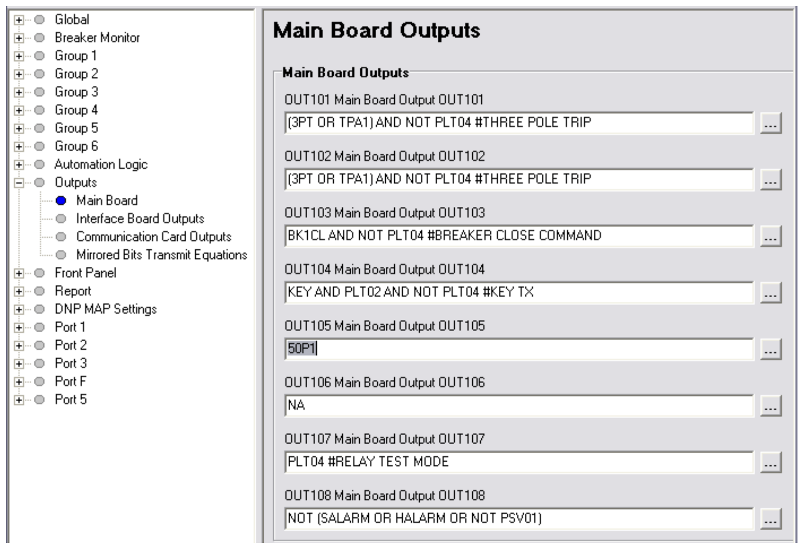


Figure 6.11 Setting Main Board Outputs: ACSELERATOR QuickSet

Step 2. Set OUT105 to respond to the 50P1 element pickup.

a. Move the cursor to the OUT105 Main Board Output105 (SELOGIC) text box and double-click the left (regular) mouse button.

b. Delete the NA default setting.

c. Type **50P1**.

d. Press **<Tab>** or click in any other text box.

e. The relay checks the validity of the setting you entered.

An invalid setting (you could have mistyped the element name) causes the OUT105 text box to turn red.

If the setting is valid, the text box displays the new setting on a white background.

Step 3. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 4. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box in *Figure 6.12*.

b. Click the **Output** check box.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box in *Figure 6.12*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.12 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

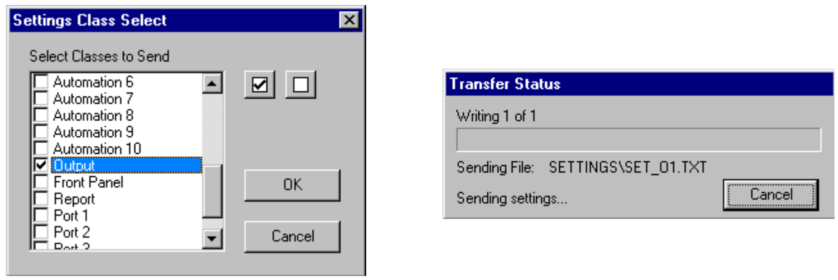


Figure 6.12 Uploading Output Settings to the SEL-421

Step 5. Connect an indicating device to OUT105 on the relay rear panel.

A VOM multi-tester on a low resistance scale can indicate an OUT105 control output closure.

Step 6. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 7. Increase the current source to produce a current magnitude greater than 10.00 A secondary in the relay (to test the element).

When the 50P1 element picks up, the relay changes the 50P1 Relay Word bit to logical 1 and closes the output contacts of control output OUT105.

The indicating device operates.

Testing With SER

You can set the relay to generate a report from the SER to test relay elements; include the element that you want to test in the SER **Points and Aliases** list. Set aliases for the element name, set state, and clear state in the SEL-421 SER to simplify reading the SER report. See *SER (Sequential Events Recorder) on page A.3.34* for complete information on the SER.

Testing the 51S1 Element Using the SER

The SER gives exact time data for testing time-overcurrent element timeouts. Subtract the 51S1T assertion time from the 51S1 assertion time to check the operation time for this element. Use the factory defaults for the operating quantity, pickup level, curve, time dial, and electromechanical reset (*Table 6.7*).

The procedure in the following steps shows how to set the SER trigger lists to capture the selectable operating quantity time-overcurrent element 51S1 operating times. The procedure also shows how to set the torque control supervision for the 51S1 element.

Table 6.7 Selectable Operating Quantity Time-Overcurrent Element (51S1) Default Settings

Setting	Description	Default 5A
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0L, 3I01, 3I02)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 amps, secondary)	0.75
51S1C	51S1 Inv-Time Overcurrent Curve (U1–U5, C1–C5)	U3
51S1TD	51S1 Inv-Time Overcurrent Time Dial (0.50–15.0)	1.00
51S1RS	51S1 Inv-Time Overcurrent EM Reset (Y, N)	N
51S1TC	51S1 Torque Control (SELOGIC control equation)	32GF

[a] n is L, 1, and 2 for Line, Circuit Breaker 1, and Circuit Breaker 2, respectively.

The relay uses *Equation 6.1* and *Equation 6.2* to determine the operating time for the 51S1 element. For a current input 50 percent greater than the default pickup, the test value, I_{TEST}, is:

$$\begin{aligned} I_{TEST} &= M \cdot (51S1P) \\ &= 1.5 \cdot (0.75\ A) \\ &= 1.125\ A \end{aligned}$$

Equation 6.1

where M is the pickup multiple and 51S1P is the element pickup value (see *Table 6.7*).

The operating time (t_p) for a time dial (TD) equal to 1 for the U3 (Very Inverse) Curve is:

$$\begin{aligned} t_p &= TD \cdot \left(0.0963 + \frac{3.88}{M^2 - 1}\right) \\ &= 1 \cdot 0.0963 + \frac{3.88}{1.5^2 - 1} \\ &= 3.2 \text{ seconds} \end{aligned}$$

Equation 6.2

For more information on the 51S elements, see *Inverse-Time Overcurrent Elements on page R.1.70*.

In this example, use ACSELERATOR QuickSet to configure the relay. You must have a computer that is communicating with the SEL-421 and running the ACSELERATOR QuickSet (see *Making Settings Changes: Initial Global Settings on page U.4.17*). You also need a variable current source for relay testing.

Step 1. Prepare to control the relay with ACSELERATOR QuickSet by establishing communication, checking passwords, and reading relay settings (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 2. Set the selectable operating quantity time-overcurrent element for test operation.

a. Open the **Group 1 > Relay Configuration > Time Overcurrent** branch of the **Settings** tree view (see *Figure 6.13*).

b. In the **Time Overcurrent** dialog box, check that setting **51S1O Operating Quantity** is at **3I0L**.

c. Check the remaining element configurations against *Table 6.7*.

➢ Set torque control 51S1TC to **1** to constantly operate the 51S1 element

➢ Type **1** in the text box for 51S1TC.

➢ For more information on using ACSELERATOR QuickSet to change settings, see *Making Initial Global Settings: ACSELERATOR QuickSet on page U.4.25*.)

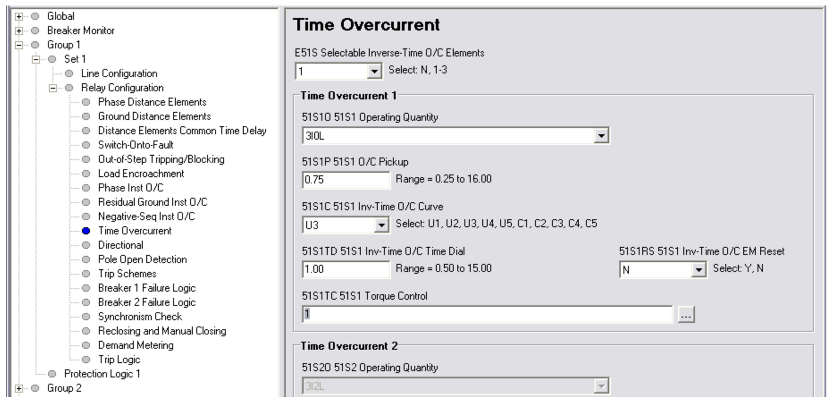


Figure 6.13 Checking the 51S1 Overcurrent Element: ACSELERATOR QuickSet

Step 3. View the SER settings.

a. Click the **+** mark next to the **Report** branch of the ACSELERATOR QuickSet **Settings** tree view structure shown in *Figure 6.14*.

b. Click on the **SER Points and Aliases** branch.

The **SER Points and Aliases** dialog box appears (see *Figure 6.14*).

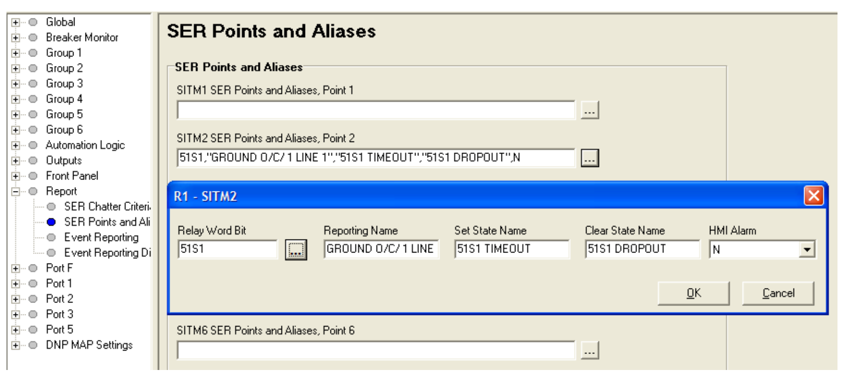


Figure 6.14 Setting SER Points and Aliases: ACSELERATOR QuickSet

Step 4. Enter SER element names and aliases.

a. Locate **SITM1 SER Points and Aliases, Point 1** entry field, and then click the [...] button beside the entry box.

b. Click the [...] button beside the **Relay Word bit** entry field.

c. Select Overcurrent Element Bits.

d. Double-click on 51S1T to copy the name into the Relay Word Bit field.

e. Type **GROUND O/C 1 LINE 1** in the **Alias Name** field.

f. Type **51S1 TIMEOUT** in the **Set Alias** field.

g. Type **51S1 DROPOUT** in the **Clear Alias** field.

h. Click on the OK button.

i. Repeat Steps *Step a–Step h* for **SITM2 SER Points and Aliases, Point 2**, with setting values **51S1, GROUND O/C 1 LINE 1, 51S1 PICKED UP, 51S1 RESET**. *Figure 6.14* shows the entry field for SITM2 just before pressing the OK button.

You can enter as many as 250 relay elements in the **SER Points and Aliases** list (see *SER (Sequential Events Recorder) on page A.3.34*).

Step 5. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 6. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

b. ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 6.15*.

c. Click the check box for **Group 1** and for **Report**.

d. Click **OK**.

ACSELERATOR QuickSet responds with a **Transfer Status** dialog box as in *Figure 6.15*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.15 are for the SEL-421. The SEL-421-1 SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

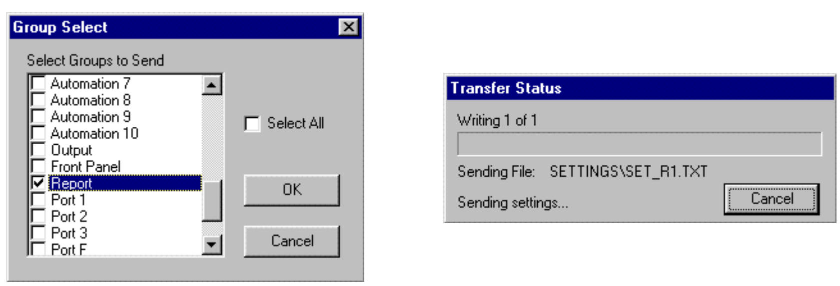


Figure 6.15 Uploading Group 1 and Report Settings to SEL-421

Step 7. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 8. Test the element.

a. Increase the current source to produce a current magnitude of 1.125 A secondary in the relay.

b. Keep the current source at this level past the expected element timeout (longer than 3.2 seconds).

c. Return the current source to zero after the element time out.

Step 9. Select the HMI menu (top toolbar) and then click **Meter and Control** to start the ACSELERATOR QuickSet HMI interface.

Step 10. View the SER report.

Step 11. Click the **SER** button of the HMI tree view (see *Figure 6.16*).

ACSELERATOR QuickSet displays the **SER** report similar to *Figure 6.17*.

The time difference between SER entries **51S1 PICKED UP** and **51S1 TIMOUT** is approximately 3.2 seconds.

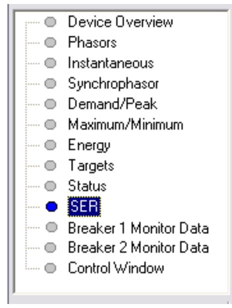


Figure 6.16 HMI Tree View: ACSELERATOR QuickSet

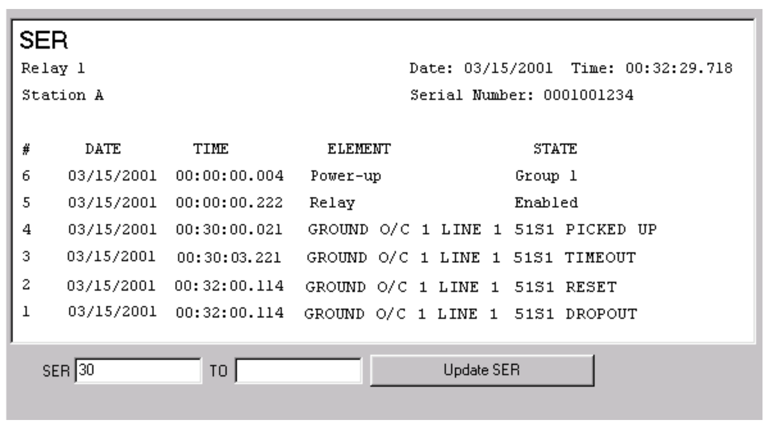


Figure 6.17 SER Report: ACSELERATOR QuickSet HMI

Checking Relay Operation

The SEL-421 comes to you with all functions fully checked and calibrated so that the relay operates correctly and accurately. You can perform tests on the relay to verify proper relay operation, but you do not need to test every relay element, timer, and function in this evaluation. The following checks are valuable for confirming proper SEL-421 connections and operation:

- AC connection check (metering)
- Commissioning tests
- Functional tests
- Element verification

An ac connection check uses relay metering to verify that the relay current and voltage inputs are the proper magnitude and phase rotation (see *Examining Metering Quantities on page U.4.33*).

Commissioning tests help you verify that you have properly connected the relay to the power system and all auxiliary equipment. These tests confirm proper connection of control inputs and control outputs as well (see *Operating the Relay Inputs and Outputs on page U.4.56*).

Brief functional tests and element verification confirm correct internal relay processing.

Selected Element Tests

This subsection discusses tests of the following relay elements:

- Overcurrent element: negative-sequence instantaneous, 50Q1
- Directional element: negative-sequence portion, F32Q/R32Q, of the phase directional element, F32P/R32P
- Distance element: phase-to-phase mho element, MBC2, of Zone 2 mho distance element M2P

Testing Overcurrent Elements

Overcurrent elements operate by detecting power system sequence quantities and asserting when these quantities exceed a preset threshold.

Apply current to the analog current inputs and compare relay operation to the element pickup settings to test the instantaneous and definite-time overcurrent elements. Be sure to apply the test current to the proper input set (IW or IX), according to the Global Current and Voltage Source Selection settings (ESS and ALINEI, for example) to accept the input. See *Current and Voltage Source Selection on page R.1.2* for more information.

Phase Overcurrent Elements

The SEL-421 phase overcurrent elements compare the phase current applied to the secondary current inputs with the phase overcurrent element pickup setting. The relay asserts the phase overcurrent elements when any of the three phase currents exceeds the corresponding element pickup setting.

Negative-Sequence Overcurrent Elements

The SEL-421 negative-sequence overcurrent elements compare a negative-sequence calculation of the three-phase secondary inputs with the corresponding negative-sequence overcurrent element pickup setting. The relay makes this negative-sequence calculation (assuming ABC rotation):

$3I_2$ = A-phase + B-phase (shifted by –120°) + C-phase (shifted by 120°)

The relay asserts negative-sequence overcurrent elements when the $3I_2$ calculation exceeds the corresponding negative-sequence current pickup setting. If balanced currents are applied to the relay, the relay reads $3I_2 \approx 0$ (load conditions) and does not pick up the negative-sequence overcurrent elements.

For testing, apply current to a single phase of the relay, causing the negative-sequence overcurrent elements to operate. For example, assume 1 A of current on A-phase and zero current input on the B-phase and C-phase:

$3I_2$ = 1 A + 0 (shifted –120°) + 0 (shifted 120°) = 1 A (a simulated ground fault condition)

Ground Overcurrent Elements

The SEL-421 ground overcurrent elements compare a residual ground calculation of the three-phase inputs with the residual overcurrent setting. The relay makes this residual current calculation:

$3I_0$ = A-phase + B-phase + C-phase

The relay asserts ground overcurrent elements when the $3I_0$ calculation exceeds the ground current element pickup setting. If balanced currents are applied to the relay, the relay reads $3I_0 = 0$ (load conditions) because the currents cancel in the calculation; the relay does not pick up the ground overcurrent elements.

For testing, apply current to a single phase of the relay, causing the residual overcurrent elements to operate. For example, assume 1 A of current on A-phase and zero current input on B-phase and C-phase:

$3I_0$ = 1 A + 0 + 0 = 1 A (a simulated ground fault condition)

Checking the Negative-Sequence Instantaneous Overcurrent Element, 50Q1

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

The procedure in the following steps tests the 50Q1 negative-sequence overcurrent element. Use a similar procedure to test other overcurrent elements.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* to change the default access level passwords and enter higher relay access levels). You should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the relay.

a. Start ACSELERATOR QuickSet and read the present configuration in the SEL-421.

b. Click **Settings > Read**.

The relay sends all settings and configuration data to ACSELERATOR QuickSet.

c. Expand the **Group 1** settings and click the **Negative-Seq Inst O/C** button of the **Settings** tree view as shown in *Figure 6.18*.

You will see the **Negative Sequence Instantaneous Overcurrent** dialog box similar to *Figure 6.18*.

d. Click the arrow in the **Instantaneous and Definite Time Overcurrent Element Levels E50Q** dialog box and select **1**.

e. For this test, set the **50Q1P** level to **1.00** and **67Q1TC** to **1**.

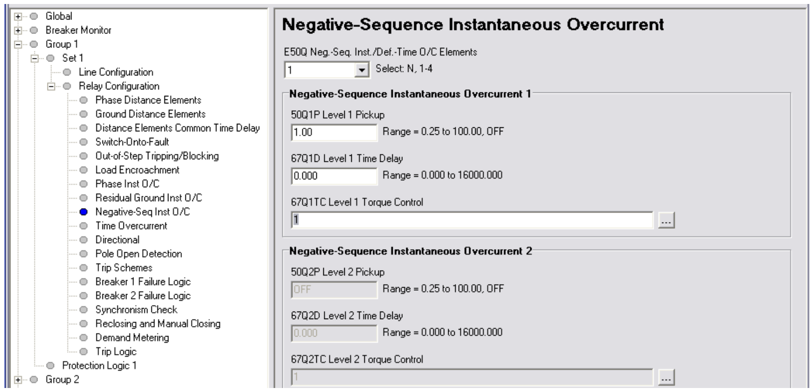


Figure 6.18 Negative-Sequence Instantaneous Overcurrent Element Settings: ACSELERATOR QuickSet

Step 2. Upload the new setting to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box in *Figure 6.19*.

b. Click the check box for **Group 1**.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box similar to *Figure 6.19*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.19 are for the SEL-421. The SEL-421-1 SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

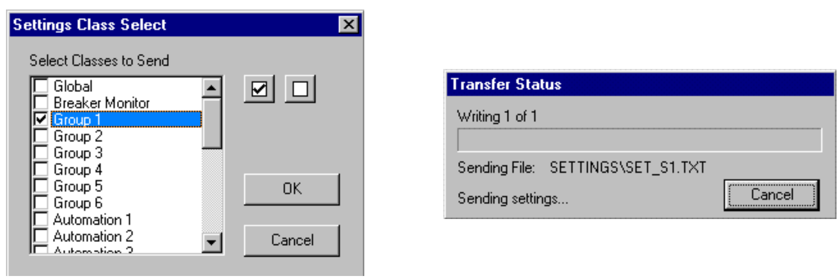


Figure 6.19 Uploading Group 1 Settings to the SEL-421

Step 3. Display the 50Q1 Relay Word bit on the front-panel LCD screen.

a. Access the front-panel LCD `MAIN MENU`.

b. Highlight `RELAY ELEMENTS` and press **{ENT}**.

c. Press **{ENT}** to go to the `ELEMENT SEARCH` submenu of *Figure 6.20*.

d. Use the navigation keys to highlight `5` and then press **{ENT}** to enter characters in the text input field.

e. Enter the **0**, **Q**, and **1** characters in turn.

f. Highlight `ACCEPT` and press **{ENT}**.

The relay displays the screen containing the 50Q1 element, as shown in *Figure 6.21*.

