SEL-2431

Voltage Regulator Control

Instruction Manual

20240909

SEL SCHWEITZER ENGINEERING LABORATORIES

 PM2431-01

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Preface

About the SEL-2431 Field Reference Guide and the SEL-2431 Instruction Manual

The *SEL-2431 Voltage Regulator Control Field Reference Guide* covers installation and set-up of the SEL-2431 Voltage Regulator Control for general applications through the front-panel HMI. A personal computer is not required for the material contained in the guide.

NOTE: These documents are not a substitute for the documentation that comes with a voltage regulator, including the safety warnings and procedures.

The *SEL-2431 Voltage Regulator Control Instruction Manual* covers the operation of the SEL-2431 for advanced applications through the serial port communications interface, front-panel HMI, or PC software interface.

Store the included SEL-2431 menu card in the control box. This card contains the HMI menu tree.

Field Reference Guide

The *SEL-2431 Voltage Regulator Control Field Reference Guide* is aimed at technicians who have some familiarity with voltage regulators and any existing voltage regulator controls, and are planning on relatively straightforward control settings. The guide contains topics not covered in the *SEL-2431 Voltage Regulator Control Instruction Manual*, including the following:

- Compatible voltage regulator types in *Section 1: Overview*
- Installation in *Section 2: Installation*
- Voltage regulator overview in *Section 2: Installation*
- Voltage regulator control wiring harness connections in *Section 2: Installation*
- Fusing in *Section 2: Installation*
- Internal wiring/functions in *Section 2: Installation*
- Basic front-panel operation in *Section 3: Front-Panel Interface*
- Jumpers and clock battery in *Section 2: Installation*
- Basic settings in *Section 4: Basic Settings*

Instruction Manual

The *SEL-2431 Voltage Regulator Control Instruction Manual* is intended for use with specialized applications such as voltage reduction, and offers more information on control operation, communications, and SELOGIC® programming.

The manual contains topics that are not in the *SEL-2431 Voltage Regulator Control Field Reference Guide*, including the following:

- Specifications in *Section 1: Introduction and Specifications*
- PC software in *Section 2: PC Software*
- Description of control algorithms in *Section 3: Control Algorithms*

- Description of control operating modes in *Section 4: Control Operating Modes*
- Tap operation details in *Section 5: Tap Operations*
- Overcurrent elements, SELOGIC control equations, and multiple setting groups in *Section 6: Logic Functions*
- Description of metering and tap counters in *Section 7: Metering and Monitoring*
- Signal profile recorder in *Section 7: Metering and Monitoring*
- Full control settings, including all factory-default settings, in *Section 8: Settings*
- Serial and Ethernet communications including commands and DNP3, in *Section 9: Communications, Appendix C: SEL Communications Processors,* and *Appendix D: DNP3 Communications*
- Advanced front-panel operations, including programmable pushbuttons and LEDs, display points and local control functions, in *Section 10: Front-Panel Operations*
- Event reports and Sequential Events Recorder (SER) in *Section 11: Analyzing Events*
- Firmware versions in *Appendix A: Firmware and Manual Versions*
- Firmware upgrade instructions in *Appendix B: Firmware Upgrade Instructions*

Safety Information

Dangers, Warnings, and Cautions

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

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

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

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

Safety Symbols

The following symbols are often marked on SEL products.

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

Safety Marks

The following statements apply to this device.

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

General Information

Typographic Conventions

There are three ways to communicate with the SEL-2431:

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

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

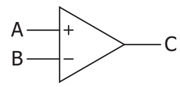
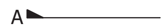
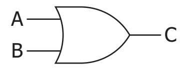
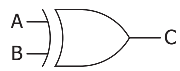
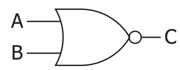
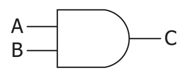
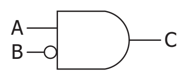
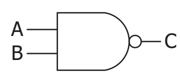
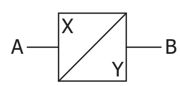
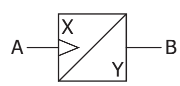
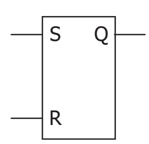
Example	Description
STATUS	Commands typed at a command line interface on a PC.
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
CLOSE	Relay front-panel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

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-2431. 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-2431.