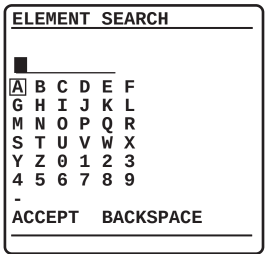


Figure 6.20 ELEMENT SEARCH Screen

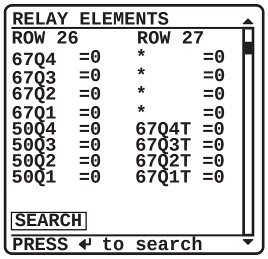


Figure 6.21 RELAY ELEMENTS Screen Containing Element 50Q1

Step 4. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 5. Increase the current source to produce a current magnitude greater than 1.00 A secondary in the relay.

You will see that the 50Q1 element state changes on the LCD screen from 50Q1 = 0 to 50Q1 = 1.

Negative-Sequence Directional Element for Phase Faults

The SEL-421 features a phase directional element (represented by Relay Word bits F32P/R32P) to supervise the phase distance elements and to control phase directional elements. The negative-sequence directional element, F32Q/R32Q, is a part of the phase directional element, F32P/R32P. Whenever the negative-sequence directional element asserts, the phase directional element asserts.

The relay also contains a ground directional element, F32G/R32G, for directional control of the ground distance elements and ground overcurrent elements. For more information on directional elements, see *Ground Directional Element on page R.1.27*, and *Section 1: Protection Application Examples in the Applications Handbook*.

The SEL-421 calculates the negative-sequence impedance Z2 from the magnitudes and angles of the negative-sequence voltage and current. *Table 6.3* defines this function (the ‘c’ in Z2c indicates “calculated”).

$$
\begin{aligned}
Z2c &= \frac{\mathrm{Re}[V_2 \bullet (1\angle Z1ANG \bullet I_2)^*]}{|I_2|^2} \\
&= \frac{|V_2|}{|I_2|} \bullet \cos(\angle V_2 - \angle Z1ANG - \angle I_2)
\end{aligned}
$$

Equation 6.3

where:

V_2 = the negative-sequence voltage
I_2 = the negative-sequence current
Z1ANG = the positive-sequence line impedance angle
Re = the real part of the term in brackets, for example, (Re[A + jB] = A)
* = the complex conjugate of the expression in parentheses, (A + jB)* = (A – jB)

The result of *Equation 6.3* is an impedance magnitude that varies with the magnitude and angle of the applied current. Normally, a forward fault results in a negative Z2c relay calculation.

Test Current

Solve *Equation 6.3* to find the test current values that you need to apply to the relay to test the element. For the negative sequence current I_2, the result is

$$|I_2| = \frac{|V_2|}{Z2c}$$ **Equation 6.4**

when:

$$\angle I_2 = \angle V_2 - \angle Z1ANG$$ **Equation 6.5**

Multiply the quantities in *Equation 6.4* by three to obtain $3I_2$, the negative-sequence current that the relay processes. With a fixed applied negative-sequence voltage V_A, the relay negative sequence voltage is $3V_2$. Set Z2c = Z2F to find the test current magnitude at the point where the impedance calculation equals the forward fault impedance threshold. *Equation 6.4* becomes:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2F}$$ **Equation 6.6**

when:

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG$$ **Equation 6.7**

For a reverse fault impedance threshold, where Z2c = Z2R, *Equation 6.4* becomes:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2R}$$ **Equation 6.8**

when the angle calculation is the same as *Equation 6.7*.

For more information on the directional elements, see *Ground Directional Element on page R.1.27* and *Quadrilateral Ground Distance Elements on page R.1.54*. For settings and application information, see *Section 1: Protection Application Examples in the Applications Handbook*.

Checking the Negative-Sequence Directional Element (Phase Faults)

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

This test confirms operation of the F32Q and the R32Q negative-sequence directional elements. This test procedure is for a 5 A relay; scale values appropriately for a 1 A relay.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* to change the default access level passwords and enter higher relay access levels). You should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the relay.

a. Open ACSELERATOR QuickSet and read the present configuration in the SEL-421.

b. Click **Settings > Read**.

The relay sends all settings and configuration data to ACSELERATOR QuickSet.

c. Expand the **Group 1** settings and click the **Relay Configuration** branch of the **Settings** tree view as shown in *Figure 6.22*.

d. Disable supervisory elements.

Confirm that **ELOP** is set to **N**.

e. In a similar sequence, click on the + button to expand the **Relay Configuration** tree view, click on **Load Encroachment**, and confirm that **ELOAD** is set to **N**.

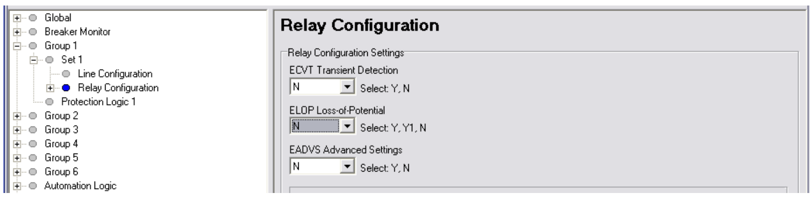


Figure 6.22 Group 1 Relay Configuration Settings: ACSELERATOR QuickSet

f. Defeat the pole-open logic.

g. Click the **+** button next to **Breaker Monitor** to expand the **Breaker Monitor** branch of the **Settings** tree view (see *Figure 6.23*).

h. Click **Breaker 1**.

You will see the **Breaker 1** dialog box similar to *Figure 6.23*.

i. Enter **1** in the text boxes for **52AA1 A-Phase N/O Contact Input -BK1**, **52AB1 B-Phase N/O Contact Input -BK1**, and **52AC1 C-Phase N/O Contact Input -BK1**.

The text boxes in *Figure 6.23* appear if Breaker Monitor setting BK1TYP := 1.

j. If BK1TYP := 3, enter **1** in the **52AA1 N/O Contact Input -BK1** text box (the other circuit breaker input boxes are dimmed.)

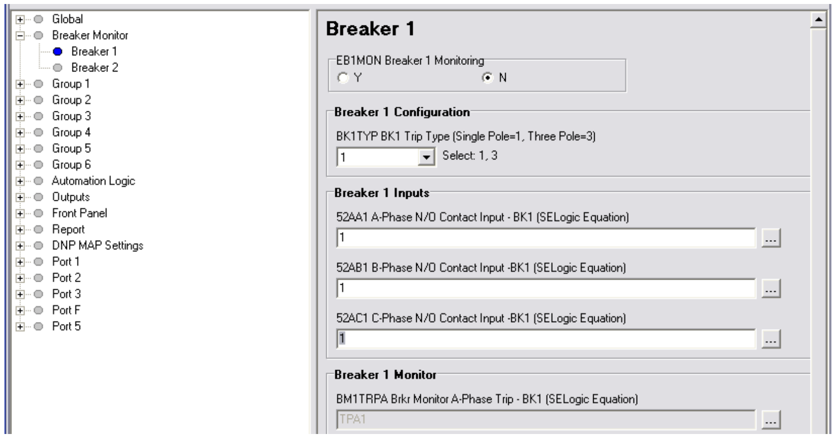


Figure 6.23 Breaker 1 Breaker Monitor Settings: ACSELERATOR QuickSet

Step 2. Set test values in the relay.

a. Expand the **Group 1** settings as shown in *Figure 6.24* and select the **Line Configuration** button.

You will see the **Line Configuration** dialog box of *Figure 6.24*.

b. Confirm the default settings of **Z1MAG** at **7.80** and **Z1ANG** at **84.00**.

c. Click the **+** mark next to the **Relay Configuration** branch to expand that **Settings** branch.

d. Select the **Directional** button.

You will see the **Directional** dialog box similar to *Figure 6.25*.

e. Confirm the following settings: **E32** is **AUTO**, **ORDER** is **Q**, **50FP** is **0.60**, **50RP** is **0.40**, **Z2F** is **3.90**, **Z2R** is **4.00**, **a2** is **0.10**, and **k2** is **0.2**.

The dialog box is dim since there are no settings to change.

The relay calculates these numeric settings automatically because **E32** is set to **AUTO**.

f. If you need to change these settings, set **E32** to **Y**.

Table 6.8 shows the calculations.

See *Ground Directional Element on page R.1.27* for details on these relay calculations.

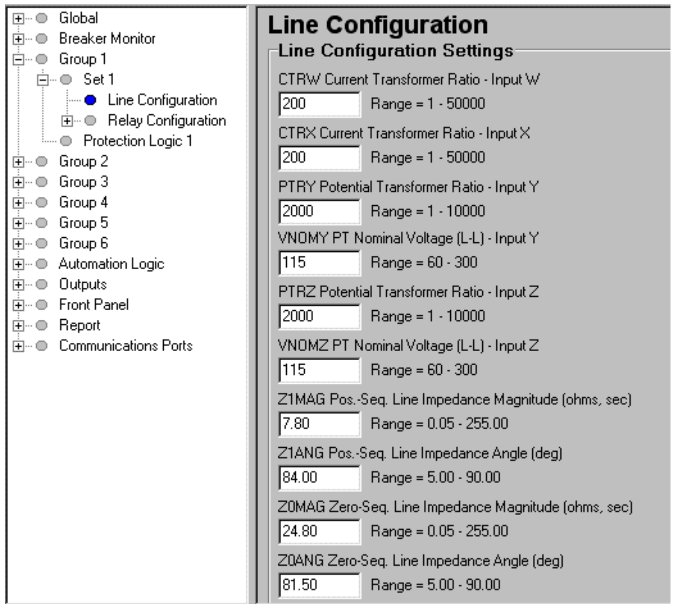


Figure 6.24 Group 1 Line Configuration Settings: ACSELERATOR QuickSet

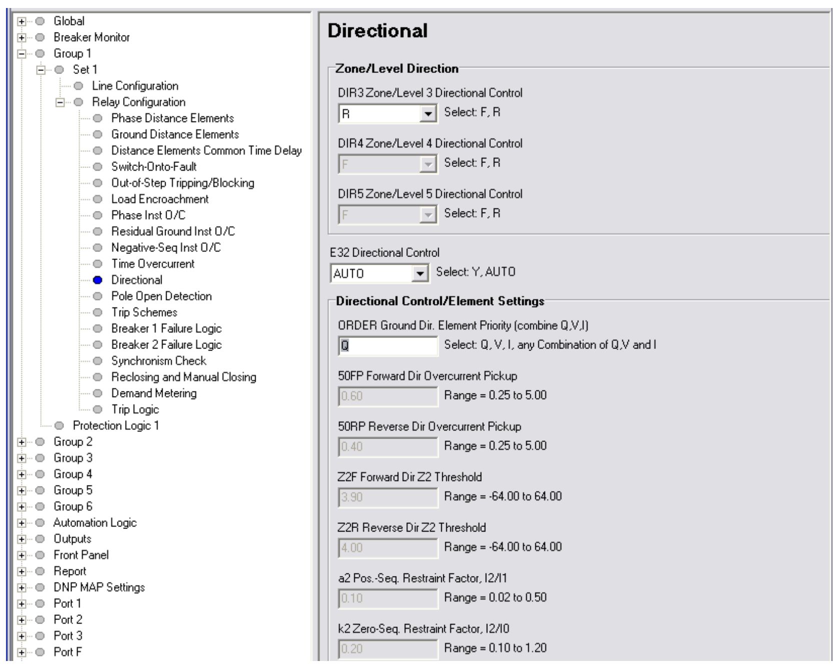


Figure 6.25 Directional Settings: ACSELERATOR QuickSet

Table 6.8 Negative-Sequence Directional Element Settings AUTO Calculations

Setting	Calculation
50FP	$0.12 \cdot I_{nom}$
50RP	$0.08 \cdot I_{nom}$
Z2F	0.5 • Z1MAG
Z2R	$Z2F + 1 / (2 \cdot I_{nom})$
a2	0.1
k2	0.2

Step 3. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box in *Figure 6.26*.

b. Click the check box for **Group 1** and for **Breaker Monitor**.

c. Click **OK**.

d. ACSELERATOR QuickSet responds with a **Transfer Status** dialog box as in *Figure 6.26*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.26 are for the SEL-421. The SEL-421-1 SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

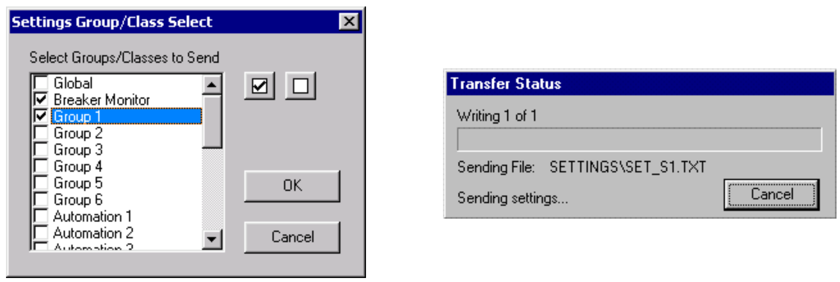


Figure 6.26 Uploading Group 1 and Breaker Monitor Settings to the SEL-421

Step 4. Display the F32Q and R32Q Relay Word bits on the front-panel LCD screen.

a. Access the front-panel LCD MAIN MENU.

b. Highlight RELAY ELEMENTS and press **{ENT}**.

You will see a RELAY ELEMENTS screen with SEARCH highlighted at the bottom of the screen.

c. Press **{ENT}** to go to the ELEMENT SEARCH submenu of *Figure 6.20*.

d. Enter characters in the text input field using the navigation keys.

e. Highlight F and press **{ENT}** to enter the F character.

f. Enter the 3, 2, and Q characters in like manner.

g. Highlight ACCEPT and press **{ENT}**.

The relay displays the screen containing the F32Q and R32Q elements, as shown in *Figure 6.27*.

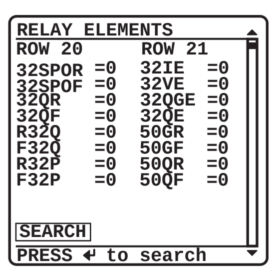


Figure 6.27 RELAY ELEMENTS LCD Screen Containing Elements F32Q and R32Q

Step 5. Calculate impedance thresholds.

a. For this test, apply an A-phase voltage of $V_A = 3V_2 = 18.0 \angle 180°$ V secondary.

b. Use *Equation 6.8* to find the current that is equal to the reverse impedance threshold Z2R:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2R} = \frac{|18.0\angle 180° V|}{4.00} = 4.50 \text{ A}$$

Step 6. Use *Equation 6.6* to find the current that is equal to the forward impedance threshold Z2F:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2RF} = \frac{|18.0\angle 180° V|}{3.90} = 4.62 \text{ A}$$

Step 7. Use *Equation 6.7* to determine the applied current angle ($\angle I_{TEST}$):

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG = 180° - 84° = 96°$$

Step 8. Apply a test current to confirm operation of R32Q and F32Q.

a. Connect a single current test source as shown in *Figure 6.5*.

b. Apply an A-phase voltage of $V_A = 18.0 \angle 180°$ V secondary.

c. Set the current source for $I_A = 0.0 \angle 96°$ A.

d. Slowly increase the magnitude of I_A to apply the source test current.

e. Observe the `RELAY ELEMENT` LCD screen.

Relay Word bit R32Q asserts when $|I_A| = 0.4$ A, indicating that the relay negative-sequence current is greater than the 50RP pickup threshold.

R32Q deasserts when $|I_A| = 4.5$ A, indicating that the relay negative-sequence calculation Z2c is now less than the Z2 reverse threshold Z2R (see *Reverse Threshold on page R.1.37* and *Forward Threshold on page R.1.36*.)

f. Continue to increase the current source while you observe the `RELAY ELEMENT` LCD screen.

Relay Word bit F32Q asserts when $|I_A| = 4.62$ A, indicating that the relay negative-sequence calculation Z2c is less than the Z2 forward threshold Z2F.

Distance Elements

Apply voltages and currents to the relay analog inputs that simulate fault and load conditions to test distance elements. The relay supervises distance elements so that these elements operate under the appropriate conditions. Be sure to satisfy all the element supervisory conditions before testing a relay element. For supervisory conditions for a particular element, see *Mho Ground Distance Elements on page R.1.49*.

Phase-to-Phase Distance Element MBC2

The SEL-421 contains mho phase distance elements among the many protection elements in the relay. The relay has phase distance elements to detect phase-to-phase faults, phase-to-phase-to-ground faults, and three-phase faults. The SEL-421 has five independent zones of mho phase distance protection; each zone consists of phase-to-phase elements that the relay combines to produce a particular zone output.

For example, the OR combination of MAB2, MBC2, and MCA2 produces the M2P Zone 2 mho phase element. For more information on the mho phase elements and other distance elements, see *Section 1: Protection Functions in the Reference Manual* and *Section 1: Protection Application Examples in the Applications Handbook*.

Test Current and Voltage for a Phase-to-Phase Fault

To find the test current for a phase-to-phase fault, consider *Equation 6.9* for a B-phase to C-phase fault:

$$I_{TEST} = I_B = -I_C \qquad \textbf{Equation 6.9}$$

The B-phase to C-phase current vector, I_{BC}, is:

$$I_{BC} = I_B - I_C = I_B + (I_B) = 2 \bullet I_B = 2 \bullet I_{TEST} \qquad \textbf{Equation 6.10}$$

Choose a convenient test source current magnitude, $|I_{TEST}| = 2.5$ A; then $|I_{BC}| = 2 \bullet |I_{TEST}| = 5$ A.

Find the magnitude of the test source voltage $|V_{TEST}|$:

$$\begin{aligned} |V_{TEST}| &= |V_{BC}| = |I_{BC}| \bullet |Z_{BC}| = |I_{BC}| \bullet Z2P \\ &= 2 \bullet |I_{TEST}| \bullet Z2P \end{aligned} \qquad \textbf{Equation 6.11}$$

where relay setting Z2P (Zone 2 Reach) substitutes for the B-phase to C-phase impedance Z_{BC}. For setting Z2P of 9.36 Ω, the test voltage magnitude $|V_{BC}|$ is:

$$\begin{aligned} |V_{TEST}| &= 2 \bullet |I_{TEST}| \bullet Z2P \\ &= 2 \bullet 2.5 \bullet 9.36 = 46.8 \text{ V} \end{aligned} \qquad \textbf{Equation 6.12}$$

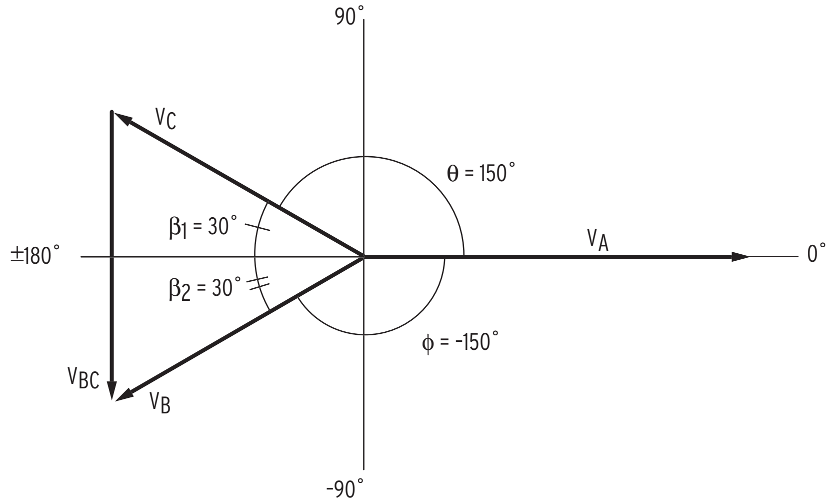


Figure 6.28 Finding Phase-to-Phase Test Quantities

One way to create a V_{BC} phasor is to equate $|V_B|$ and $|V_C|$ and determine the appropriate angles to make an equilateral triangle as shown in *Figure 6.28*.

Subtract 30 degrees (angle β_1) from 180 degrees to obtain the angle for test source V_C phasor; $V_C = 46.8 \angle 150°$ V.

Similarly, add 30 degrees (angle β_2) to –180 degrees to obtain test source V_B phasor; $V_B = 46.8 \angle –150°$ V.

Test voltage V_A can be the nominal value, $V_A = 67 \angle 0°$ V.

Thus, the resulting phase-to-phase voltage is $V_{BC} = 46.8 \angle –90°$ V, referenced to the V_A phasor at 0 degrees.

The relay measures phase distance element maximum reach when the faulted phase-to-phase current lags the faulted phase-to-phase voltage by the distance element maximum torque angle. In the SEL-421, the phase distance element maximum torque angle is setting Z1ANG. Current I_{BC} should lag voltage V_{BC} by Z1ANG.