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 Input A is greater than Input B.
Input Flag		Input A comes from other logic.
OR		If either Input A or Input B asserts, Output C asserts.
Exclusive OR		If either Input A or Input B asserts, Output C asserts. If Input A and Input B are of the same state, Output C deasserts.
NOR		If neither Input A nor Input B asserts, Output C asserts.
AND		If Input A and Input B assert, Output C asserts.
AND w/ Inverted Input		If Input A asserts and Input B deasserts, Output C asserts. Inverter "O" inverts any input or output on any gate.
NAND		If Input A and/or Input B deassert, Output C asserts.
Time-Delayed Pick Up and/or Time-Delayed Drop Out		X is a time-delay-pickup value; Y is a time-delay-dropout value. Output B asserts Time X after Input A asserts; Output B does not assert if Input A does not remain asserted for Time X. If Time X is zero, Output B asserts when Input A asserts. If Time Y is zero, Input B deasserts when Input A deasserts.
Edge Trigger Timer		Rising edge of Input A starts timers. Output B asserts Time X after the rising edge of Input A. Output B remains asserted for Time Y. If Time Y is zero, Output B asserts 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 Input R asserts.
Falling Edge		Output B asserts at the falling edge of Input A.
Rising Edge		Output B asserts at the rising edge of Input A.

Trademarks

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

acSELerator Analytic Assistant®	acSELerator QuickSet®
acSELerator Architect®	SELogic®
acSELerator Team®	SEL Compass®

Technical Support

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

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SECTION 1

Introduction and Specifications

Introduction

The SEL-2431 Voltage Regulator Control is constructed to high standards and offers proven features from SEL's popular lineup of protective relays and recloser controls.

The SEL-2431 comes with a 10-year warranty, and can be configured for use with many standard single-phase, 32-Tap step-type voltage regulators. The SEL-2431 is available for both new and retrofit applications.

The advanced communications features allow easy sharing of data in a substation environment, while the nonvolatile storage of operations counter, Sequential Events Recorder (SER), Event Report, and Load Profile data are valuable in remote installations, where communications are not yet available.

Time synchronization, available through the optional serial port IRIG-B input, makes your SEL-2431 clock match all of your other IRIG-B connected devices.

A powerful front-panel HMI makes field configuration easy. Advanced logic, communications, and configuration features are accessible with a laptop computer, through either an ASCII terminal emulator, or through QuickSet.

This section introduces the SEL-2431 and provides information on the following topics:

Features

The SEL-2431 front panel is shown in *Figure 1.1* and *Figure 1.2*.