In this example, Z1ANG is 84.0 degrees. From *Equation 6.9*, the angle of I_B is the angle of I_{TEST}, and the angle of I_C is 180 degrees from the angle of I_{TEST}. The test source current for I_B is the following:

$$
\begin{aligned}
I_B &= 2.5\angle(-90° - \text{Z1ANG})\text{A} \\
&= 2.5\angle(-90° - 84°)\text{A} \\
&= 2.5\angle -174°\text{A}
\end{aligned}
$$

Equation 6.13

And the test source current for I_C is the following:

$$I_C = -I_B = -(2.5\angle -174°\text{A}) = 2.5\angle 6°\text{A}$$

Equation 6.14

Checking the MBC2 Portion of the M2P Phase Distance Element

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

The following procedure describes how to test the B-phase to C-phase distance element MBC2. Although this test refers directly to the Zone 2 phase distance element, you can apply this procedure to any other forward-reaching phase-to-phase distance element zone.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* to change the default access level passwords and enter higher relay access levels). You should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the relay.

Perform the procedure listed under *Step 1* in *Checking the Negative-Sequence Directional Element (Phase Faults) on page U.6.30*.

Step 2. Set test values in the relay.

Perform the procedure listed under *Step 2* in *Checking the Negative-Sequence Directional Element (Phase Faults) on page U.6.30*.

Step 3. Set the phase distance element reach.

a. Select the **Phase Distance** button of the ACSELERATOR QuickSet **Settings** tree view.

You will see the Phase Distance Elements dialog box similar to *Figure 6.29*.

b. Confirm the settings of **E21P** at **2**, **Z1P** at **6.24** and **Z2P** at **9.36**.

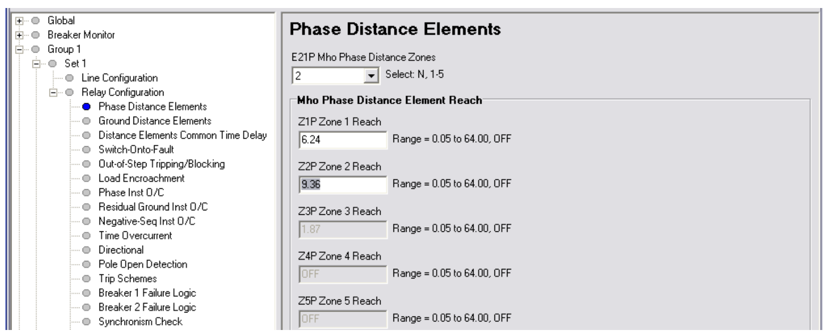


Figure 6.29 Phase Distance Elements Settings: ACSELERATOR QuickSet

Step 4. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

b. ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 6.26*.

c. Click the check box for **Group 1**.

d. Click **OK**.

ACSELERATOR QuickSet responds with a dialog box similar to the second dialog box of *Figure 6.26*.

If you see no error message, the new settings are loaded in the relay.

Step 5. Display the MBC2 Relay Word bit on the front-panel LCD screen.

a. Access the front-panel LCD `MAIN MENU`.

b. Highlight `RELAY ELEMENTS` and press **{ENT}**.

c. You will see a RELAY ELEMENTS screen with SEARCH highlighted at the bottom of the screen.

d. Press **{ENT}** to go to the ELEMENT SEARCH submenu of *Figure 6.20*.

e. Use the navigation keys to highlight M and press **{ENT}** to enter character in the text input field.

f. Enter the B, C, and 2 characters in like manner.

g. Highlight ACCEPT and press **{ENT}**.

The relay displays the LCD screen containing the MBC2 element, as shown in *Figure 6.30*.

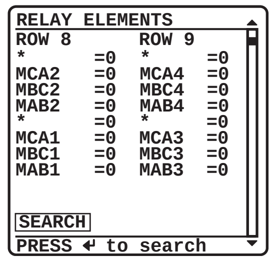


Figure 6.30 RELAY ELEMENTS LCD Screen Containing Element MBC2

Step 6. Set the magnitudes and angles of the test signals for a B-phase-to-C-phase fault.

a. Connect the test sources (with power off) to the relay, as in *Figure 6.6*.

This connection is a B-phase-to-C-phase fault where $I_A \approx 0$ and $I_B = -I_C$.

b. Adjust the voltage sources to provide the following test voltages: $V_A = 67\ V \angle 0°$, $V_B = 46.8\ V \angle -150°$, and $V_C = 46.8\ V \angle 150°$.

c. Set the current source for $I_B = 0.0\ A \angle -174°$.

Step 7. Apply the sources to confirm operation of MBC2.

a. Apply the source test current by slowly increasing the magnitude of I_B.

b. Observe the RELAY ELEMENT LCD screen.

Relay Word bit MBC2 asserts when $|I_B| \geq 2.5$ A, indicating that the relay impedance calculation is less than the Z2P reach setting.

Relay Self-Tests

The SEL-421 continuously runs many self-tests to detect out-of-tolerance conditions. These tests run at the same time as relay protection and automation logic, but do not degrade SEL-421 performance.

Status Warning and Status Failure

The relay reports out-of-tolerance conditions as a status warning or a status failure. For conditions that do not compromise relay protection, yet are beyond expected limits, the relay issues a status warning and continues to operate. A severe out-of-tolerance condition causes the relay to declare a status failure and enter a protection-disabled state. During a protection-disabled state, the relay suspends protection element processing and trip/close logic processing and deenergizes all control outputs. When disabled, the **ENABLED** front-panel LED is not illuminated.

The relay signals a status warning by pulsing the HALARM Relay Word bit (hardware alarm) to logical 1 for five seconds. For a Status Failure, the relay latches the HALARM Relay Word bit at logical 1. SEL-421 relays will restart on certain diagnostic failures. When this occurs, the relay will log a `Diagnostic Restart` in the SER, and the HALARM Relay Word bit will assert for five seconds. See *Appendix A: Firmware and Manual Versions* for affected firmware revisions. To provide remote status indication, connect the b contact of OUT108 to your control system remote alarm input and program the output SELOGIC control equation to respond to NOT (SALARM OR HALARM). See *Alarm Output on page U.2.43* on connecting this alarm output for the SEL-421.

If you repeatedly receive status warnings, check the relay operating conditions as soon as possible. Take preventive action early during the development of potential problems to avoid system failures. For any status failure, contact your Technical Service Center or the SEL factory immediately (see *Factory Assistance on page U.6.45*).

The relay generates an automatic status report at the serial ports for a self-test status failure if you set Port setting AUTO := Y. The relay issues a status message with a format identical to the **STATUS** command output (see *Status*), except that the power supply information from the **STA A** response is included after the SELOGIC control equation error messages.

The relay also displays status warning and status failure automatic messages on the front-panel LCD. Use the serial port **STATUS** and **CSTATUS** commands, the ACSELERATOR QuickSet HMI **Status** button, and the front-panel `RELAY STATUS` menu to display status warnings and status failures. See *STATUS on page R.9.48*, *Checking Relay Status on page U.4.10*, and *Relay Status on page U.5.32* for more information on automatic status notifications and on viewing relay status.

Status

Figure 6.31 is a sample **STATUS** screen from the Status option of the ACSELERATOR QuickSet **HMI > Meter and Control** tree view (the terminal **STATUS** report is similar). *Figure 6.32* is the **STATUS A** report showing all status information on a terminal.

Firmware Version Number

At the top of each status report the relay displays the present firmware version number that identifies the software program that controls relay functions. The firmware version is the four-place designator immediately following the relay model number (the first characters in the firmware identification string). The first character in the four-place firmware version number is R (representing Release).

For example, in *Figure 6.31* and *Figure 6.32*, the firmware version number is R101. SEL numbers subsequent firmware releases sequentially; the next revision following R101 is R102. See *Appendix A: Firmware and Manual Versions* for firmware version information.

```
Status

Relay 1                                     Date: 03/15/2001  Time: 09:11:54.451
Station A                                   Serial Number: 2001001234

FID=SEL-421-R101-V0-Z001001-D20010315       CID=0x6d72

Failures
  No Failures

Warnings

  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
```

Figure 6.31 Relay Status: ACSELERATOR QuickSet HMI

```
=>>STA A <Enter>

Relay 1                                       Date: 03/15/2001  Time: 04:48:49.938
Station A                                     Serial Number: 2001001234

FID=SEL-421-R101-V0-Z001001-D20010315      CID=0x4572

Failures
  No Failures

Warnings
  No Warnings

Channel Offsets (mV)   W=Warn    F=Fail
  CH1  CH2  CH3  CH4  CH5  CH6  CH7  CH8  CH9 CH10 CH11 CH12  MOF
    0    0    0    0    0    0    0    0    0    0    0    0    0

Power Supply Voltages (V)   W=Warn    F=Fail
  3.3V_PS  5V_PS  N5V_PS  15V_PS   N15V_PS
     3.28   4.91   -4.93   14.70    -14.79

Temperature
   23.7 degrees Celsius

Communication Interfaces

Active High Accuracy Time Synchronization Source: IRIG-B
  IRIG-B Source PRESENT

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
=>>
```

Figure 6.32 Relay Status From a STATUS A Command on a Terminal

CSTATUS

The relay also reports status information in the Compressed ASCII format when you issue the **CST** command. The Compressed ASCII status message is shown in *Figure 6.33*:

```
"RID","SID","FID","yyyy",

"relay_name","station_name","FID=SEL-xxx-x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx","yyyy"

"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"

(Month),(Day),(Year),(Hour),(Min),(Sec),(MSec),"yyyy"

"CPU_RAM","CPU_Prog","SELBOOT","CPU_Settings","DSP_RAM","DSP","DSP_Chksum","DSP_TIME
    OUT","CPU_CARD_RAM","CPU_DSP_RAM","FRONT_PANEL","CAL_BOARDA","CAL_BOARDB","Comm_
    Card_Change","Comm_Card","Comm_Card_Code","QUART","Analog_Conv","IO_1","IO_2","I
    O_3","IO_4","yyyy"

(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok
    or F),(Ok or F),(Ok or W or F),(Ok or W or F),(Ok or W or F),(Ok or W),(Ok or
    W),(ccrdh),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),"yyyy"

"AtoD_Offset","Master_Offset","3.3V_PS","5V_PS","N5V_PS","15V_PS","N15V_PS","Temp_St
    atus","Temp","FPGA","ADC_FPGA","yyyy"

(Ok or W),(Ok or W or F),(Ok or W or F),(Ok or W or F),(Ok or W or F),(Ok or W or
    F),(Ok or W or F),(Ok or W or F),(Temp value),(Ok or Fail),(Ok or Fail),"yyyy"

"Fast_Fiber_Port","MBA","MBB","Active_Time_Source","SELogic_Math","FM_Test","CCrd_Te
    st","DNP_Test","Event_Playback_Mode","Relay_Status","Port_F_Transp","Port_1_Tran
    sp","Port_2_Transp","Port_3_Transp","Port_4_Transp","Port_5_Transp","yyyy"
(Ok_or_F),(Inac or Ok or F),(Inac or Ok or F),(HIRIG or IRIG or " "), (Ok or F),
    (Enabled or Disabled),(Enabled or Disabled),(Enabled or Disabled),(Enabled or
    Disabled),(Enabled or Disabled),(F, 0 - 5),(F, 0 - 5),(F, 0 - 5),(F, 0 - 5),(F, 0
    - 5),(F, 0 - 5),"yyyy"
```

Figure 6.33 Compressed ASCII Status Message

Definitions for the items and fields in the Compressed ASCII configuration are listed below:

- yyyy is the checksum
- x is text in the FID (Firmware ID) string
- ccrd is the communications card hex code
- (description) is text that the relay supplies
- (Ok or W or F) is normal, warning, or failure, respectively

Figure 6.34 is a sample Compressed ASCII status message.

```
=>CST <Enter>

"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-421-R101-V0-Z001001-D20010315","0e06"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0ACA"
3,15,2001,13,2,26,938,"0437"
"CPU_RAM","CPU_Prog","SELBOOT","CPU_Settings","DSP_RAM","DSP","DSP_Chksum","DSP_
TIMEOUT","CPU_CARD_RAM","CPU_DSP_RAM","FRONT_PANEL","CAL_BOARD","Comm_Card","Com
m_Card_Code","QUART","Analog_Conv","IO_1","IO_2","3B86"
"Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok",,,"Ok","Ok","Ok","Ok
","12F8"
"AtoD_Offset","Master_Offset","3.3V_PS","5V_PS","N5V_PS","15V_PS","N15V_PS","Tem
p_Status","Temp","FPGA","ADC_FPGA","20C0"
"Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok",24.8,"Ok","Ok","0C9C"
"Fast_Fiber_Port","MBA","MBB","Active_Time_Source","SELogic_Math","FM_Test","CCr
d_Test","DNP_Test","Relay_Status","Port_F_Transp","Port_1_Transp","Port_2_Transp
","Port_3_Transp","Port_5_Transp","4029"
"Not_Installed","Inac","Inac"," ","Ok","Disabled","Disabled","Disabled","Enabled"
,"0","0","0","0","0","yyyy"
=>
```

Figure 6.34 Compressed ASCII CST Command on a Terminal

Relay Troubleshooting

Inspection Procedure

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

Step 1. Confirm that the power is on. Do not turn the relay off.

Step 2. Measure and record the control power voltage at the relay **POWER** terminals marked **+** and **–** on the rear-panel terminal strip.

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

Step 4. Measure and record the state of all control outputs.

Step 5. Inspect the serial communications ports cabling to be sure that a communications device is connected to at least one communications port.

Troubleshooting Procedures

Troubleshooting procedures for common problems are listed in *Table 6.9*. The table lists each symptom, possible causes, and corresponding diagnoses/ solutions. Related SEL-421 commands are listed in bold capitals. See *Section 9: ASCII Command Reference in the Reference Manual* for details on SEL-421 commands and *Section 10: Settings in the Reference Manual* for details on relay settings.

Table 6.9 Troubleshooting Procedures (Sheet 1 of 3)

Possible Cause	Diagnosis/Solution
Dark Front Panel	
Power is off.	Verify that substation battery power is operational.
Input power is not present.	Verify that power is present at the rear-panel terminal strip.
Blown power supply fuse.	Replace the fuse (see *Power Supply Fuse Replacement on page U.2.40*).
Poor contrast adjustment.	Press and hold **{ESC}** for two seconds. Press **{Up Arrow}** and **{Down Arrow}** pushbuttons to adjust contrast.
Status Failure Notice on Front Panel	
Self-test failure.	Contact the SEL factory or your Technical Service Center. The OUT108 relay control output b contacts will be closed if you programmed NOT HALARM to OUT108 (see *Alarm Output on page U.2.43*).
Alarm Output Asserts	
Power is off.	Restore power.
Blown power supply fuse.	Replace the fuse (see *Power Supply Fuse Replacement on page U.2.40*).
Power supply failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Main board or interface board failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.

Table 6.9 Troubleshooting Procedures (Sheet 2 of 3)

Possible Cause	Diagnosis/Solution
Other self-test failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
System Does Not Respond to Commands	
No communication.	Confirm cable connections and types. If correct, type **<Ctrl+X> <Enter>**. This resets the terminal program.
Communications device is not connected to the system.	Connect a communications device.
Incorrect data speed (baud rate) or other communications parameters.	Configure your terminal port parameters to the particular relay port settings. Use the front panel to check port settings (see *Set/Show on page U.5.28*).
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications (see *Communications Ports Connections on page U.2.47*).
Communications cabling error.	Check cable connections.
Handshake line conflict; system is attempting to transmit information, but cannot do so.	Check communications cabling. Use SEL communications cables, or cables you build according to SEL specifications (see *Communications Ports Connections on page U.2.47*).
System is in the XOFF state, halting communications.	Type **<Ctrl+Q>** to put the system in the XON state.
Terminal Displays Meaningless Characters	
Data speed (baud rate) is set incorrectly.	Check the terminal parameters configuration (see *Communications Ports Connections on page U.2.47*).
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Faults	
Relay is set improperly.	Review the relay settings (see *Section 1: Protection Application Examples in the Applications Handbook*).
Improper test settings.	Restore operating settings.
PT or CT connection wiring error.	Confirm PT and CT wiring.
Input voltages and currents phasing, and rotation errors.	Use relay metering. Use the **TRI** event trigger command and examine the generated event report (see *Examining Metering Quantities on page U.4.33*).
The analog input (flat multipin ribbon) cable between the input module board and the main board is loose or defective.	Reseat both ends of the analog input cable, observing proper ESD precautions (see *Installing Optional I/O Interface Boards on page U.2.15*).
Check the relay self-test status.	Take preventive action as directed by relay Status Warning and Status Failure information (see *Relay Self-Tests on page U.6.38* and *Checking Relay Status on page U.4.10*).

NOTE: If Port setting PROTO := PMU, that serial port will not respond to ASCII commands. Additionally, a PROTO := PMU port will not respond to any messages when Global setting EPMU := N.

Table 6.9 Troubleshooting Procedures (Sheet 3 of 3)

Possible Cause	Diagnosis/Solution
Tripping Output Relay Remains Closed Following a Fault	
Auxiliary contact control inputs are improperly wired.	Check circuit breaker auxiliary contacts wiring.
Control output relay contacts have burned closed.	Remove relay power. Remove the control output connection. Check continuity; a contacts will be open and b contacts will be closed. Contact the SEL factory or your Technical Service Center if continuity checks fail.
I/O interface board failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Warning	
Power supply voltage(s) are out-of-tolerance.	Log the Status Warning. If repeated warnings occur, take preventive action.
A/D converter failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Failure	
Power supply voltage(s) are out-of-tolerance.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
A/D converter failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
A/D OFFSET WARN Status Warning	
Loose ribbon cable between the input module board and the main board.	Reseat both ends of the analog input cable.
A/D converter drift.	Log the Status Warning. If repeated warnings occur, contact the SEL factory or your Technical Service Center.
Master offset drift.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Time/Date Errors	
External IRIG time source error.	Check IRIG-B time source or cables. Check **TIME Q** command or HMI SET/SHOW | Date/Time screen
1k PPS cable still connected.	Remove 1k PPS cable (see *Configuring High-Accuracy Timekeeping on page U.4.71*)
IRIG-B connected to incorrect BNC input.	Ensure that the correct BNC connector is being used. See *Figure 4.63 on page U.4.74*.
A low-priority time source error.	Check last update source (**TIME Q** command or HMI SET/SHOW | Date/Time screen). See *Table 4.9 on page U.4.71*.
Lithium clock battery failure.	Verify that the battery has failed before replacing the battery—it should last for 10 years if the relay is energized. See *Battery-Backed Clock on page U.2.11*.

Factory Assistance

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

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E-mail: info@selinc.com

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Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

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

FID=SEL-421-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx, or

FID=SEL-421-x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

You can also view the FID label from the front panel. From the ROTATING DISPLAY front-panel screen, press the **{ENT}** pushbutton to advance to the MAIN MENU screen. Use the **{Down Arrow}** pushbutton to highlight the RELAY STATUS option, and press the **{ENT}** pushbutton. The FID label displays on the screen:

SEL-421-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx, or

SEL-421-x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

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

For example,

FID=SEL-421-R115-V0-Z006005-D20051107

is firmware revision number 115, release date November 7, 2005.

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

Table A.1 Firmware Revision History (Sheet 1 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R130-V0-Z015011-D20111004 SEL-421-3-R130-V0-Z015011-D20111004	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20111215
SEL-421-2-R130-V0-Z015011-D20111004 SEL-421-3-R130-V0-Z015011-D20111004	➤ Improved reclosing function so recloser goes to lockout if circuit breaker does not open after a reclose initiate. ➤ Added CCOK bit to indicate Ethernet card is alive. ➤ Added real-time watchdog to quickly detect Ethernet card failures.	20111004
SEL-421-2-R129-V0-Z012011-D20100803 SEL-421-3-R129-V0-Z012011-D20100803	➤ Ethernet card update only (see *Table A.2*).	20101109
SEL-421-2-R129-V0-Z012011-D20100803 SEL-421-3-R129-V0-Z012011-D20100803	➤ Corrected DNP SER point initialization issue when using the Extended DNP Map. ➤ Corrected issue with the DNP3 Cold Restart operation.	20100803

Table A.1 Firmware Revision History (Sheet 2 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R128-V0-Z012011-D20090428 SEL-421-3-R128-V0-Z012011-D20090428	➤ Manual update only (see *Table A.5*).	20090715
SEL-421-2-R128-V0-Z012011-D20090428 SEL-421-3-R128-V0-Z012011-D20090428	➤ Manual update only (see *Table A.5*).	20090529
SEL-421-2-R128-V0-Z012011-D20090428 SEL-421-3-R128-V0-Z012011-D20090428	➤ Improved accuracy of fault locator when used with a fast breaker by using only full-cycle data. ➤ Improved loss-of-potential handling during the transition of a breaker from opened to closed. ➤ Corrected handling of DNP fault summary records when EVELOCK = 0.	20090428
SEL-421-2-R127-V0-Z012011-D20090218 SEL-421-3-R127-V0-Z012011-D20090218	➤ Added EPORT port setting so user can disable ports. ➤ Added MAXACC port setting so user can restrict maximum privileges on a port. ➤ Extended password length from 6 to 12 characters. ➤ Ethernet card firmware (see *Table A.2*) and manual update (see *Table A.5*).	20090218
SEL-421-2-R125-V0-Z011011-D20090105 SEL-421-3-R125-V0-Z011011-D20090105 SEL-421-R204-V0-Z007007-D20090105 SEL-421-1-R204-V0-Z007007-D20090105	**Applies to firmware version R125 only.** ➤ Modified LOP logic to include negative-sequence check when breaker is closed. ➤ Added ability to act as client for up to two remote synchrophasor units. Time align collected data with local data to permit control operations using this data. **Applies to firmware version R125 and R204.** ➤ Security correction (see www.selinc.com/privacy.htm for details). ➤ Corrected possible bad timestamps in synchrophasor messages after relay enable. ➤ Corrected issue that could cause Fast SER to stop.	20090105
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20081022
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20080917
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20080110
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20070914
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Manual update only (see *Table A.5*).	20070717

Table A.1 Firmware Revision History (Sheet 3 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223	➤ Added support for synchrophasors over Ethernet. ➤ Added TLED_17 through TLED_24 and PB9_LED through PB12_LED to the Fast Message response. ➤ Corrected intermittent pickup of RTDCOMF bit when connected to an SEL-2600. ➤ Expanded diagnostics coverage to include additional failure modes that will result in a relay restart. ➤ Modified frequency and rate-of-change of frequency (DFDT) measurements in the synchrophasor data packet. These quantities are now calculated using synchrophasor data. ➤ Added a new global setting (IRIGC) that selects if the IRIG signal uses the C37.118 control bits. ➤ Added Ethernet card information in the **ID** command.	20070223
SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Made enhancements to diagnostics. Expanded coverage to include additional failure modes that will result in a relay restart.	20070223
SEL-421-2-R122-V0-Z009009-D20061215 SEL-421-3-R122-V0-Z009009-D20061215	Note: This firmware version was not production released. See R123 above. ➤ Added support for expanded HMI features: auxiliary {TRIP}/{CLOSE} pushbuttons, 12 operator control pushbuttons, 24 target LEDs, double-height display points, and tri-colored LEDs. ➤ Added Alias Settings class. ➤ Added new DNP setting MAPSEL and implemented extended binary input map. ➤ Implemented DNP single-event mode. ➤ Increased number of SELOGIC conditional timers from 16 to 32. ➤ Decreased LOP latching delay from 60 cycles to 15 cycles. ➤ Added Fast Message commands to read database regions. ➤ Added 3I01 and 3I02 to Selectable Operating Quantity Inverse-Time Overcurrent Elements (51S). ➤ Restrained DNP power factor binary inputs from updating if voltage falls below 10 percent of nominal or Open Phase Detection Logic asserts. ➤ Modified HMI password entry so that characters are not echoed to the screen.	20061215
SEL-421-2-R121-V0-Z008008-D20060814 SEL-421-3-R121-V0-Z008008-D20060814 SEL-421-R200-V0-Z007007-D20060814 SEL-421-1-R200-V0-Z007007-D20060814	➤ Modified diagnostic failure mode management. Certain diagnostic test errors will result in a relay restart. Relay will log `Diagnostic Restart` in the SER if this event occurs.	20060814
SEL-421-2-R120-V0-Z008008-D20060808 SEL-421-3-R120-V0-Z008008-D20060808 Note: This version was not released from the factory.	➤ Fixed incorrect metering condition following a pulse of the Alternate Voltage Source (ALTV) or Alternate Current Source (ALTI) SELOGIC equations. ➤ Enhanced rms metering to properly measure analog quantities with greater than 50% harmonic content.	20060808
SEL-421-2-R119-V0-Z008008-D20060710 SEL-421-3-R119-V0-Z008008-D20060710	➤ Improvement to automatic removal of chattering SER points where the status of the chattering element is reported after it is reinserted in the SER record. ➤ Improvement to dropout time of breaker failure overcurrent fault detector under extreme subsidence current conditions.	20060710

Table A.1 Firmware Revision History (Sheet 4 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R118-V0-Z008008-D20060630 SEL-421-3-R118-V0-Z008008-D20060630	Note: Firmware version R118 and newer are not applicable to the SEL-421 and SEL-421-1. ➤ Corrected IG magnitude and angle calculations in the CEV summary report. ➤ Added IEC 61850 support for the optional Ethernet card.	20060703
SEL-421-R117-V0-Z007007-D20060413 SEL-421-1-R117-V0-Z007007-D20060413 SEL-421-2-R117-V0-Z007007-D20060413 SEL-421-3-R117-V0-Z007007-D20060413	Note: This firmware version requires the use of R109 or later firmware on any installed SEL-2701 Ethernet Card. ➤ Improved accuracy of time-tagged DNP LAN/WAN binary inputs.	20060413
SEL-421-R116-V0-Z007007-D20060126 SEL-421-1-R116-V0-Z007007-D20060126 SEL-421-2-R116-V0-Z007007-D20060126 SEL-421-3-R116-V0-Z007007-D20060126	➤ Manual update only (see *Table A.5*).	20060302
SEL-421-R116-V0-Z007007-D20060126 SEL-421-1-R116-V0-Z007007-D20060126 SEL-421-2-R116-V0-Z007007-D20060126 SEL-421-3-R116-V0-Z007007-D20060126	➤ Added support for Main Board B and interface boards INT2, INT7, and INT8 which are optoisolated versions of Main Board A and interface boards INT1, INT5, and INT6. ➤ Updated to the released (non-draft) version of C37.118 IEEE Synchrophasor Standard. ➤ Added support for SEL-421-2 and SEL-421-3. ➤ Updated to the released (non-draft) version of C37.118 IEEE Synchrophasor Standard. ➤ Added alarm points and SER settings parameter HMI Alarm in order to enable automatic HMI display of alarm points. ➤ Added analog display points. ➤ Expanded to 96 display points and changed format to display on a single line. ➤ Changed Global setting class for contact inputs to support Main Board A and Main Board B and interface boards INT1, INT2, INT4, INT5, INT6, INT7, and INT8. ➤ Added setting SCROLD for changing the ROTATING DISPLAY update rate. ➤ Added settings PB1_HMI through PB8_HMI for assigning alarm point, display point, or event summary screens to the selectable operator pushbuttons. ➤ Added settings DISP_ER and TYPE_ER for enabling and configuring automatic HMI display of event summary screens. ➤ Added setting NUM_ER to specify the number of event summary screens viewed through the operator pushbutton. ➤ Added 15 messages per second option for Global setting MRATE. ➤ Corrected the voltage check element logic which is using incorrect input voltages. ➤ Improved performance of phase directional element logic. ➤ Corrected transition from ROTATING DISPLAY to manual mode when using navigational arrows.	20060126

Table A.1 Firmware Revision History (Sheet 5 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-R115-V0-Z006006-D20051107 SEL-421-1-R115-V0-Z006006-D20051107	Note: This firmware version requires the use of R108 or later firmware on any installed SEL-2701 Ethernet card. ➤ Added DNP3 LAN/WAN support when using the SEL-2701 Ethernet Card. ➤ The **STATUS A** command will now include information on how many Telnet sessions are active. ➤ Added second file transfer session to allow access to SEL-2701 settings files (SET_DNP*n*.TXT) via FTP. ➤ Fixed the Trip Unlatch logic to ignore 52AA2 logic when NUMBK =1. ➤ SET_DNP*n*.TXT files from the SEL-2701 are now available in the relay file system and can be accessed via FTP or the ASCII **FILE** command. ➤ Added time-stamped SER data from the relay into TARGET region of the SEL-2701 DNP3 database. ➤ Fixed IRIG/HIRIG time synchronization problem to properly lock onto the incoming time signal after a year rollover. ➤ Enhanced the LOP logic to accommodate a corner case scenario. If SPO bit is set to three-pole tripping and 52AA*n* status shows breaker is open, even though it is closed (due to removing dc or settings mistake) and phase current is below the open pole detection then LOP will assert. ➤ Enhanced the **PORT 5** command to allow transparent access to the SEL-2701 user interface from the host relay.	20051107
SEL-421-R114-V0-Z005005-D20050805 SEL-421-1-R114-V0-Z005005-D20050805	➤ Adjusted processing to make synchrophasor analog quantities contemporaneous with streamed synchrophasor data. ➤ Improved POTT logic to speed up tripping in WIF applications (ELOP := Y1). ➤ Added independent two-breaker reclosing (E79 := Y1). ➤ Added single- and three-pole open interval supervision condition logic (SPOISC, SPOISD, 3POISC, 3POISD). ➤ Corrected issue where momentary setting of LOP can slow down tripping in WIF applications (ELOP = Y1). ➤ Expanded front-panel target rows from 255 to 323. ➤ Removed scaling from floating point phasor magnitudes per IEEE C37.118. ➤ Adjusted Second-of-Century (SOC) to Universal-Time-Coordination (UTC) rather than local time. ➤ Corrected issue where incoming IRIG/HIRIG data is ignored for two minutes after a year rollover. ➤ Provided autoscaling of voltage magnitudes on front-panel HMI. ➤ Corrected issue where daylight savings time (DST) or UTC offset (TUTC) assertion could corrupt SOC value.	20050805
SEL-421-R113-V0-Z004005-D20050119 SEL-421-1-R113-V0-Z004005-D20050119	➤ Improvements for manufacturability. This firmware includes all of the enhancements listed under R112, below.	20050119

Table A.1 Firmware Revision History (Sheet 6 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-R112-V0-Z004005-D20041217 SEL-421-1-R112-V0-Z004005-D20041217	Note: This firmware version was not production released. See R113, above. ➤ Added support for IEEE C37.118, Standard for Synchrophasors for Power Systems. ➤ Added Synchrophasor support to the SEL-421-1. ➤ Added PMU (Phasor Measurement Unit) to the serial port settings protocol (PROTO) options for dedicated synchrophasor communications. ➤ Removed port settings PMADDR and PMDATA. Similar functionality is now provided through Global settings, Synchrophasor category. ➤ Changed the TIME input processing to provide high-accuracy timekeeping with a GPS-synchronized IRIG-B signal applied to the IRIG-B BNC connector. ➤ Removed 1k PPS BNC input. ➤ Renamed high-accuracy timekeeping mode HIRIG (previously called PPS mode). ➤ Added timekeeping-related analog quantities for time quality (TQUAL) and UTC Offset (TUTC). ➤ Added Synchrophasor data to the analog quantities available for use in SELOGIC®. ➤ Added a rate-of-change-of-frequency calculation analog quantity, DFDT. ➤ Added time-error calculation logic, and analog quantities TE and TECORR. ➤ Added **TEC** (Time-Error Calculation) command for viewing the time-error, or pre-loading a correction value. ➤ Added support for INT4 I/O Interface Board with 24 optoisolated control inputs and 8 control outputs. ➤ Added Relay Word bits for Synchrophasor (PMU) Triggers, Time and Synchronization Control, Time-Error Calculation, and INT4 I/O Interface board support. ➤ Changed Global settings class to support new Synchrophasor settings, Time-Error Calculation settings, and settings for INT4 I/O Interface Board support. ➤ Removed Time and Date Management settings from Global settings class. ➤ Added **SER CV** and **SER RV** commands for clearing viewed SER data. ➤ Added analog quantities CTRW, CTRX, PTRY, PTRZ, based on the active group settings of the same name. ➤ Reduced minimum allowable pickup settings for the inverse-time overcurrent elements to 0.05 • I_{NOM}. ➤ Modified auto-reclose logic for two circuit breaker, three-pole cycle state to include a check for enable conditions E3PR1 and E3PR2 to properly handle reclose supervision after multi-phase faults. ➤ Corrected error in logic for breaker monitor mechanical operating time alarm that may have caused incorrect B1MSOAL operation. Error introduced in firmware revision R110. ➤ Improved faulted phase identification logic performance for isolated zero-sequence source conditions. ➤ Corrected port settings class handling of leading spaces in MIRRORED BITS® analog settings MBANA*n*. ➤ Reduced healthy voltage qualifying time from 15 to 6 cycles in 25ENBK1 and 25ENBK2 synchronism check enable logic. ➤ Corrected uncompensated synch check element logic for 25A1BK1, which may have caused incorrect assertion under test conditions.	20041217

Table A.1 Firmware Revision History (Sheet 7 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Corrected issue where a conflict in DNP processing and communications could suspend all relay communications. ➤ Corrected issue where incorrect scaling of stored values could cause an erroneous drift in metered quantities. ➤ Corrected issue where incorrect scaling of stored values could cause an erroneous drift in the metered slip frequency for synchronism check. ➤ Added Security Enhancements when used with the SEL-2701 Ethernet Processor.	
SEL-421-R111-V0-Z003004-D20040602 SEL-421-1-R111-V0-Z003004-D20040602	➤ Corrected issue where turning off power may cause a low-set (less than 50% of I_{NOM}) 50G or 67G element to inadvertently operate. ➤ Corrected issue where the dc battery monitor may report incorrect values for Vdc.	20040602
SEL-421-R110-V0-Z003004-D20030918 SEL-421-1-R110-V0-Z003004-D20030918	➤ Added fast message protocol compatibility with the SEL-2600 RTD Module. ➤ Improved distance elements. ➤ Improved out-of-step logic. ➤ Increased free-form protection SELOGIC capacity from 100 lines to 250 lines. ➤ Improved cross-country fault detection. ➤ Added high-speed distance elements to the Relay Word. ➤ Improved relay security features, including the addition of the BADPASS Relay Word bit. ➤ Increased number of SELOGIC math variables displayed from 16 to all. ➤ Addressed condition in which if IRIG-B time source is used and the date rolls over from December 31st to January 1st, the year may not increment. ➤ Corrected file command error message. ➤ Fixed condition where the SEL-421 does not send the fast message power-up bit in the status byte of the first message. ➤ Fixed condition in R109 where a file read of events or compressed history using the no modem option may cause the relay to become non-responsive. ➤ Fixed condition where significant communications traffic, i.e., MIRRORED BITS at 38400 baud with an SEL-2701 Ethernet card installed, may cause delays in servicing of low-priority background tasks.	20030918
SEL-421-R109-V0-Z002003-D20030409 SEL-421-1-R109-V0-Z002003-D20030409	➤ Fixed condition where inverse-time overcurrent protection does not operate for multiples of pickup setting greater than 50 when U1, U2, U3, U5, C1, or C5 characteristic is selected.	20030409
SEL-421-R108-V0-Z002003-D20021216 SEL-421-1-R108-V0-Z002003-D20021216	➤ Fixed condition where protection and automation latch elements may not restore to previous set state after loss of power.	20021216
SEL-421-R107-V0-Z002003-D20020918 SEL-421-1-R107-V0-Z002003-D20020918	➤ Modified handling of RTS signal with DNP protocol to properly act as a transmit enable with a non-zero PREDLY setting. ➤ Enabled MIRRORED BITS communications loopback function. ➤ Added enable condition to pole open logic so that single-pole open (SPO) indication does not operate for three-pole trip applications.	20020918

Table A.1 Firmware Revision History (Sheet 8 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-R106-V0-Z002003-D20020819 SEL-421-1-R106-V0-Z002003-D20020819	➤ Corrected issue that causes front-panel display and serial port to simultaneously lock up during settings save/rotating display change. ➤ Corrected OFF value for phase-to-phase, phase-to-ground, and ground quadrilateral distance zones. ➤ Corrected KEY1 and KEY3 pulse during relay warm start. ➤ Paused unsolicited Sequence of Events message during a file transfer. ➤ Corrected the default value for the Ground Detection Factor for DC Monitor 1.	20020819
SEL-421-R105-V0-Z002003-D20020621 SEL-421-1-R105-V0-Z002003-D20020621	➤ Updated values stored in the meter region of the communications card database to be stored in volts rather than kilovolts. ➤ Updated values stored in the meter region of the communications card database to be stored in volts rather than kilovolts.	20020621
SEL-421-R104-V0-Z002002-D20020528 SEL-421-1-R104-V0-Z002002-D20020528	➤ Corrected issue with update of Object 1 status for Object 2 default map indices over 800. ➤ Increased DNP event buffer for Object Type 2 to 1024 from 512.	20020528
SEL-421-R103-V0-Z002002-D20020417 SEL-421-1-R103-V0-Z002002-D20020417	➤ Manual update only (see *Table A.5*).	20020501
SEL-421-R103-V0-Z002002-D20020417 SEL-421-1-R103-V0-Z002002-D20020417	➤ Using a serial port for interleaved data may cause the relay to disable. This condition occurs when a communications processor is automatically retrieving data from the relay simultaneously with a serial port terminal session.	20020417
SEL-421-R102-V0-Z002001-D20020403 SEL-421-1-R102-V0-Z002001-D20020403	➤ Added new analog quantities for use in the following SELOGIC control equations: Terminal W and X current magnitudes Terminal Y and Z voltage magnitudes Instantaneous sequence quantities Contact inputs ➤ Initial Release with Synchrophasor Measurement capability to the SEL-421 (not in the SEL-421-1). ➤ Added VAZ, VBZ, VCZ settings options to SYNCP. ➤ Added VAY, VBY, VCY settings options to SYNCS1, SYNCS2, and ASYNCS2. ➤ Added ACOS, ASIN, CEIL, FLOOR, and LOG math functions to SELOGIC® control equations. ➤ Modified CHI output for SEL-2030 compatibility.	20020403
SEL-421-R101-V0-Z001001-D20020104 SEL-421-1-R101-V0-Z001001-D20020104	➤ Added 8-cycle lockout for subsequent ALTI or ALTV switches. ➤ Initial SEL-421-1 version.	20020108
SEL-421-R100-V0-Z001001-D20010703	➤ Initial SEL-421 version.	20010703

Table A.2 lists the Ethernet card firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.2 Ethernet Card Firmware Revision History

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2702-R113-V0-Z002002-D20111215 SLBT-2701-R103-V0-Z000000-D20080820	➤ Added support for database references in IEC 61850 configuration files.	20111215
SEL-2702-R112-V0-Z002002-D20110715 SLBT-2701-R103-V0-Z000000-D20080820	➤ Improved port failover performance.	20111004
SEL-2702-R111-V0-Z002002-D20101109 SLBT-2701-R103-V0-Z000000-D20080820	➤ Added support for multicast synchrophasors.	20101109
SEL-2702-R110-V0-Z001001-D20090205 SLBT-2701-R103-V0-Z000000-D20080820	➤ Improved security (see www.selinc.com/privacy.htm for details).	20090205
SEL-2702-R109-V0-Z001001-D20081022 SLBT-2701-R103-V0-Z000000-D20080820	➤ Updated IEC 61850 firmware to streamline MMS processing and improve TCP/IP connections. ➤ Security correction (see www.selinc.com/privacy.htm for details). ➤ Corrected issue that could cause the Ethernet card to fail under heavy DNP traffic.	20081022
SEL-2702-R108-V0-Z001001-D20080729 SLBT-2701-R103-V0-Z000000-D20080820	➤ Corrected issue that could cause the Ethernet card to fail under heavy DNP traffic.	20080917
SEL-2702-R107-V0-Z001001-D20080107 SLBT-2701-R102-V0-Z000000-D20051107	➤ Enhanced IEC 61850 with KEMA certification updates. ➤ Added indication of ICD/CID file parse failure to the SEL-2702 user interface (**ID**, **STA**, **GOO** commands).	20080110
SEL-2702-R106-V0-Z001001-D20070914 SLBT-2701-R102-V0-Z000000-D20051107	➤ Added additional improvements to IEC 61850 control operation priorities when using IEC 61850 GOOSE messaging. ➤ Corrected issue where communications card MAC address is deleted when upgrading from SEL-2701 firmware version R105 to an SEL-2702.	20070914
SEL-2702-R104-V0-Z001001-D20070717 SLBT-2701-R102-V0-Z000000-D20051107	➤ Made improvements to IEC61850 control operation priorities when using IEC61850 GOOSE messaging. ➤ Allocated additional memory for read/write of large IEC 61850 messages. ➤ Fixed ability to pulse Breaker and Latch control bits using DNP LAN/WAN when DNPMAP = AUTO.	20070717
SEL-2702-R103-V0-Z001001-D20070223 SLBT-2701-R102-V0-Z000000-D20051107	➤ Added support for synchrophasors over Ethernet.	20070223
SEL-2702-R101-V0-Z000000-D20060808 SLBT-2701-R102-V0-Z000000-D20051107	➤ Added support for pulse operations on DNP LAN/WAN control points, both paired and unpaired. ➤ Added ability to sense local operations and update IEC 61850 origination category.	20060808
SEL-2702-R100-V0-Z000000-D20060630 SLBT-2701-R102-V0-Z000000-D20051107	➤ Initial version.	20060703

The optional Ethernet card (SEL-2701 or SEL-2702) must be paired with a compatible SEL-421 or SEL-421 version. You may need to upgrade your SEL-421 firmware to access features in new versions of the Ethernet cards. *Table A.1* includes notes on SEL-421 modifications that support new features of the Ethernet cards.

To find the firmware revision number in your Ethernet card, first connect to the SEL-421 with the **ACC** command. View the FIDs with the **VERSION** command. Look for the Ethernet card Firmware Identification (FID) label in the response under Communications Card:

FID=SEL-270x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

In the FID label, the 4 digits after "SEL" indicate which Ethernet card is installed. The firmware revision number follows the R and the release date follows the D.