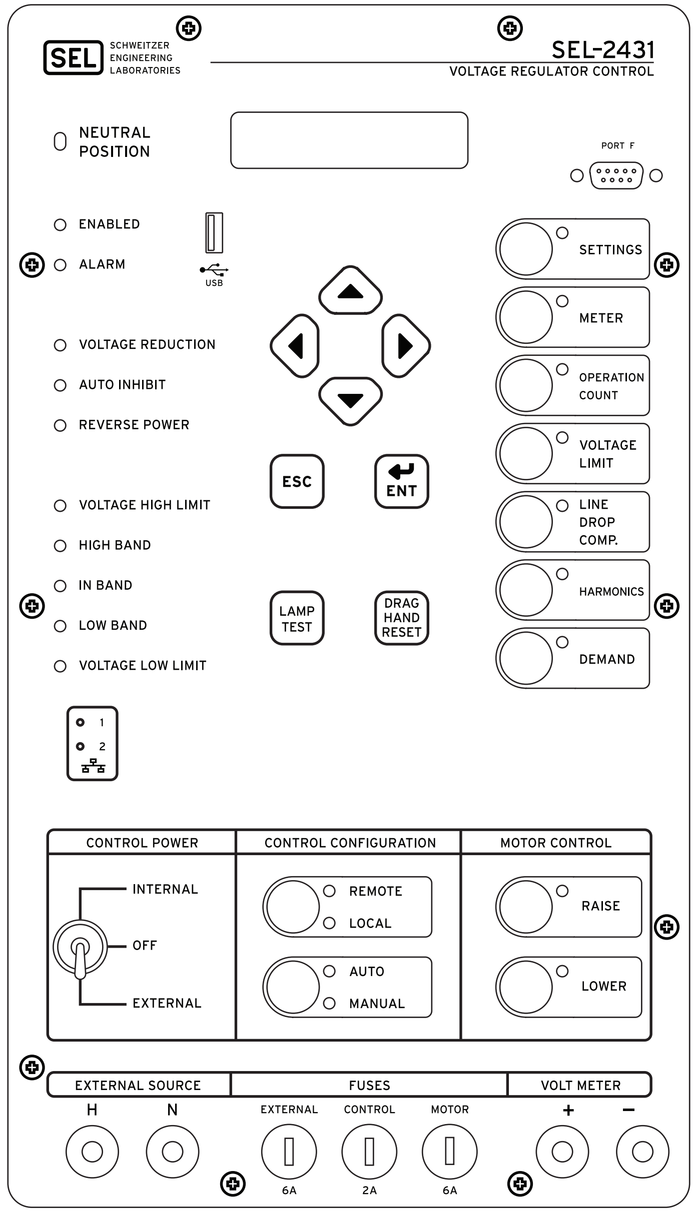

Figure 1.1 SEL-2431 Front Panel (With Pushbutton Raise/Lower Controls)

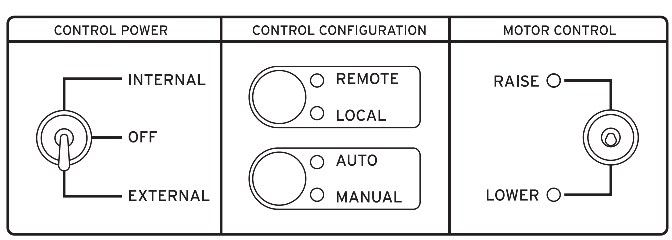

Figure 1.2 SEL-2431 Front Panel—Lower Portion (With Toggle Switch Raise/ Lower Controls)

Easy-to-Use Front Panel

Upper Section

The dual LED **NEUTRAL POSITION** is featured prominently on the upper left area of the SEL-2431 front panel. Ten additional LEDs arranged down the left side provide information in an easy-to-see format.

The center portion contains the 2 x 20 character backlit LCD screen, menu navigation buttons, and **LAMP TEST** and **DRAG HAND RESET** pushbuttons. The LCD screen displays metering values, tap operations counter, control status, settings, and customer-defined messages. Password security allows the authorized user to modify most control settings.

Just below the LCD screen is the Type A USB port. The Type A USB port is used to interface with the device in ways that eliminate the need for a laptop computer in the field.

A convenient DB-9 serial port, and seven programmable pushbuttons and LEDs with configurable labels, appear on the right side. These pushbuttons can be configured to allow quick access to certain settings and metering data in the LCD, or they can be used for general applications in SELOGIC control equations.

Lower Section

The lower portion includes the **Control Power**, **Control Configuration**, **Motor Control**, **External Source**, **Fuses**, and **Volt Meter** areas. The motor control section can be equipped with a toggle switch in place of the standard pushbuttons. On controls with a second PT connected, the voltmeter terminals automatically connect to the present load-side PT, depending on power flow direction (this feature may be customized or disabled through settings). If the device is equipped with a dual Ethernet card, the Ethernet link lights are located here.

Multiple Setting Groups

The SEL-2431 includes four independent setting groups with separate forward and reverse voltage control set points, time delays, line-drop compensation settings, operating mode, voltage reduction, voltage limiting, and runback settings. The voltage regulator control may be switched to a different settings group by command or by programmable SELOGIC control equations. The included logic function allows for calendar- or clock-based group switching, and additional elements and programming make group switching possible by criteria such as line overcurrent and high-power demand conditions.

Flexible Operating Modes and Programmability

The SEL-2431 includes the standard operating modes Locked Forward, Locked Reverse, Idle Reverse, Cogeneration, Bidirectional, and Flexible Distribution Generation. Programmable raise, lower, inhibit, and block conditions allow further customization of control operation.