For example,

SEL-2701-R108-V0-Z002001-D20051205

is for an SEL-2701 Ethernet card, firmware revision number 108, release date December 5, 2005.

Table A.3 lists current Ethernet card firmware versions with compatible SEL-421 versions.

Table A.3 Compatible SEL-421 and Ethernet Card Firmware Versions

SEL-421 Firmware	Ethernet Card	Ethernet Card Firmware
R123 or higher	SEL-2702	R103 or higher
R118–R122	SEL-2702	R100–R101
R115–R116; R200 or higher	SEL-2701	R106 or higher
R114 or lower	SEL-2701	R105 or lower

Newer SEL-2702 card firmware (R106 and higher) uses a different software library from lower versions and is unable to process version 001 CID files. ACSELERATOR Architect generates CID files from ICD files so the ICD file version number and CID file version number are the same. If downloaded to the Ethernet card, an incompatible CID file will generate file parse errors during processing and disable the IEC 61850 protocol.

If you perform an Ethernet card firmware upgrade that spans different file version compatibilities, the relay may not be able to process the stored CID file. See the *Ethernet Port Firmware Upgrade Instructions* in the *SEL-400 Series Firmware Upgrade Instructions* for CID file conversion procedures.

See *Table A.4* for compatibilities between ACSELERATOR Architect, ICD/CID file, and Ethernet card firmware versions.

Table A.4 ACSELERATOR Architect CID File Compatibility

ACSELERATOR Architect Software Version	ACSELERATOR Architect ICD/CID File Version	SEL-2702 Card Firmware
All versions	Ver 001	R100–R106
R.1.1.69.0 or higher	Ver 002 (all)	R107 or higher

Instruction Manual

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

Table A.5 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.5 Instruction Manual Revision History (Sheet 1 of 17)

Revision Date	Summary of Revisions
20111215	**User's Guide** Section 2 ➤ Updated *Specifications*. Appendix A ➤ Updated for Ethernet card firmware version R113. **Reference Manual** Section 3 ➤ Updated *Table 3.27 Math Error Examples*. Section 6 ➤ Updated *Table 6.24 SEL-421 DNP3 Object List*. Section 10 ➤ Updated *Table 10.10 Settings Group Selection*.
20111004	**User's Guide** Appendix A ➤ Updated for firmware version R130. ➤ Updated for Ethernet card firmware version R112. **Reference Manual** Section 2 ➤ Added information about reclose cycle operations in under *Single-Pole Mode* and *Three-Pole Mode* in *One Circuit Breaker Auto-Reclose Modes*. Section 4 ➤ Added description of Relay bit CCOK actions in *Ethernet Card*. Appendix A ➤ Updated *Table A.1: Relay Word Bits: Relay Alarms*. ➤ Updated *Table A.35: Relay Word Bits: Relay Alarms*.
20101109	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R111.
20100803	**User's Guide** Appendix A ➤ Updated for firmware version R129.
20090715	**Reference Manual** Section 2 ➤ Added information about reclose cycle operations.

Table A.5 Instruction Manual Revision History (Sheet 2 of 17)

Revision Date	Summary of Revisions
20090529	**User's Guide** Section 1 ➤ Removed reference to 10BASE-FL communications card option. Section 2 ➤ Removed reference to 10BASE-FL communications card option. ➤ Removed *Figure 2.44: Two 10BASE-FL Port Configuration*, *Figure 2.45: 100BASE-FX and 10BASE-FL Port Configuration*, and *Figure 2.46: 10BASE-FL and 10/100BASE-T Port Configuration*. **Applications Handbook** Section 7 ➤ Removed reference to 10BASE-FL communications card option from *Table 7.2: Ethernet Connection Options*.
20090428	**User's Guide** Appendix A ➤ Updated for firmware version R128.
20090218	**User's Guide** Section 4 ➤ Updated *Changing the Default Passwords* to add Access Level C information. ➤ Updated *Figure 4.5: Access Level Structure*. ➤ Updated *Table 4.3: SEL-421 Access Levels* and *Table 4.4: SEL-421 Access Level Commands and Passwords*. ➤ Updated *Communications Ports Access Levels* to reflect new Access Level C port settings. ➤ Updated steps under *Passwords*. Appendix A ➤ Updated for Ethernet card firmware version R110. ➤ Updated for firmware version R127. **Reference Manual** Section 9 ➤ Modified *Password* to reflect the extended password length from 6 to 12 characters. Section 10 ➤ Updated *Table 10.93: Protocol Selection*.

Table A.5 Instruction Manual Revision History (Sheet 3 of 17)

Revision Date	Summary of Revisions
20090105	**User's Guide** Section 1 ➤ Updated *Table 1.1: Application Highlights*. Section 4 ➤ Added description of **CAL** access level. Appendix A ➤ Updated for firmware version R125 (SEL-421-2, -3) and R204 (SEL-421-0, -1). **Reference Manual** Section 7 ➤ Added synchrophasor settings MRTCDLY, RTCRATE, PMUMODE, RTCID. ➤ Updated *Table 7.1: PMU Settings in the SEL-421 for C37.118 Protocol in Global Settings* and *Table 7.3: SEL-421 Serial Port Settings for Synchrophasors*. ➤ Added *Table 7.11: Synchrophasor Client Status Bits*, *Table 7.12: Remote Synchrophasor Data Bits*, and *Table 7.14: Synchrophasor Aligned Analog Quantities*. Section 9 ➤ Added **CAL**, **COM RTC**, **COM RTC *c* C** and **COM RTC *c* R**, **MET RTC**, and **RTC** commands and descriptions. ➤ Modified the **PAS** command description. Section 10 ➤ Updated *Table 10.15: Synchronized Phasor Measurement*. ➤ Added *Table 10.99: PMU Protocol Settings*. Appendix A ➤ Updated *Table A.1: Alphabetic List of Relay Word Bits* and *Table A.50: Time and Synchronization Control Bits*. ➤ Added *Table A.55: RTC Remote Digital Status* and *Table A.56: Fast Operate Transmit Bits*. Appendix B ➤ Updated *Table B.1: Analog Quantities Sorted Alphabetically* and *Table B.2: Analog Quantities Sorted by Function*.
20081022	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R109 and SELBOOT firmware version R103.
20080917	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R108 and SELBOOT firmware version R103.

20080110	**User's Guide**
	Appendix A
	➤ Updated for Ethernet card firmware version R107.
	➤ Added *Table A.4: ACSELERATOR Architect CID File Compatibility*.
	Reference Manual
	Section 4
	Added descriptions of **ID**, **STA**, and **GOO** commands ICD/CID file parse failure indication.
	Section 8
	➤ Added and edited tables to document new ICD file versions supported by ACSELERATOR Architect version R.1.1.69.0.
	  ➢ Added *Table 8.7: ICD Logical Nodes Summary*.
	  ➢ Updated *Table 8.8: Logical Device: PRO (Protection)* through *Table 8.11: Logical Device: ANN (Annunciation)*.

Table A.5 Instruction Manual Revision History (Sheet 4 of 17)

<table>
<tr><th>Revision Date</th><th>Summary of Revisions</th></tr>
<tr><td>20070914</td><td>User's Guide
Appendix A
➤ Updated for Ethernet card firmware version R106.
Reference Manual
Added details and examples to indicate how to get SOE-quality timestamped data over a DNP LAN/WAN connection in the following sections.
Section 4
➤ Updated titles in Table 4.19–Table 4.27.
Section 6
➤ Updated Table 6.21, Table 6.26, and Table 6.28.
➤ Added Figure 6.4.</td></tr>
<tr><td>20070717</td><td>User's Guide
Section 5
➤ Added SER section to Front-Panel Menus and Screens.
➤ Revised Local Control Bits in Front-Panel Menus and Screens.
Appendix A
➤ Updated for Ethernet card firmware version R104.
Reference Manual
Section 2
➤ Updated Figure 2.10, Figure 2.11, Figure 2.12, Figure 2.14, and Figure 2.15.
Section 10
➤ Added Local Bit SELOGIC table.
Appendix A
➤ Added LB_DP01 through LB_DP32 to Table A.1.
➤ Added LB_SP01 through LB_SP32 to Table A.1.
➤ Added Relay Word bits: Local Bit Supervision and Status table for rows 284–291 to Table A.53.</td></tr>
<tr><td>20070223</td><td>User's Guide
Appendix A
➤ Updated for firmware version R123 (SEL-421-2, -3) and R201 (SEL-421-0, -1).

Applications Handbook
Section 6
➤ Added LED and pushbutton statuses from expanded HMI to Table 6.7.
Section 7
➤ Added synchrophasor to list of available protocols.

Reference Manual
Section 1
➤ Added Frequency Estimation Provided by Synchrophasor.
Section 4
➤ Added the Ethernet card as one of the available communications interfaces for the Phasor Measurement Protocol.
Section 7
➤ Added Table 7.2 for the Time and Date Management setting IRIGC.
➤ Added Table 7.4 Ethernet Port Settings for Synchrophasors.
➤ Changed FREQ to FREQ_PM (frequency measurement using phasor measurement quantities) in Table 7.9.
➤ Added synchrophasor protocol availability when EPMIP := Y.
➤ Revised example logic settings in Table 7.15.
Section 10
➤ Added Table 10.16 for the Time and Date Management setting IRIGC.</td></tr>
</table>

Table A.5 Instruction Manual Revision History (Sheet 5 of 17)

Revision Date	Summary of Revisions

20061215	Note: This version was not released from the factory. The 20070223 version contains the following changes.
	User's Guide
	Section 1
	➤ Added *Alias Settings* and *Auxiliary {TRIP}/{CLOSE} Pushbuttons* to *Features*.
	➤ Added INT3 to *Models and Options*.
	➤ Added INT3 to *SEL-421 Versions and Supported Features*.
	➤ Added INT3 and Auxiliary {TRIP}/{CLOSE} Pushbuttons to *Specifications*.
	
	Section 2
	➤ Added INT3 to *Control Inputs*.
	➤ Added *Figure 2.12*.
	➤ Added INT3 to *Table 2.3* and *Table 2.4*.
	➤ Added INT3 to *I/O Interface Board Jumpers*.
	➤ Added *Figure 2.22*.
	➤ Added *Auxiliary {TRIP}/{CLOSE} Pushbutton and Breaker Status LED Jumpers (select models only)* with *Table 2.8*, *Table 2.9*, and *Table 2.10*.
	➤ Updated *Figure 2.26* to include optional pushbuttons.
	➤ Added *Figure 2.32*.
	➤ Add INT3 to *Control Inputs*.
	➤ Added *Auxiliary {TRIP}/{CLOSE} Pushbuttons and OPEN/CLOSED LEDs (select models only)* to *Connection*.
	➤ Added *Figure 2.51*.
	
	Section 4
	➤ Added Alias Settings to *Table 4.5*.
	➤ Edited *Figure 4.13* and *Figure 4.14* for Display Points Text Size parameter.
	➤ Added *Alias Settings*.
	➤ Added *Figure 4.15*, *Figure 4.16*, and *Figure 4.17*.
	
	Section 5
	➤ Added *Figure 5.2*.
	➤ Updated *Front-Panel Layout* for HMI changes: expanded pushbuttons, expanded target LEDs, tri-color LEDs, and auxiliary {TRIP}/{CLOSE} pushbuttons.
	➤ Updated *Figure 5.5*, *Figure 5.11*, and *Example 5.2* to include double-height Display Points.
	➤ Updated *Display Points* and *Table 5.4* and *Table 5.5* to include Text Size parameter.
	➤ Updated *Relay Elements (Relay Word Bits)* for Alias impact.
	➤ Updated *Operation and Target LEDs* for HMI changes: expanded target LEDs and tri-color LEDs.
	➤ Updated *Figure 5.43* for expanded target LEDs.
	➤ Added *Table 5.11*.
	➤ Updated *Recloser Status* for expanded target LEDs.
	➤ Added *Miscellaneous Status* and *Synchrophasor Status* for expanded target LEDs.
	➤ Updated *Figure 5.44*, *Table 5.13*, and *Figure 5.45* for expanded pushbuttons.
	
	Section 6
	➤ Updated *Figure 6.8* for Alias impact.
	
	Appendix A
	➤ Updated for firmware version R122.
	
	Applications Handbook
	Section 1
	➤ Updated 3I0*n* 51S quantity in the following:
	  ➢ *230 kV Overhead Transmission Line Example* and *Table 1.6*.
	  ➢ *500 kV Parallel Transmission Lines With Mutual Coupling Example* and *Table 1.13*.
	  ➢ *345 kV Tapped Overhead Transmission Line Example* and *Table 1.21*.
	  ➢ *EHV Parallel 230 kV Underground Cables Example* and *Table 1.31*.

Table A.5 Instruction Manual Revision History (Sheet 6 of 17)

Revision Date	Summary of Revisions
	Section 3 ➤ Added INT3 to *Data Processing*. ➤ Added *Alias Names* to *Event Reports, Event Summaries, and Event Histories*. ➤ Updated *Digital Section of the Event Report* and *Settings Section of the Event Report* for Alias impact. ➤ Updated *Figure 3.12* and *Figure 3.13* to include Alias settings. Section 6 ➤ Updated *Table 6.3* to include new database region 20 messages. **Reference Manual** Section 1 ➤ Updated *Figure 1.17* to decrease LOP latching delay from 60 cycles to 15 cycles. ➤ Updated *Table 1.56*, *Table 1.57*, and *Table 1.58* for 3I0*n* 51S quantity. ➤ Updated *Figure 1.70* to include NUMBK = 2 logic input. Section 3 ➤ Added Aliases to *Table 3.1*. ➤ Updated *Table 3.2* and *Table 3.13* to include 32 conditioning timers. ➤ Added *Aliases*. ➤ Added *Example 3.10*. ➤ Updated *Table 3.28* to include 32 conditioning timers. Section 5 ➤ Updated *Table 5.10* to include Alias settings. Section 6 ➤ Updated *Table 6.6* for new settings EVELOCK, MINDIST, and MAXDIST. ➤ Updated *Table 6.7* new setting for MAPSEL. ➤ Updated *Default Data Map* to explain new reference maps. ➤ Updated *Table 6.10* to include two reference maps and new index 182. ➤ Added *Reading Relay Event Data* section. ➤ Corrected Bit values in *Table 6.14*. ➤ Updated *Figure 6.2* for new setting MAPSEL. ➤ Updated *Table 6.18* for new settings EVELOCK, MINDIST, and MAXDIST. Section 9 ➤ Added ***SET T*** and ***SHO T*** commands. ➤ Updated ***TAR*** command to include aliases. Section 10 ➤ Added Alias Settings and *Table 10.1* and *Figure 10.1*. ➤ Updated *Table 10.11* for new setting RSTDNPE. ➤ Updated *Table 10.52*, *Table 10.53*, and *Table 10.54* for 3I0*n* 51S quantity. ➤ Updated *Table 10.65* for new BK1MCL default settings. ➤ Updated *Table 10.70* for new BK1MTR default settings. ➤ Updated *Table 10.79* for HMI changes: tri-color LEDs, expanded pushbuttons, and expanded target LEDs. ➤ Updated Table 10.81 for expanded pushbuttons. ➤ Updated *Table 10.83* and *Table 10.84* for Text Size parameter. ➤ Updated *Table 10.96* for new settings EVELOCK, MINDIST, and MAXDIST. ➤ Added *Table 10.101*. Appendix A ➤ Updated *Table A.1* to increment certain Relay Word bit rows and added Relay Word bits EVELOCK, PB9_PUL-PB12PUL, PCT17Q–PCT32Q, PB_CLSE, PB_TRIP, RSTDNPE, and TLED_17–TLED_24. ➤ Added PCT17Q–PCT32Q to *Table A.27*. ➤ Added RSTDNPE to *Table A.39*. ➤ Added *Table A.50*. ➤ Added *Table A.52*.

Table A.5 Instruction Manual Revision History (Sheet 7 of 17)

Revision Date	Summary of Revisions
	Appendix B ➤ Added PCT17DO–PCT32DO and PCT17PU–PCT32PU to *Table B.1* and *Table B.2*.
20060814	**User's Guide** Section 6 ➤ In *Status Warning and Status Failure* added information about the relay restarting on certain diagnostic failures. Appendix A ➤ Updated for firmware version R121 (SEL-421-2, -3) and R200 (SEL-421-0, -1). **Applications Handbook** Section 3 ➤ Added diagnostic restart to the list of conditions captured by the SER.
20060808	Note: This version was not released from the factory. The 20060814 version contains the following changes. **User's Guide** Section 2 ➤ Updated Ethernet card rear-panel layouts. Appendix A ➤ Updated for firmware revision R120. ➤ Updated for SEL-2702 firmware version R101. **Reference Manual** Section 6 ➤ Documented additional support for paired control outputs (BO). Section 8 ➤ Clarified multiple client access for Unbuffered Reports. ➤ Added Protocol Implementation Conformance Statement (PICS).
20060710	**User's Guide** Appendix A ➤ Updated for firmware revision R119.
20060703	**User's Guide** Section 2 ➤ Included network port configurations and safety warnings in *Network Connection*. Appendix A ➤ Updated for firmware revision R118. **Applications Handbook** Section 7 ➤ Revised FTP File Structure description in *FTP*. ➤ Specified CID file location in *FTP*. **Reference Manual** Section 4 ➤ Added Ethernet card commands to *Ethernet Card Commands*. ➤ Added "keep alive" settings ETCPKA, KAIDLE, KAINTV, and KACNT to *Ethernet Network Operation Settings*. ➤ Revised FTP File Structure description in *File Structure*. Section 6 ➤ Increased CCINs from 32 to 128 (DNP LAN/WAN map) and adjusted indices as necessary. Section 8 ➤ Added new IEC 61850 section (replaced the UCA2 section).

Table A.5 Instruction Manual Revision History (Sheet 8 of 17)

Revision Date	Summary of Revisions
	Section 9 ➤ Added information about new **ID** command response for an Ethernet card with IEC 61850 support. Appendix A ➤ Increased CCINs from 32 to 128 (Relay Word bits) and adjusted row numbers for those and all subsequent rows. Glossary ➤ Added IEC 61850 entries. Miscellaneous ➤ Removed GOMSFE appendix. ➤ Removed references to UCA2 and GOMSFE. ➤ Modified GOOSE references to describe IEC 61850 GOOSE.
20060413	**User's Guide** Appendix A ➤ Updated for firmware version R117.
20060302	**User's Guide** Appendix A ➤ Corrected Z-numbers in *Table A.1* for firmware versions R115 and R116. ➤ Corrected Z-number in *Table A.1* for firmware version R116.
20060126	Preface ➤ Moved cautions, warnings, and dangers in English and French from reverse of front cover to the *Preface*. **User's Guide** Section 1 ➤ Added a table distinguishing the versions of the SEL-421. ➤ Added information about Main Board A and Main Board B and interface boards INT2, INT7, and INT8. Section 2 ➤ Corrected *Figure 2.5* to remove positive polarity mark. ➤ Corrected number of Form C outputs for INT6 shown in *Table 2.4*. ➤ Adjusted *Table 2.5* to add more description on the control enable jumper. ➤ Added more description of the J18C jumper. ➤ Added information that BADPASS Relay Word bit pulses after three unsuccessful password entry attempts in the Alarm Output subsection. ➤ Added Main Board B and interface boards INT2, INT7, and INT8. ➤ Added rear-panel drawings: 4U Rear Panel, Main Board B, INT8 I/O Interface Board; 5U Rear Panel, Main Board A, INT6 and INT4 I/O Interface Board; 5U Rear Panel, Main Board B, INT2 and INT7 I/O Interface Board. Section 3 ➤ Corrected reference to the Settings Editor Selection dialog box. ➤ Updated *Figure 3.16: Setting the Relay Part Number in ACSELERATOR*. Section 4 ➤ Corrected *Figure 4.1*. ➤ Made typographical corrections. ➤ Added footnote to *Table 4.2*. ➤ Corrected the IRIG-B jitter tolerance level. ➤ Modified *Figure 4.41* to reflect new SER setting parameter HMI Alarm. ➤ Modified *Figure 4.42* to reflect Report Settings upload. ➤ Modified *Figure 4.45* to reflect new SER setting parameter HMI Alarm. ➤ Updated *Table 4.8* with the information for Main Board A and Main Board B and interface board INT2, INT7, and INT8. ➤ Updated *Figure 4.57* to reflect changes to Control Inputs settings and added *Figure 4.58* to reflect changes to Main Board Control Inputs settings.

Table A.5 Instruction Manual Revision History (Sheet 9 of 17)

Revision Date	Summary of Revisions
	Section 5 ➤ Made typographical corrections. ➤ Updated figures throughout to correct **Enter** pushbutton graphic. ➤ Updated figures throughout to correct footer capitalization errors. ➤ Added alarm points screen to *Figure 5.4*. ➤ Added *Alarm Points*. ➤ Modified *Display Points* to allow for analog quantity display points. ➤ Added note clarifying the line current and voltage source for protection functions. ➤ Modified *Events* to explain event summary access options. ➤ Modified *Front-Panel Automatic Messages* to include alarm points. ➤ Added alarm points screen to *Figure 5.32*. ➤ Added application references for TRGTR Relay Word bit and group setting ULTR. ➤ Modified *Front-Panel Operator Control Pushbuttons* to include alarm points, display points, and event summary viewing options. Section 6 ➤ Made typographical corrections. ➤ Modified *Figure 6.9* to update for new front-panel settings categories. ➤ Modified *Figure 6.14* to reflect new SER setting parameter HMI Alarm. Command Summary ➤ Added footnote explaining that the SEL-421-1 and SEL-421-2 have only one instance of automation logic settings. **Applications Handbook** Section 1 ➤ Corrected *Equation 1.74*. ➤ Clarified when BK1CLST will assert. Section 2 ➤ Revised *Example 2.3* and *Example 2.4*. ➤ Corrected name of Relay Word bit B1ITAL to B1BITAL. ➤ Corrected typographical errors. ➤ Corrected range for EDEM in *Table 2.20*. Section 3 ➤ Corrected typographical errors. ➤ Modified Setting SER Points and Aliases section to reflect new SER setting parameter HMI Alarm. ➤ Updated *Figure 3.1* to include Main Board A and Main Board B and Interface Boards INT1, INT2, INT4, INT5, INT6, INT7, and INT8. ➤ Added IN101 through IN107 analog channels in *Figure 3.5*. Section 4 ➤ Corrected *Figure 4.5* and *Figure 4.6*. Section 6 ➤ Added note about IRIG-B time signal and high-accuracy IRIG timekeeping. **Reference Manual** Section 1 ➤ Corrected Relay Word bit names DSTART to DSTRT and NSTART to NSTRT. ➤ Corrected a cross reference in *Table 1.13*. ➤ Corrected *Figure 1.25*. ➤ Corrected *Figure 1.26*. ➤ Corrected *Figure 1.68*. ➤ Added the heading Trip Logic Settings and Relay Word Bits, text, and footnotes to *Table 1.72*. ➤ Corrected Relay Word bit names BTPA to ATPB and CTPA to ATPC in *Table 1.73*.

Table A.5 Instruction Manual Revision History (Sheet 10 of 17)

Revision Date	Summary of Revisions
	Section 2 ➤ Changed title of section to *Auto-Reclosing and Synchronism Check*. ➤ Deleted duplicative *Figure 2.10: Voltage Check Elements*. ➤ Added note about voltage check elements and synchronism check feature. ➤ Corrected *Figure 2.21* and *Figure 2.22*. Section 3 ➤ Corrected typographical errors. Section 4 ➤ Corrected cross references on first page. Section 5 ➤ Corrected typographical error. ➤ Updated *Table 4.4*. Section 6 ➤ Corrected typographical errors. ➤ Added information about setting TIMERQ. Section 7 ➤ Added footnote to *Table 7.9*. ➤ Added a row (15 option to the range of MRATE in the Global setting class) to *Table 7.11*. ➤ Corrected typographical errors. ➤ Corrected footnote to *Table 7.16*. Section 9 ➤ Corrected typographical errors. ➤ Corrected *Table 9.113*. Section 10 ➤ Corrected typographical errors. ➤ Updated *Table 10.5*, *Table 10.6*, *Table 10.7*, and *Table 10.8* for the changes in the Control Inputs, Main Board Control Inputs, Interface Board #1 Control Inputs, and Interface Board #2 Control Inputs settings. ➤ Added 15 option to the range of MRATE setting in *Table 10.19*. ➤ Added new front-panel settings categories to *Table 10.78*. ➤ Added new setting SCROLD to *Table 10.80*. ➤ Added new front-panel settings *Table 10.81* and *Table 10.82*. ➤ Split Display Points and Aliases table into two separate tables, *Table 10.81* and *Table 10.82*, for Boolean and Analog Display Points. ➤ Added new setting parameter HMI Alarm to *Table 10.86*. Appendix A ➤ Corrected typographical errors. Appendix B ➤ Corrected typographical errors.
20051107	Revised entire manual to include new DNP3 LAN/WAN functionality.
20050805	**General** ➤ Added independent two-breaker reclosing functionality (E79 := Y1). **User's Guide** Section 4 ➤ Added note describing internal clock year value behavior in *TIME Q Descriptions*. Appendix A ➤ Updated *Table A.1* with firmware version R114.

Table A.5 Instruction Manual Revision History (Sheet 11 of 17)

Revision Date	Summary of Revisions
	Applications Handbook Section 1 ➤ Added text explaining auto-reclose sequence for both dependent (E79 := Y) and independent (E79 := Y1) two-breaker reclosing applications. ➤ Updated E79 entries in *Table 1.6*, *Table 1.13*, *Table 1.21*, *Table 1.31*, and *Table 1.39*. ➤ Added E79 row to *Table 1.40*. **Reference Manual** Section 1 ➤ Updated *Figure 1 26*. ➤ Updated *Figure 1 63* to match firmware change. ➤ Updated *Figure 1 65*. Section 2 ➤ Added text explaining two auto-reclose modes available for two-breaker reclosing applications. ➤ Added text explaining single-pole open interval supervision condition (SPOISC) and corresponding timer (SPOISD) for single-pole two-circuit-breaker auto-reclosing applications. ➤ Added text detailing both dependent (E79 := Y) and independent (E79 := Y1) three-pole two-circuit-breaker auto-reclosing applications. ➤ Added text explaining three-pole open interval supervision condition (3POISC) and corresponding timer (3POISD) for three-pole two-circuit-breaker auto-reclosing applications. ➤ Modified *Figure 2 6* title (added “E79 := Y”). ➤ Added *Figure 2 7* (“Line-Open Logic Diagram When E79 := Y1”). ➤ Modified *Figure 2 13* title (added “E79 := Y”). ➤ Modified *Figure 2 15* title (added “E79 := Y”). ➤ Updated E79 entries in *Table 2 19* and *Table 2 20*. Section 10 ➤ Updated E79 entry in *Table 10 29*. ➤ Updated *Table 10 64* to include new settings SPOISC and SPOISD. ➤ Updated *Table 10 65* to include new settings 3POISC and 3POISD. Appendix A ➤ Updated *Table A.1* to include new Relay Word Bits SPOISC and 3POISC. ➤ Updated *Table A.2* footnote describing internal clock year value behavior. ➤ Updated *Table A.9* to include new Relay Word Bits SPOISC and 3POISC. ➤ Updated *Table A.50* footnote describing internal clock year value behavior.
20050119	**User’s Guide** Appendix A ➤ Updated *Table A.1* and *Table A.5* with firmware version R113.
20041217	**General** ➤ Changed DNP 3.0 to DNP3 throughout manual. ➤ Added contents list to the start of each section. ➤ Added Glossary entries for C37.118, Fast Message, IEEE, RTD, Time Error, Time Quality, and TVE. ➤ Updated Glossary entry for PPS. **User’s Guide** Section 1 ➤ Updated *Specifications*. Section 2 ➤ Added INT4 I/O Interface Board information, including instructions for using the optoisolated control inputs to detect ac control signals. ➤ Updated rear-panel figures and related text to show new TIME input configuration. ➤ Removed *Front-Panel Labels*—the configurable label instructions are now in a separate package included with the relay.

Table A.5 Instruction Manual Revision History (Sheet 12 of 17)

Revision Date	Summary of Revisions
	Section 3
	➤ Updated ACSELERATOR SEL-5030 screen captures and related text.
	Section 4
	➤ Updated ACSELERATOR SEL-5030 screen captures and related text.
	➤ Updated serial number label in *Figure 4 1* and related text.
	➤ Added Access Level information to *Table 4 5*.
	➤ Added INT4 I/O Interface Board control inputs information and *Figure 4 8*.
	➤ Updated Configuring High-Accuracy Timekeeping subsection.
	Section 6
	➤ Updated ACSELERATOR SEL-5030 screen captures and related text.
	Appendix A
	➤ Updated *Table A.1* and *Table A.5* with firmware version R112 and literature changes.
	Applications Handbook
	Section 2
	➤ Updated *Time-Synchronized Metering*.
	Section 3
	➤ Updated *Figure 3.1*.
	Section 4
	➤ Updated *Relay Configuration for High-Accuracy Timekeeping*.
	➤ Updated *State Estimation Verification*.
	Section 6
	➤ Updated *Table 6.7*.
	Reference Manual
	Section 1
	➤ Updated *Current and Voltage Source Selection*, including new *Figure 1.1* through *Figure 1.4*, and new *Table 1.1* through *Table 1.3*.
	➤ Updated *Frequency Estimation*, and added rate-of-change-of-frequency, DFDT, to *Table 1.13* and *Figure 1.12*.
	➤ Added *Time-Error Calculation*.
	➤ Updated pickup setting range for Inverse-Time Overcurrent Elements in *Table 1.57*.
	➤ Renamed and clarified *Trip During Open-Pole Time Delay.*
	Section 2
	➤ Reorganized subsections.
	➤ Clarifications made to *Figure 2.10* and *Figure 2.11*. Updated *Figure 2.15* to reflect changes made to the two circuit breaker, three-pole auto-reclose logic.
	➤ Added *Voltage Checks for Auto-Reclosing and Manual Closing* (in place of previous *Voltage Checks* subsection).
	➤ Reduced healthy voltage qualifying time from 15 to 6 cycles in *Figure 2.28*.
	Section 3
	➤ Added Multiple Setting Groups subsection to describe this feature already in the SEL-421.
	Section 4
	➤ Updated *Table 4.1* and *Figure 4.2*.
	Section 5
	➤ Updated *Table 5.2*.
	➤ Added Automatic Messages and Timeout subsections to describe these features already in the SEL-421.
	➤ Removed Fast Message Synchrophasor information—now covered in *Section 7*.
	Section 6
	➤ Updated *Table 6.10* to include analog quantity information, and the new TECORR value (Object 40, 41; Index 1).
	➤ Updated Application Example to show DNP Map settings entry, including custom scaling.

Table A.5 Instruction Manual Revision History (Sheet 13 of 17)

Revision Date	Summary of Revisions
	Section 7 ➤ Added new *Section 7: Synchrophasors*. Includes information on both IEEE C37.118 and SEL Fast Message synchrophasor protocols. Section 9 ➤ Updated **MET PM** command description. ➤ Added **SER CV**, **SER RV**, and **TEC** commands. Section 10 ➤ Removed Global settings for Time and Date Management. ➤ Added Global settings for INT4 I/O Interface Board (*Table 10.5*, *Table 10.8*, and *Table 10.10*), Time-Error Calculation (*Table 10.12*), and Synchrophasors (*Table 10.3* and *Table 10.14*). ➤ Updated Group settings 51S1P, 51S2P, 51S3P (*Table 10.50* through *Table 10.52*). ➤ Added PMU protocol option to Port settings (*Table 10.90*). ➤ Removed Port settings PMADDR and PMDATA. Appendix A ➤ Updated tables with new Relay Word bits, and new row numbers for Relay Word bits above row 96. Appendix B ➤ Reordered tables to match Appendix A (alphabetic list first). ➤ Added function subheadings to *Table B.2*. ➤ Added new analog quantities DFDT, TUTC, TQUAL, TECORR, TE, CTRW, CTRX, PTRY, PTRZ, and 66 synchrophasor measurement quantities.
20040602	**User's Guide** Appendix A ➤ Included information on new firmware R111.
20030918	Introduced new typographic and step instruction conventions in the Preface and applied them throughout the manual. **User's Guide** Section 1 ➤ Added EA Certification statement to *Specifications*. Appendix A ➤ Included information on new firmware R110 and instruction manual changes. ➤ Added EA Certification statement to *Specifications*. **Applications Handbook** Section 1 ➤ Modified the application examples to include new information on communications-assisted protection schemes and out-of-step logic. **Reference Manual** Section 1 ➤ Added information (including new logic diagram figures) about communications-assisted protection schemes, out-of-step logic, and trip logic. ➤ Updated *Figure 1.65*, *Figure 1.66*, and *Figure 1.68*. Section 3 ➤ Changed quantity of free-form protection SELOGIC. ➤ Updated *Table 3.6*, *Table 3.7*, and *Table 3.8*. Section 5 ➤ Added new section on using the SEL-2600A RTD module.

Table A.5 Instruction Manual Revision History (Sheet 14 of 17)

Revision Date	Summary of Revisions
	Section 9 ➤ Added OFF to the XC setting range. Appendix A ➤ Added new Relay Word bits to support communications-assisted protection schemes, security, and the SEL-2600 RTD module. Appendix B ➤ Added analog quantities to support the SEL-2600A RTD module.
20030409	**User's Guide** Section 2 ➤ Modified all of the installation instructions that include removing and reattaching the front panel to reflect changes in the front-panel hardware. ➤ Replaced *Figure 2.26* with latest rear-panel diagram. Appendix A ➤ Included information on new firmware R109.
20021216	**User's Guide** Section 1 ➤ Added Terminal Connection information. ➤ Corrected typographic error. ➤ Corrected pickup accuracy for *Station DC Battery System Monitor.* Appendix A ➤ Included information on new firmware R108. **Applications Handbook** Section 1 ➤ Corrected *Equation 1.74*. Section 2 ➤ Clarified synchrophasor measurement statement. **Reference Manual** Section 1 ➤ Added NAND gates (SPOA, SPOB, and SPOC) at the DTA, DTB, and DTC SELOGIC Settings inputs in *Figure 1.60, Trip During Pole Open to TPA*. Section 3 ➤ Corrected *Example 3.6*. ➤ Change “conditioning” to “sequence” in the sentence before *Figure 3.8* and in the caption for *Figure 3.8*. ➤ Corrected typographical error.
20020918	**User's Guide** Appendix A ➤ Included information on new firmware R107. **Reference Manual** Section 1 ➤ Modified *Figure 1.9* and *Figure 1.63*.
20020819	**User's Guide** Appendix A ➤ Included information on new firmware R106. ➤ Removed “Instruction” from appendix title.

Table A.5 Instruction Manual Revision History (Sheet 15 of 17)

Revision Date	Summary of Revisions
20020621	Removed Manual Change Information section and integrated it into User's Guide *Appendix A: Firmware and Instruction Manual Versions*. **User's Guide** Section 2 ➤ Updated *Figure 2.2*, *Figure 2.3*, *Figure 2.10*, *Figure 2.13*, *Figure 2.21*, *Figure 2.25*, *Figure 2.27*, and *Figure 2.28*. Appendix A ➤ Firmware updated. **Reference Manual** Section 6 ➤ Updated *Table 6.9*. ➤ Updated *Table 6.10*.
20020528	**User's Guide** Appendix A ➤ Firmware updated. **Reference Manual** Section 6 ➤ Updated *Table 6.5*.
20020501	**Reference Manual** Section 6 ➤ Updated *Table 6.17*. Appendix C ➤ All UCA2 control points were made readable. Default data were set for the UCA2 FAULT model.
20020417	**User's Guide** Appendix A ➤ Firmware updated. Spurious Quart interrupts caused by varying character spacing will cause the relay to disable. This condition occurs when a communications processor is automatically retrieving data from the relay simultaneously with a serial port terminal session.
20020403	➤ Initial Release with Synchrophasor Measurement capability to SEL-421. ➤ Added VAZ, VBZ, VCZ settings options to SYNCP. ➤ Added VAY, VBY, VCY settings options to SYNCS1, SYNCS2 and ASYNCS2. ➤ Added ACOS, ASIN, CEIL, FLOOR and LOG math functions to SELOGIC control equations. ➤ Added new analog quantities for use in SELOGIC control equations: ➢ Terminal W and X current magnitudes ➢ Terminal Y and Z voltage magnitudes ➢ Instantaneous sequence quantities ➢ Contact inputs ➤ Modified CHI output for SEL-2030 compatibility.

Table A.5 Instruction Manual Revision History (Sheet 16 of 17)

Revision Date	Summary of Revisions
20020108	➤ SEL-421-1 Relay introduction. ➤ Configurable front-panel labels. ➤ I and V Source Selection settings clarifications. Preface ➤ Added Notes explanation. **User's Guide** Section 1 ➤ Added description of SEL-421-1 Relay. ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Added Humidity to *Specifications*. ➤ Added SEL-421-1 Relay Maximum Operating Time to *Specifications*. ➤ Revised Power and Energy in *Specifications*. Section 2 ➤ Added *Front-Panel Labels* to describe configurable front-panel labels. Section 3 ➤ Added description of ACSELERATOR® SEL-5030 software Analysis function keys F2, F3, and F4. ➤ Revised Relay Editor settings tree view operation. Section 4 ➤ Included front-panel label kit in shipped items list. ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Fixed *Figure 4.45* and setting SER example procedure. ➤ Fixed *Figure 4.55* and setting control input/52A example procedure. Section 5 ➤ Added descriptions of configurable front-panel labels. Section 6 ➤ Updated ACSELERATOR software screen captures. **Applications Handbook** Section 1 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Corrected control inputs in *Auto-Reclose Examples*. ➤ Added explanation for missing setting 3PMRCD (Manual Close Reclaim Time Delay) in *Recloser Closing*. Section 2 ➤ Corrected communications equipment battery voltage to 48 Vdc in *Figure 2.12*. ➤ Revised text and *Table 2.16* for power and energy specifications. Section 3 ➤ Corrected Compressed ASCII command example in Event File Download procedure.

Table A.5 Instruction Manual Revision History (Sheet 17 of 17)

Revision Date	Summary of Revisions
	Reference Manual Section 1 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Included more explanation for settings ALTI and ALTV in *Current and Voltage Source Selection*. ➤ Corrected setting ORDER text in *ORDER*. ➤ Supplemented *Series-Compensation Line Logic* material. Section 3 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. Section 6 ➤ Updated setting TIMERQ to reflect correct prompt and default (no change in the relay). Section 9 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. Appendix A ➤ Added Notes to flag the differences in the SEL-421-1 Relay. Index ➤ Added index entries for configurable front-panel labels, SEL-421-1 Relay, and series-compensated line.
20010703	Initial version.

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Glossary

“a” Contact A breaker auxiliary contact (ANSI Standard Device Number 52A) that closes when the breaker is closed and opens when the breaker is open.

“a” Output A relay control output that closes when the output relay asserts.

“b” Contact A breaker auxiliary contact (ANSI Standard Device Number 52B) that opens when the breaker is closed and closes when the breaker is open.

“b” Output A relay control output that opens when the output relay asserts.

“c” Contact A breaker auxiliary contact that can be set to serve either as an “a” contact or as a “b” contact.

“c” Output An output with both an “a” output and “b” output sharing a common post.

3U, 4U, 5U The designation of the vertical height of a device in rack units. One rack unit, U, is approximately 1.75 inches or 44.45 mm.

A Abbreviation for amps or amperes; unit of electrical current flow.

ABS Operator An operator in math SELOGIC® control equations that provides absolute value.

AC Ripple The peak-to-peak ac component of a signal or waveform. In the station dc battery system, monitoring ac ripple provides an indication of whether the substation battery charger has failed.

Acceptance Testing Testing that confirms that the relay meets published critical performance specifications and requirements of the intended application. Such testing involves testing protection elements and logic functions when qualifying a relay model for use on the utility system.

Access Level A relay command level with a specified set of relay information and commands. Except for Access Level 0, you must have the correct password to enter an access level.

Access Level 0 The least secure and most limited access level. No password protects this level. From this level, you must enter a password to go to a higher level.

Access Level 1 A relay command level you use to monitor (view) relay information. The default access level for the relay front panel.

Access Level 2 The most secure access level where you have total relay functionality and control of all settings types.

Access Level A A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Automation, Alias, Global, Front Panel, Report, Port, and DNP settings.

Access Level B A relay command level you use for Access Level 1 functions plus circuit breaker control and data.

Access Level O A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Output, Alias, Global, Front Panel, Report, Port, and DNP settings.

Access Level P A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Protection, SELOGIC, Alias, Global, Group, Breaker Monitor, Front Panel, Report, Port, and DNP settings.

ACSELERATOR Architect® SEL-5032 Software ACSELERATOR Architect is an add-on to the ACSELERATOR Suite that utilizes the IEC 61850 Substation Configuration Language to configure SEL IEDs.

ACSELERATOR QuickSet® SEL-5030 Software A Windows®-based program that simplifies settings and provides analysis support.

ACSI Abstract Communications Service Interface for the IEC 61850 protocol. Defines a set of objects, a set of services to manipulate and access those objects, and a base set of data types for describing objects.

Active Settings Group The settings group that the SEL-421 is presently using from among six settings groups available in the relay.

Admittance The reciprocal of impedance; I/V.

Advanced Settings Settings for customizing protection functions; these settings are hidden unless you set EADVS := Y and EGADVS := Y.

Analog Quantities Variables represented by such fluctuating measurable quantities as temperature, frequency, current, and voltage.

AND Operator Logical AND. An operator in Boolean SELOGIC control equations that requires fulfillment of conditions on both sides of the operator before the equation is true.