PC Software

In addition to communicating and setting the voltage regulator control using an ASCII terminal, use the PC-based QuickSet to easily configure the SEL-2431. Use the built-in oscillography viewer to analyze event reports with control element response and details of the voltage regulator interface signals and power system conditions.

Metering Functions

Metering capabilities include real-time voltages, current, frequency, power quantities, and date and time-stamped Max/Min metering with separate registers for forward and reverse power conditions. Demand and peak demand metering includes forward and reverse registers for current and power quantities, with peak-value date and time stamps, and four-quadrant reactive power quantities. The energy metering functions have separate in and out registers for real and reactive power.

Harmonics Metering

Improve power quality by tracking system harmonic levels. The SEL-2431 meters harmonics from the second to the fifteenth, as well as total harmonic distortion (THD), which is also available for system control and voltage regulation decisions.

Auxiliary Power Supply

Power your 12 Vdc accessories with a built-in 6 W (continuous) auxiliary power supply.

Extensive Voltage Regulator Compatibility (Interface Ordering Option)

Connect voltage regulators made by Cooper/McGraw Edison, GE, Howard Industries, Siemens/Allis, Toshiba CR-3, ITB RAV-2, and Romagnole SVR. Enter the regulator nameplate data, system information, and desired control set points using the front-panel HMI, a terminal emulator program on a laptop computer, or QuickSet.

Models and Options

Voltage Regulator Compatibility

Consult the SEL-2431 Model Option Table (available at selinc.com) to determine the control ordering options for your SEL-2431 application. Model selections include the following:

- Type A USB flash drive or no USB Type A flash drive
- Pushbutton or toggle switch raise/lower
- Serial communications ports. Formats include copper (EIA-232. 4-wire EIA-485, or 2-wire EIA-485) or multimode fiber (200 µm with V-pin connector, or 62.5 µm with ST connector).

- Dual Ethernet Communications ports. These are installed in the slot for Port 2 only. Formats include copper/copper, copper/multimode fiber, copper/single-mode fiber, multimode/multimode fiber, and single-mode/single-mode fiber.
- Conformally coated circuit boards
- Wiring harness. Choose from several available retrofit kits.
- Optional Enclosure. Incorporates a complete pre-wired controller and a painted, marine-grade aluminum enclosure with expanded space for accessories for use in new and retrofit applications. The enclosure achieves an IP55 rating for dust protection and water ingress resistance.

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Technical Support* on page 12.10).

Applications

There are two standard applications of the SEL-2431, which include a control and harness retrofit and a completed control, universal wiring, and enclosure retrofit. First, a control and harness retrofit installation is shown in *Figure 1.3*, where an older control is removed from the weather-resistant enclosure and the new SEL-2431 is installed and wired to the same connections in the enclosure. Second, a completed control, universal wiring, and enclosure retrofit, where a complete SEL-2431 enclosure assembly is installed either with a new voltage regulator or is retrofited to replace an older control/weather resistant enclosure. The voltage regulator control wires are then connected to the terminals of the SEL-2431 cabinet assembly.