ANSI Standard Device Numbers A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include the following:

21	Distance element
25	Synchronism-check element
27	Undervoltage Element
32	Directional Elements
50	Overcurrent Element
51	Inverse-Time Overcurrent Element
52	AC Circuit Breaker
59	Overvoltage Element
67	Definite Time Overcurrent
79	Recloser
86	Breaker Failure Lockout
89	Disconnect

These numbers are frequently used within a suffix letter to further designate their application. The suffix letters used in this instruction manual include the following:

P	Phase Element
G	Residual/Ground Element
N	Neutral/Ground Element
Q	Negative-Sequence (3I2) Element

Anti-Aliasing Filter A low pass filter that blocks frequencies too high for the given sampling rate to accurately reproduce.

Apparent Power, S Complex power expressed in units of volt-amps (VA), kilovolt-amps (kVA), or megavolt-amps (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: S = P + jQ. This is power at the fundamental frequency only; no harmonics are included in this quantity.

Arcing Resistance The resistance in the arc resulting from a power line fault.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The SEL-421 uses ASCII text characters to communicate using front-panel and rear-panel EIA-232 serial ports on the relay and through virtual serial ports.

ASCII Terminal A terminal without built-in logic or local processing capability that can only send and receive information.

Assert To activate. To fulfill the logic or electrical requirements needed to operate a device. To set a logic condition to the true state (logical 1) of that condition. To apply a closed contact to an SEL-421 input. To close a normally open output contact. To open a normally closed output contact.

AT Modem Command Set Dialing String Standard The command language standard that Hayes Microcomputer Products, Inc. developed to control auto-dial modems from an ASCII terminal (usually EIA-232 connected) or a PC (personal computer) containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, baud rate, passwords, relay elements, and other information that an IED (an SEL-2020/2030 communications processor) needs to automatically communicate with relays.

Automatic Messages Messages including status failure and status warning messages that the relay generates at the serial ports and displays automatically on the front-panel LCD.

Automatic Reclose Automatic closing of a circuit breaker after a breaker trip by a protective relay.

Automation Variables Variables that you include in automation SELOGIC control equations.

Auto-Reclose-Drive-to-Lockout A logical condition that drives the auto-reclose function out of service with respect to a specific circuit breaker.

Autotransformer A transformer with at least two common windings.

AX-S4 MMS "Access for MMS" is an IEC 61850, UCA2, and MMS client application produced by SISCO, Inc., for real-time data integration in Microsoft Windows-based systems supporting OPC and DDE. Included with AX-S4

MMS is the interactive MMS Object Explorer for browser-like access to IEC 61850 / UCA2 and MMS device objects.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Best Choice Ground Directional Supervision™ logic An SEL logic that determines the directional element that the relay uses for ground faults.

Bit Label The identifier for a particular bit.

Bit Value Logical 0 or logical 1.

Block Trip Extension Continuing the blocking signal at the receiving relay by delaying the dropout of Relay Word bit BT.

Blocking Signal Extension The blocking signal for the DCB (directional comparison blocking) trip scheme is extended by a time delay on dropout timer to prevent unwanted tripping following current reversals.

Bolted Fault A fault with essentially zero impedance or resistance between the shorted conductors.

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators such as AND, NOT, and OR.

Breaker Auxiliary Contact An electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A form-a breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed and opens when the breaker is open. A form-b breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Breaker-and-a-half Configuration A switching station arrangement of three circuit breakers per two circuits; the two circuits share one of the circuit breakers.

Buffered Report IEC 61850 IEDs can issue buffered reports of internal events (caused by trigger options data-change, quality-change, and data-update). These event reports can be sent immediately or buffered (to some practical limit) for transmission, such that values of data are not lost due to transport flow control constraints or loss of connection. Buffered reporting provides sequence-of-events (SOE) functionality.

C37.118 IEEE C37.118, Standard for Synchrophasors for Power Systems

Category A collection of similar relay settings.

CCVT Coupling-capacitor voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CVT.

Checksum A method for checking the accuracy of data transmission involving summation of a group of digits and comparison of this sum to a previously calculated value.

CID Checksum identification of the firmware.

CID File IEC 61850 Configured IED Description file. XML file that contains the configuration for a specific IED.

Circuit Breaker Failure Logic This logic within the SEL-421 detects and warns of failure or incomplete operation of a circuit breaker in clearing a fault or in performing a trip or close sequence.

Circuit Breaker History Report A concise circuit breaker event history that contains as many as 128 events. This breaker history report includes circuit breaker mechanical operation times, electrical operation times, interrupted currents, and dc battery monitor voltages.

Circuit Breaker Report A full report of breaker parameters for the most recent operation. These parameters include interrupted currents, number of operations, and mechanical and electrical operating times among many parameters.

Class The first level of the relay settings structure including Global, Group, Breaker Monitor, Port, Report, Front Panel, DNP settings, Protection SELOGIC control equations, Automation SELOGIC control equations, and Output SELOGIC control equations.

Cold Start Beginning a system from power up without carryover of previous system activities.

Commissioning Testing Testing that serves to validate all system ac and dc connections and confirm that the relay, auxiliary equipment, and SCADA interface all function as intended with your settings. Perform such testing when installing a new protection system.

Common Class Components Composite data objects that contain instances of UCA standard data types.

Common Data Class IEC 61850 grouping of data objects that model substation functions. Common Data Classes include Status information, Measured information, Controllable status, Controllable analog, Status settings, Analog settings, and Description information.

Common Inputs Relay control inputs that share a common terminal.

Common Time Delay Both ground and phase distance protection follow a common time delay on pickup.

Common Zone Timing Both ground and phase distance protection follow a common time delay on pickup.

Communications Protocol A language for communication between devices.

Communications-Assisted Tripping Circuit breaker tripping resulting from the transmission of a control signal over a communications medium.

Comparison Boolean SELOGIC control equation operation that compares two numerical values. Compares floating-point values such as currents, total counts, and other measured and calculated quantities.

COMTRADE Abbreviation for Common Format for Transient Data Exchange. The SEL-421 supports the IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999.

Conditioning Timers Timers for conditioning Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state.

Contact Input See Control input.

Contact Output See Control output.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

Control Input Relay inputs for monitoring the state of external circuits. Connect auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay outputs that affect the state of other equipment. Connect control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

COS Operator Operator in math SELOGIC control equations that provides the cosine function.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

Cross-country fault A cross-country fault consists of simultaneous separate single phase-to-ground faults on parallel lines.

CT Current transformer.

CT Subsidence Current Subsidence current appears as a small exponentially decaying dc current with a long time constant. This current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load.

CTR Current transformer ratio.

Current Reversal Guard Logic Under this logic, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal when a reverse-looking element detects an external fault.

Current Transformer Saturation The point of maximum current input to a current transformer; any change of input beyond the saturation point fails to produce any appreciable change in output.

CVT Capacitive voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CCVT.

CVT Transient Blocking Logic that prevents transient errors on capacitive voltage transformers from causing false operation of Zone 1 mho elements.

CVT Transient Detection Logic Logic that detects transient errors on capacitive voltage transformers.

Data Attribute In the IEC 61850 protocol, the name, format, range of possible values, and representation of values being communicated.

Data Bit A single unit of information that can assume a value of either logical 0 or logical 1 and can convey control, address, information, or frame check sequence data.

Data Class In the IEC 61850 protocol, an aggregation of classes or data attributes.

Data Label The identifier for a particular data item.

Data Object In the IEC 61850 protocol, part of a logical node representing specific information (status or measurement, for example). From an object-oriented point of view, a data object is an instance of a data class.

DC Offset A dc component of fault current that results from the physical phenomenon preventing an instantaneous change of current in an inductive circuit.

DCB (Directional Comparison Blocking) A communications-assisted protection scheme. A fault occurring behind a sending relay causes the sending relay to transmit a blocking signal to a remote relay; the blocking signal interrupts the tripping circuit of the remote relay and prevents tripping of the protected line.

DCE Devices Data communication equipment devices (modems).

DCUB (Directional Comparison Unblocking) A communications-assisted tripping scheme with logic added to a POTT scheme that allows high-speed tripping of overreaching elements for a brief time during a loss of channel. The logic then blocks trip permission until the communications channel guard returns for a set time.

Deadband The range of variation an analog quantity can traverse before causing a response.

Deassert To deactivate. To remove the logic or electrical requirements needed to operate a device. To clear a logic condition to its false state (logical 0). To open the circuit or open the contacts across an SEL-421 input. To open a normally open output contact. To close a normally closed output contact.

Debounce Time The time that masks the period when relay contacts continue to move after closing; debounce time covers this indeterminate state.

Default Data Map The default map of objects and indices that the SEL-421 uses in DNP protocol.

Delta A phase-to-phase series connection of circuit elements, particularly voltage transformers or loads.

Demand Meter A measuring function that calculates a rolling average or thermal average of instantaneous measurements over time.

Direct Tripping Local or remote protection elements provide tripping without any additional supervision.

Directional Start A blocking signal provided by reverse reaching elements to a remote terminal used in DCB communications-assisted tripping schemes. If the fault is internal (on the protected line), the directional start elements do not see the fault and do not send a blocking signal. If the fault is external (not on the protected line), the directional start elements start sending the block signal.

Directional Supervision The relay uses directional elements to determine whether protective elements operate based on the direction of a fault relative to the relay.

Disabling Time Delay A DCUB scheme timer (UBDURD) that prevents high-speed tripping following a loss-of-channel condition.

Distance Calculation Smoothness A relay algorithm that determines whether the distance-to-fault calculation varies significantly or is constant.

Distance Protection Zone The area of a power system where a fault or other application-specific abnormal condition should cause operation of a protective relay.

DMTC Period The time of the demand meter time constant in demand metering.

DNP (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol.

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. You can set the time, in the case of a logic variable timer, or the dropout time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

DTE Devices Data terminal equipment (computers, terminals, printers, relays, etc.).

DTT (Direct Transfer Trip) A communications-assisted tripping scheme. A relay at one end of a line sends a tripping signal to the relay at the opposite end of the line.

Dumb Terminal See ASCII terminal.

DUTT (Direct Underreaching Transfer Trip) A communications-assisted tripping scheme. Detection of a Zone 1 fault at either end of a line causes tripping of the local circuit breaker as well as simultaneous transmission of a tripping signal to the relay at the opposite end of the line. The scheme is said to be underreaching because the Zone 1 relays at both ends of the line reach only 80 percent (typically) of the entire line length.

Echo The action of a local relay returning (echoing) the remote terminal permissive signal to the remote terminal when the local breaker is open or a weak infeed condition exists.

Echo Block Time Delay A time delay that blocks the echo logic after dropout of local permissive elements.

Echo Duration Time Delay A time delay that limits the duration of the echoed permissive signal.

ECTT (Echo Conversion to Trip) An element that allows a weak terminal, after satisfaction of specific conditions, to trip by converting an echoed permissive signal to a trip signal.

EEPROM Electrically Erasable Programmable Read-Only Memory. Nonvolatile memory where relay settings, event reports, SER records, and other nonvolatile data are stored.

EHV Extra high voltage. Voltages greater than 230 kV.

EIA-232 Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

EIA-485 Electrical standard for multidrop serial data communications interfaces, based on the standard EIA/TIA-485. Formerly known as RS-485.

Electrical Operating Time Time between trip or close initiation and an open phase status change.

Electromechanical Reset Setting of the relay to match the reset characteristics of an electromechanical overcurrent relay.

End-Zone Fault A fault at the farthest end of a zone that a relay is required to protect.

Energy Metering Energy metering provides a look at imported power, exported power, and net usage over time; measured in MWh (megawatt hours).

Equalize Mode A procedure where substation batteries are overcharged intentionally for a preselected time in order to bring all cells to a uniform output.

ESD (Electrostatic Discharge) The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

Ethernet A network physical and data link layer defined by IEEE 802.2 and IEEE 802.3.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; fault location; maximum fault phase current; active group at the trigger instant; and targets.

Event Report A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or ASCII **TRI** command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, fault location, time source, recloser shot counter, prefault and fault voltages, currents, and sequence current, and MIRRORED BITS® communications channel status (if enabled).

The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

EXP Operator Math SELOGIC control equation operator that provides exponentiation.

F_TRIG Falling-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a falling edge.

Fail-Safe Refers to an output that is open during normal relay operation and closed when relay power is removed or if the relay fails. Configure alarm outputs for fail-safe operation.

Falling Edge Transition from logical 1 to logical 0.

Fast Hybrid Control Output A control output similar to, but faster than, the hybrid control output. The fast hybrid output uses an insulated gate bipolar junction transistor (IGBT) to interrupt (break) high inductive dc currents and to very rapidly make and hold the current until a metallic contact operates, at which time the IGBT turns off and the metallic contact holds the current. Unlike the hybrid control output, this output is not polarity sensitive; reversed polarity causes no misoperations.

Fast Meter SEL binary serial port command used to collect metering data with SEL relays.

Fast Operate SEL binary serial port command used to perform control with SEL relays.

Fast Message SEL binary serial port protocol used for Fast SER, Fast Message Synchrophasors, and RTD communications.

Fault Type Identification Selection Logic the relay uses to identify balanced and unbalanced faults (FIDS).

FID Relay firmware identification string. Lists the relay model, firmware version and date code, and other information that uniquely identifies the firmware installed in a particular relay.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Flashover A disruptive discharge over the surface of a solid dielectric in a gas or liquid.

Float High The highest charging voltage supplied by a battery charger.

Float Low The lowest charging voltage supplied by a battery charger.

Free-Form Logic Custom logic creation and execution order.

Free-Form SELOGIC Control Equations Free-form relay programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

FTP File transfer protocol.

Function In IEC 61850, task(s) performed by the substation automation system, i.e., by application functions. Generally, functions exchange data with other functions. Details are dependent on the functions involved.

Functions are performed by IEDs (physical devices). A function may be split into parts residing in different IEDs but communicating with each other (distributed function) and with parts of other functions. These communicating parts are called logical nodes.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

Functional Component Portion of a UCA GOMSFE brick dedicated to a particular function including status, control, and descriptive tags.

Fundamental Frequency The component of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Global Settings General settings including those for relay and station identifiers, number of breakers, date format, phase rotation, nominal system frequency, enables, station dc monitoring, control inputs, settings group selection, data reset controls, frequency tracking, time and date management, and current and voltage source selection.

GOMSFE Generic Object Model for Substation and Feeder Equipment; a system for presenting and exchanging IED data.

GOOSE IEC 61850 Generic Object Oriented Substation Event. GOOSE objects can quickly and conveniently transfer status, controls, and measured values among peers on an IEC 61850 network.

GPS Global Positioning System. Source of position and high-accuracy time information.

Ground Directional Element Priority The order the relay uses to select directional elements to provide ground directional decisions; relay setting ORDER.

Ground Distance Element A mho or quadrilateral distance element the relay uses to detect faults involving ground along a transmission line.

Ground Fault Loop Impedance The impedance in a fault-caused electric circuit connecting two or more points through ground conduction paths.

Ground Overcurrent Elements Elements that operate by comparing a residual ground calculation of the three-phase inputs with the residual overcurrent threshold setting. The relay asserts ground overcurrent elements when a relay residual current calculation exceeds ground current setting thresholds.

Ground Quadrilateral Distance Protection Ground distance protection consisting of a four-sided characteristic on an R-X diagram.

Ground Return Resistance Fault resistance that can consist of ground path resistance typically in tower footing resistance and tree resistance.

Guard-Present Delay A timer that determines the minimum time before the relay reinstates permissive tripping following a loss-of-channel condition in the DCUB communications-assisted tripping scheme; relay setting GARD1D.

GUI Graphical user interface.

Hexadecimal Address A register address consisting of a numeral with an “h” suffix or a “0x” prefix.

High-Resolution Data Capture Reporting of 3 kHz low-pass analog filtered data from the power system at each event trigger or trip at high sample rates of 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second.

HMI Human machine interface.

Homogeneous System A power system with nearly the same angle (<5 ° difference) for the impedance angles of the local source, the protected line, and the remote source.

HV High voltage. System voltage greater than or equal to 100 kV and less than 230 kV.

Hybrid Control Output Contacts that use an insulated gate bipolar junction transistor (IGBT) in parallel with a mechanical contact to interrupt (break) high inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients. These contacts are polarity dependent and cannot be used to switch ac control signals.

IA, IB, IC Measured A-phase, B-phase, and C-phase currents.

ICD File IEC 61850 IED Capability Description file. XML file that describes IED capabilities, including information on logical node and GOOSE support.

IEC 61850 Internationally standardized method of communications and integration conceived with the goal of supporting systems of multivendor IEDs networked together to perform protection, monitoring, automation, metering, and control.

IED Intelligent electronic device.

IEEE Institute of Electrical and Electronics Engineers, Inc.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero.

IGBT Insulated gate bipolar junction transistor.

Independent Zone Timing The provision of separate zone timers for phase and ground distance elements.

Infinite Bus A constant-voltage bus.

Input Conditioning The establishment of debounce time and assertion level.

Instance A subdivision of a relay settings class. Group settings have several subdivisions (Group 1–Group 6), while the Global settings class has one instance.

Instantaneous Meter Type of meter data presented by the SEL-421 that includes the present values measured at the relay ac inputs. The word “Instantaneous” is used to differentiate these values from the measurements presented by the demand, thermal, energy, and other meter types.

IP Address An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the IP address of the destination. The format of an IP address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

IRIG-B A time code input that the relay can use to set the internal relay clock.

Jitter Time, amplitude, frequency, or phase-related abrupt, spurious variations in duration, magnitude, or frequency.

L/R Circuit inductive/resistive ratio.

Latch Bits Nonvolatile storage locations for binary information.

LED Light-emitting diode. Used as indicators on the relay front panel.

Left-Side Value LVALUE. Result storage location of a SELOGIC control equation.

Line Impedance The phasor sum of resistance and reactance in the form of positive-sequence, negative-sequence, and zero-sequence impedances of the protected line.

LMD SEL distributed port switch protocol.

LN Operator Math SELOGIC control equation operator that provides natural logarithm.

Load Encroachment The load-encroachment feature allows setting of phase overcurrent elements and phase distance elements independent of load levels.

Local Bits The Relay Word bit outputs of local control switches that you access through the SEL-421 front panel. Local control switches replace traditional panel-mounted control switches.

Lockout Relay An auxiliary relay that prevents operation of associated devices until it is reset either electrically or by hand.

Logical 0 A false logic condition, dropped out element, or deasserted control input or control output.

Logical 1 A true logic condition, picked up element, or asserted control input or control output.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function.

Loss of Channel Loss of guard and no permissive signal from communications gear in a DCUB (directional comparison unblocking scheme) for either two or three terminal lines.

Loss of Guard No guard signal from communications gear.

Loss of Potential Loss of one or more phase voltage inputs to the relay secondary inputs.

Low-Level Test Interface An interface that provides a means for interrupting the connection between the relay input transformers and the input processing module and allows inserting reduced-scale test quantities for relay testing.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

Maintenance Testing Testing that confirms that the relay is measuring ac quantities accurately and verifies correct functioning of auxiliary equipment, scheme logic, and protection elements.

Math Operations Calculations for automation or extended protection functions.

Math Operators Operators that you use in the construction of math SELOGIC control equations to manipulate numerical values and provide a numerical base-10 result.

Maximum Dropout Time The maximum time interval following a change of input conditions between the deassertion of the input and the deassertion of the output.

Maximum/Minimum Meter Type of meter data presented by the SEL-421 that includes a record of the maximum and minimum of each value, along with the date and time that each maximum and minimum occurred.

Mechanical Operating Time Time between trip initiation or close initiation and the change in status of an associated circuit breaker auxiliary 52A normally open contacts.

Mho Characteristic A directional distance relay characteristic that plots a circle for the basic relay operation characteristic on an R-X diagram.

MIRRORED BITS® Communications Patented relay-to-relay communications technique that sends internal logic status, encoded in a digital message, from one relay to the other. Eliminates the need for some communications hardware.

MMS Manufacturing Messaging Specification, a data exchange protocol used by UCA.

MOD Motor-operated disconnect.

Model Model of device (or component of a device) including the data, control access, and other features in UCA protocol.

Motor Running Time The circuit breaker motor running time. Depending on your particular circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressor motor.

MOV Metal-oxide varistor.

Negation Operator A SELOGIC control equation math operator that changes the sign of the argument. The argument of the negation operation is multiplied by –1.

Negative-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°, and have clockwise phase rotation with current and voltage maxima that occur differently from that for positive-sequence configuration. If positive-sequence maxima occur as ABC, negative-sequence maxima occur as ACB.

Negative-Sequence Current Supervision Pickup An element allowed to operate only when a negative-sequence current exceeds a threshold.

Negative-Sequence Directional Element An element that provides directivity by the sign, plus or minus, of the measured negative-sequence impedance.

Negative-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced negative-sequence set of voltage sources.

Negative-Sequence Overcurrent Elements Elements that operate by comparing a negative-sequence calculation of the three-phase secondary inputs with negative-sequence overcurrent setting thresholds. The relay asserts these elements when a relay negative-sequence calculation exceeds negative-sequence current setting thresholds.

Negative-Sequence Voltage-Polarized Directional Element These directional elements are 32QG and 32Q. 32QG supervises the ground distance elements and residual directional overcurrent elements; 32Q supervises the phase distance elements.

NEMA National Electrical Manufacturers' Association.

Neutral Impedance An impedance from neutral to ground on a device such as a generator or transformer.

No Current/Residual Current Circuit Breaker Failure Protection Logic Logic for detecting and initiating circuit breaker failure protection with a logic transition, or when a weak source drives the fault or a high-resistance ground fault occurs.

Nondirectional Start A blocking signal provided by nondirectional overcurrent elements to a remote terminal used in DCB communications-assisted tripping schemes. The nondirectional start elements start sending the block signal.

Nonhomogeneous System A power system with a large angle difference (>5° difference) for the impedance angles of the local source, the protected line, and the remote source.

Nonvolatile Memory Relay memory that persists over time to maintain the contained data even when the relay is deenergized.

NOT Operator A logical operator that produces the inverse value.

OR Operator Logical OR. A Boolean SELOGIC control equation operator that compares two Boolean values and yields either a logical 1 if either compared Boolean value is logical 1 or a logical 0 if both compared Boolean values are logical 0.

OSI Open Systems Interconnect. A model for describing communications protocols. Also an ISO suite of protocols designed to this model.

Out-of-Step Blocking Blocks the operation of phase distance elements during power swings.

Out-of-Step Tripping Trips the circuit breaker(s) during power swings.

Override Values Test values you enter in Fast Meter, DNP, and communications card database storage.

Parentheses Operator Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Peak Demand Metering Maximum demand and a time stamp for phase currents, negative-sequence and zero-sequence currents, and powers. The SEL-421 stores peak demand values and the date and time these occurred to nonvolatile storage once per day, overwriting the previously stored value if the new value is larger. Should the relay lose control power, the relay restores the peak demand information saved at 23:50 hours on the previous day.

Phase Distance Element A mho distance element the relay uses to detect phase-to-phase and three-phase faults at a set reach along a transmission line.

Phase Overcurrent Element Elements that operate by comparing the phase current applied to the secondary current inputs with the phase overcurrent setting. The relay asserts these elements when any combination of the phase currents exceeds phase current setting thresholds.

Phase Rotation The sequence of voltage or current phasors in a multiphase electrical system. In an ABC phase rotation system, the B-phase voltage lags the A-phase voltage by 120°, and the C-phase voltage lags B-phase voltage by 120°. In an ACB phase rotation system, the C-phase voltage lags the A-phase voltage by 120°, and the B-phase voltage lags the C-phase voltage by 120°.

Phase Selection Ability of the relay to determine the faulted phase or phases.

Pickup Time The time measured from the application of an input signal until the output signal asserts. You can set the time, as in the case of a logic variable timer, or the pickup time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

Polarizing Memory A circuit that provides a polarizing source for a period after the polarizing quantity has changed or gone to zero.

Pole Discrepancy A difference in the open/closed status of circuit breaker poles. The relay continuously monitors the status of each circuit breaker pole to detect open or close conditions among the three poles.

Pole-Open Logic Logic that determines the conditions that the relay uses to indicate an open circuit breaker pole.

Pole Scatter Deviation in operating time between pairs of circuit breaker poles.

Port Settings Communications port settings such as Data Bits, Speed, and Stop Bits.

Positive-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°. With conventional rotation in the counter-clockwise direction, the positive-sequence current and voltage maxima occur in ABC order.

Positive-Sequence Current Restraint Factor, a2 This factor compensates for highly unbalanced systems with many untransposed lines and helps prevent misoperation during current transformer saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current (I2/I1).

Positive-Sequence Current Supervision Pickup An element that operates only when a positive-sequence current exceeds a threshold.

Positive-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced positive-sequence set of voltage sources.

POTT (Permissive Overreaching Transfer Trip) A communications-assisted line protection scheme. At least two overreaching protective relays must receive a permissive signal from the other terminal(s) before all relays trip and isolate the protected line.

Power Factor The cosine of the angle by which phase current lags or leads phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a pure resistive load.

PPS Pulse per second from a GPS receiver. Previous SEL-421 relays had a TIME 1k PPS input.

Protection and Automation Separation Segregation of protection and automation processing and settings.

Protection Settings Group Individual scheme settings for as many as six different schemes (or instances).

Protection-Disabled State Suspension of relay protection element and trip/close logic processing and deenergization of all control outputs.

PT Potential transformer. Also referred to as a voltage transformer or VT.

PTR Potential transformer ratio.

Quadrilateral Characteristic A distance relay characteristic on an R-X diagram consisting of a directional measurement, reactance measurement, and two resistive measurements.

Qualifier Code Specifies type of range for DNP3 objects. With the help of qualifier codes, DNP master devices can compose the shortest, most concise messages.

R_TRIG Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.

RAM Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data.

Reactance Reach The reach of a distance element in the reactive (X) direction in the R-X plane.

Real Power Power that produces actual work. The portion of apparent power that is real, not imaginary.

Reclose The act of automatically closing breaker contacts after a protective relay trip has opened the circuit breaker contacts and interrupted current through the breaker.

Relay Word Bit A single relay element or logic result. A Relay Word bit can equal either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted control input or control output. Logical 0 represents a false logic condition, dropped out element, or deasserted control input or control output. Use Relay Word bits in SELOGIC control equations.

Remapping The process of selecting data from the default map and configuring new indices to form a smaller data set optimized to your application.

Remote Bit A Relay Word bit with a state that is controlled by serial port commands, including the **CONTROL** command, a binary Fast Operate command, DNP binary output operation, or a UCA control operation.

Report Settings Event report and Sequential Events Recorder settings.

Residual Current The sum of the measured phase currents. In normal, balanced operation, this current is very small or zero.

Residual Directional Overcurrent Element A residual overcurrent element allowed to operate in only the forward or reverse direction.

Residual Overcurrent Protection Overcurrent protection that operates at conditions exceeding a threshold of system unbalance ($3I_0 = I_A + I_B + I_C$).

Resistance Blinder An operate boundary in the resistive direction of a ground quadrilateral distance element.

Resistive Reach The reach of a distance element in the resistive (R) direction in the R-X plane.

Retrip A subsequent act of attempting to open the contacts of a circuit breaker after the failure of an initial attempt to open these contacts.

Reverse Fault A fault operation behind a relay terminal.

Rising Edge Transition from logical 0 to logical 1, or the beginning of an operation.

RMS Root-mean-square. This is the effective value of the current and voltage measured by the relay, accounting for the fundamental frequency and higher-order harmonics in the signal.

Rolling Demand A sliding time-window arithmetic average in demand metering.

RTD Resistance Temperature Detector

RTU Remote Terminal Unit.

RXD Received data.

SCADA Supervisory control and data acquisition.

SCD File IEC 61850 Substation Configuration Description file. XML file that contains information on all IEDs within a substation, communications configuration data, and a substation description.

SCL IEC 61850 Substation Configuration Language. An XML-based configuration language that supports the exchange of database configuration data among different software tools that can be from different manufacturers. There are four types of SCL files used within IEC 61850: CID, ICD, SCD, and SSD.

Self-Description A feature of GOMSFE in the UCA2 protocol. A master device can request a description of all of the GOMSFE models and data within the IED.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates detection of an out-of-tolerance condition. The SEL-421 has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR QuickSet software program for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as a control output) using a logical combination of relay element outputs and fixed logic outputs.

Sequencing Timers Timers designed for sequencing automated operations.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a list that you set in the relay. SER provides a useful way to determine the order and timing of events of a relay operation.

SER Sequential Events Recorder or the relay serial port command to request a report of the latest 1000 sequential events.

Series-Compensated Line A power line on which the addition of series capacitance compensates for excessive inductive line impedance.

Settle/Settling Time Time required for an input signal to result in an unvarying output signal within a specified range.

Shot Counter A counter that records the number of times a recloser attempts to close a circuit breaker.

Shunt Admittance The admittance resulting from the presence of a device in parallel across other devices or apparatus that diverts some current away from these devices or apparatus.

Shunt Capacitance The capacitance between a network connection and any existing ground.

Shunt Current The current that a parallel-connected high-resistance or high-impedance device diverts away from devices or apparatus.

SIN Operator Operator in math SELOGIC control equations that provides the sine function.

Single-Pole Trip A circuit breaker trip operation that occurs when one pole of the three poles of a circuit breaker opens independently of the other poles.

SIR Source-to-line impedance ratio.

SOTF (Switch-Onto-Fault Protection Logic) Logic that provides tripping if a circuit breaker closes into a zero voltage bolted fault, such as would happen if protective grounds remained on the line following maintenance.

Source Impedance The impedance of an energy source at the input terminals of a device or network.

SQRT Operator Math SELOGIC control equation operator that provides square root.

SSD File IEC 61850 System Specification Description file. XML file that describes the single-line diagram of the substation and the required logical nodes.

Stable Power Swing A change in the electrical angle between power systems. A control action can return the angular separation between systems to less than the critical angle.

Status Failure A severe out-of-tolerance internal operating condition. The relay issues a status failure message and enters a protection-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise relay protection, yet are beyond expected limits. The relay issues a status warning message and continues to operate.

Strong Password A mix of valid password characters in a six-character combination that does not spell common words in any portion of the password. Valid password characters are numbers, upper- and lower-case alphabetic characters, "." (period), and "-" (hyphen).

Subnet Mask The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

Subsidence Current See CT subsidence current.

Synch Reference A phasor the relay uses as a polarizing quantity for synchronism check calculations.

Synchronism Check Verification by the relay that system components operate within a preset frequency difference and within a preset phase angle displacement between voltages.

Synchronized Phasor A phasor calculated from data samples using an absolute time signal as the reference for the sampling process. The phasors from remote sites have a defined common phase relationship. Also known as Synchrophasor.

Telnet An Internet protocol for exchanging terminal data that connects a computer to a network server and allows control of that server and communication with other servers on the network.

Terminal Emulation Software Software that can be used to send and receive ASCII text messages and files via a computer serial port.

Thermal Demand Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities; used in demand metering.

Thermal Withstand Capability The capability of equipment to withstand a predetermined temperature value for a specified time.

Three-Phase Fault A fault involving all three phases of a three-phase power system.

Three-Pole Trip A circuit breaker operation that occurs when the circuit breaker opens all three poles at the same time.

Time Delay on Pickup The time interval between initiation of a signal at one point and detection of the same signal at another point.

Time Dial A control that governs the time scale of the time-overcurrent characteristic of a relay. Use the time-dial setting to vary relay operating time.

Time-Delayed Tripping Tripping that occurs after expiration of a pre-determined time.

Time Error A measurement of how much time an ac powered clock would be ahead or behind a reference clock, as determined from system frequency measurements.

Time-Overcurrent Element An element that operates according to an inverse relationship between input current and time, with higher current causing faster relay operation.

Time Quality An indication from a GPS clock receiver that specifies the maximum error in the time information. Defined in IEEE C37.118.

Torque Control A method of using one relay element to supervise the operation of another.

Total Clearing Time The time interval from the beginning of a fault condition to final interruption of the circuit.

Tower Footing Resistance The resistance between true ground and the grounding system of a tower.

Transformer Impedance The resistive and reactive parameters of a transformer looking in to the transformer primary or secondary windings. Use industry accepted open-circuit and short-circuit tests to determine these transformer equivalent circuit parameters.

Tree Resistance Resistance resulting from a tree in contact with a power line.

TVE Total Vector Error. A measurement of accuracy for phasor quantities that combines magnitude and angle errors into one quantity. Defined in IEEE C37.118.

TXD Transmitted data.

UCA2 Utility Communications Architecture. A network-independent protocol suite that serves as an interface for individual intelligent electronic devices.

Unbalanced Fault All faults that do not include all three phases of a system.

Unbuffered Report IEC 61850 IEDs can issue immediate unbuffered reports of internal events (caused by trigger options data-change, quality-change, and data-update) on a "best efforts" basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

Unconditional Tripping Protection element tripping that occurs apart from conditions such as those involving communication, switch-onto-fault logic, etc.

Unstable Power Swing A change in the electrical angle between power systems for which a control action cannot return the angular separation between systems to an angle less than the critical angle.

Untransposed Line A transmission line with phase conductors that are not regularly transposed. The result is an imbalance in the mutual impedances between phases.

User ST Region in GOOSE for user-specified applications.

VA, VB, VC Measured A-phase-to-neutral, B-phase-to-neutral, and C-phase-to-neutral voltages.

VAB, VBC, VCA Measured or calculated phase-to-phase voltages.

VG Residual voltage calculated from the sum of the three phase-to-neutral voltages, if connected.

Virtual Terminal Connection A mechanism that uses a virtual serial port to provide the equivalent functions of a dedicated serial port and a terminal.

Volatile Storage A storage device that cannot retain data following removal of relay power.

VT Voltage transformer. Also referred to as a potential transformer or PT.

Warm Start The reset of a running system without removing and restoring power.

Weak Infeed Logic Logic that permits rapid tripping for internal faults when a line terminal has insufficient fault current to operate protective elements.

Wye A phase-to-neutral connection of circuit elements, particularly voltage transformers or loads. To form a wye connection using transformers, connect the nonpolarity side of each of three voltage transformer secondaries in common (the neutral), and take phase to neutral voltages from each of the remaining three leads. When properly phased, these leads represent the A-phase-, B-phase-, and C-phase-to-neutral voltages. This connection is frequently called 'four-wire wye,' alluding to the three phase leads plus the neutral lead.

XML Extensible Markup Language. This specification developed by the W3C (World Wide Web Consortium) is a pared-down version of SGML designed especially for web documents. It allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data among applications and organizations.

Zero-Sequence A configuration of three-phase currents and voltages with currents and voltages that occur simultaneously, are always in phase, and have equal magnitude ($3I_0 = I_A + I_B + I_C$).

Zero-Sequence Compensation Factor A factor based on the zero-sequence and positive-sequence impedance of a line that modifies a ground distance element to have the same reach as a phase distance element.

Zero-Sequence Impedance Impedance of a device or circuit resulting in current flow when a single voltage source is applied to all phases.

Zero-Sequence Mutual Coupling Zero-sequence current in an unbalanced circuit in close proximity to a second circuit induces voltage into the second circuit. When not controlled by protection system design and relay settings, this situation can cause improper operation of relays in both systems.

Zero-Sequence Overcurrent Element Overcurrent protection that operates at conditions exceeding a threshold of system unbalance.

Zero-Sequence Voltage-Polarized Directional Element An element that provides directionality by the sign, plus or minus, of the measured zero-sequence impedance.

Z-Number That portion of the relay FID string that identifies the proper ACSELERATOR QuickSet software relay driver version and HMI driver version when creating or editing relay settings files.

Zone Time Delay Time delay associated with the forward or reverse step distance and zone protection.

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Page numbers appearing in bold mark the location of the topic's primary discussion.

U=User's Guide; A=Applications Handbook; R=Reference Manual

Symbols

A

B

C

D

T

SEL-421 Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
AACCESS	Go to Access Level A (automation control)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor relay and control circuit breakers)
BNAME	ASCII names of all relay status bits (Fast Meter)
BREAKER *n*	Display the circuit breaker report and breaker history; preload and reset breaker monitor data (*n* = 1 is BK1; *n* = 2 is BK2)
CASCII	Generate the Compressed ASCII response configuration message
CBREAKER	BREAKER command for the Compressed ASCII response
CEVENT	EVENT command for the Compressed ASCII response
CHISTORY	HISTORY command for the Compressed ASCII response
CLOSE *n*	Close the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
COMM *c*	Display relay-to-relay MIRRORED BITS communications or remote synchrophasor data (*c* = A is channel A; *c* = B is channel B; *c* = M is either enabled single channel; *c* = RTC for remote synchrophasors)
CONTROL *nn*	Set, clear, or pulse an internal remote bit (*nn* is the remote bit number from 01–32)
COPY *m n*	Copy settings between instances in the same class (m and n are instance numbers; for example: *m* = 1 is Group 1; *n* = 2 is Group 2)
CSER	SER command for the Compressed ASCII response
CSTATUS	STATUS command for the Compressed ASCII response
CSUMMARY	SUMMARY command for the Compressed ASCII response
DATE	Display and set the date
DNAME X	ASCII names of all relay digital I/O (Fast Meter)
DNP	Access or modify serial port DNP3 settings (similar to SHOW D and SET D)
EVENT	Display and acknowledge event reports
FILE	Transfer data between the relay and external software
GROUP	Display the active group number or select the active group
HELP	Display available commands or command help at each access level
HISTORY	View event summaries/histories; clear event data
ID	Display the firmware id, user id, device code, part number, and configuration information
LOOPBACK	Connect MIRRORED BITS data from transmit to receive on the same port
MAP 1	Analyze the communications card database
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output control)
OPEN *n*	Open the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
PACCESS	Go to Access Level P (protection control)
PASSWORD	Change relay passwords
PORT	Connect to a remote relay via MIRRORED BITS virtual terminal (for port number *p* = 1–3, and F), or the Ethernet card (port *p* = 5)
PULSE OUT*nnn*	Pulse a relay control output (OUT*nnn* is a control output number)

Command[a, b]	Description
QUIT	Reduce access level to Access Level 0 (exit relay control)
RTC	Display configuration of received remote synchrophasors
SER	View Sequential Events Recorder reports
SET[c]	Enter relay settings
SHOW[c]	Display relay settings
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Report or clear relay status and SELOGIC control equation errors
SUMMARY	View summary event reports
TARGET	Display relay elements for a row in the Relay Word table
TEC	Display time-error estimate; display or modify time-error correction value.
TEST DB	Display or place values in the communications card database (useful for Ethernet protocol read tests)
TEST DNP	Display or place values in the serial port DNP3 object map
TEST FM	Display or place values in metering database (Fast Meter)
TIME	Display and set the internal clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configurations
VIEW 1	View data from the communications card database

[a] See Section 9: ASCII Command Reference in the Reference Manual.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.
[c] See the table below for SET/SHOW options.

SET/SHOW Command Options

Option	Setting Type	Description
[S] ***n***	Group Settings 1–6	Particular application settings
A *n*[a]	Automation Logic Block 1–10	Automation SELOGIC control equations
D	DNP3	Direct Network Protocol remapping (serial port only)
F	Front Panel	Front-panel HMI settings
G	Global	Relay-wide settings
L *n*	Protection Logic Group 1–6	Protection SELOGIC control equations
M	Breaker Monitor	Circuit breaker monitor settings
O	Outputs	Output SELOGIC control equations
P *n*	Port 1–3, F, 5	Communications port settings
R	Report	Event report and SER settings
T	Alias	Alias names for analog quantities and Relay Word bits

[a] The SEL-421-1 and the SEL-421-2 have only one instance of automation logic settings.

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BREAKER *n*	Display the circuit breaker report and breaker history; preload and reset breaker monitor data (*n* = 1 is BK1; *n* = 2 is BK2)
CASCII	Generate the Compressed ASCII response configuration message
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GROUP	Display the active group number or select the active group
HELP	Display available commands or command help at each access level
HISTORY	View event summaries/histories; clear event data
ID	Display the firmware id, user id, device code, part number, and configuration information
LOOPBACK	Connect MIRRORED BITS data from transmit to receive on the same port
MAP 1	Analyze the communications card database
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output control)
OPEN *n*	Open the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
PACCESS	Go to Access Level P (protection control)
PASSWORD	Change relay passwords
PORT	Connect to a remote relay via MIRRORED BITS virtual terminal (for port number *p* = 1–3, and F), or the Ethernet card (port *p* = 5)
PULSE OUT*nnn*	Pulse a relay control output (OUT*nnn* is a control output number)

Command[a, b]	Description
QUIT	Reduce access level to Access Level 0 (exit relay control)
RTC	Display configuration of received remote synchrophasors
SER	View Sequential Events Recorder reports
SET[c]	Enter relay settings
SHOW[c]	Display relay settings
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Report or clear relay status and SELOGIC control equation errors
SUMMARY	View summary event reports
TARGET	Display relay elements for a row in the Relay Word table
TEC	Display time-error estimate; display or modify time-error correction value.
TEST DB	Display or place values in the communications card database (useful for Ethernet protocol read tests)
TEST DNP	Display or place values in the serial port DNP3 object map
TEST FM	Display or place values in metering database (Fast Meter)
TIME	Display and set the internal clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configurations
VIEW 1	View data from the communications card database

[a] See Section 9: ASCII Command Reference in the Reference Manual.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.
[c] See the table below for SET/SHOW options.

SET/SHOW Command Options

Option	Setting Type	Description
[S] ***n***	Group Settings 1–6	Particular application settings
A *n*[a]	Automation Logic Block 1–10	Automation SELOGIC control equations
D	DNP3	Direct Network Protocol remapping (serial port only)
F	Front Panel	Front-panel HMI settings
G	Global	Relay-wide settings
L *n*	Protection Logic Group 1–6	Protection SELOGIC control equations
M	Breaker Monitor	Circuit breaker monitor settings
O	Outputs	Output SELOGIC control equations
P *n*	Port 1–3, F, 5	Communications port settings
R	Report	Event report and SER settings
T	Alias	Alias names for analog quantities and Relay Word bits

[a] The SEL-421-1 and the SEL-421-2 have only one instance of automation logic settings.