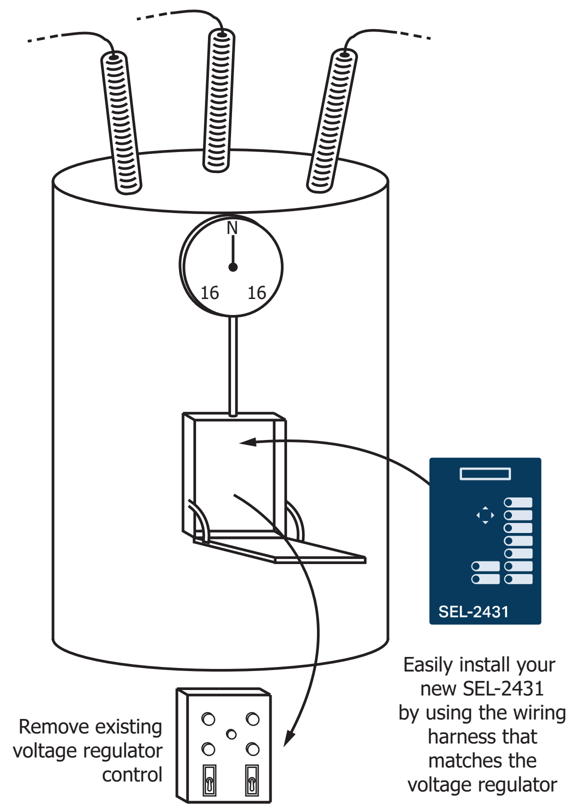

Figure 1.3 Control Retrofit With SEL-2431

The SEL-2431 can be used for:

- ➤ Replacement by field personnel of existing voltage regulator controls for various manufacturers (retrofit)
- ➤ Control of new voltage regulators supplied as original equipment
- ➤ Line-to-neutral or line-to-line voltage regulation applications (with a properly rated voltage regulator)
- ➤ Distribution feeders with forward, reverse, or bidirectional power flow
- ➤ Voltage reduction schemes (internally or externally initiated)
- ➤ Metering (phase measurement unit) in a wide-area measurement system
- ➤ Data collection/remote control (intelligent electronic device) in a SCADA/VVO/ADMS system
- ➤ Long-term system data collection on connected USB flash drive

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system.

General

AC Current Input

0.2 A nominal:	0.64 A continuous, 4 A for 1 s, linear to 2.18 A symmetrical. 20 A for 1 cycle.
Burden:	<1 VA

Power Supply

120 Vac

Range:	88–132 Vac
Burden:	≤ 35 VA
Interruption:	≤ 50 ms at 120 Vac per IEC 60255-11

120 Vac Whetting Source

Range:	88–132 Vac
Rated current:	6 A (motor fuse)

12 Vdc Auxiliary Output Source

Range:	11–14 Vdc
Output power:	6 W at 12 Vdc

Output Contacts

Make:	30 A
Carry:	3 A continuous carry at 120 Vac
MOV Protection:	270 Vac/360 Vdc; 40 J
Pickup Time:	≤ 16 ms
Dropout Time:	≤16 ms
Update Rate:	1/16 cycle

Breaking Capacity (10000 operations):

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

Cyclic Capacity (2.5 cycle/second):

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

Note: Make per IEEE C37.90:1989; Breaking and Cyclic Capacity per IEC 60255-23 [IEC 255-23]:1994.

Raise/Lower Outputs

Carry:	6 A continuous at 120 Vac

Optoisolated Inputs

120 Vac:	Pickup 80–145 Vac
12 Vdc:	Pickup 9.6–14.4 Vdc

Note: 12 Vdc optoisolated inputs draw approx. 10 mA of current.

Frequency

System Frequency:	50 or 60 Hz

Communications Ports

Standard:	1 front EIA-232 (300–38400 bps)
Optional:	1 or 2 rear-mounted serial communications cards, or 1 rear-mounted serial communications card and 1 rear-mounted Ethernet communications card
Available Serial Communications Card Types:	EIA-232 (300–57600 bps) 2-Wire EIA-485 (300–57600 bps) 4-Wire EIA-485 (300–57600 bps) 200 µm multimode fiber with VPIN connector (300–38400 bps) 62.5 µm fiber with ST connector (300–57600 bps)
Available Dual Ethernet Communications Card Types:	Dual Fiber Ethernet 100BASE-FX (Multimode) LC Connectors Dual Copper Ethernet (10/100BASE-T) RJ45 Connectors One Copper Ethernet (10/100BASE-T) RJ45 Connector and One Fiber Ethernet 100BASE-FX (Multimode) LC Connector Dual Fiber Ethernet 100BASE-LX10 (Single-mode) LC Connectors One Copper Ethernet (10/100BASE-T) RJ45 Connector, and One Fiber Ethernet 100BASE-LX10 (Single-mode) LC Connector

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20° and above +70°C (–4° and +158°F, respectively)

Time-Code Input

Device accepts demodulated IRIG-B time-code input at Port 1 if Port 1 contains either an EIA-232 card, a 4-Wire EIA-485 card, or a fiber-optic serial card.

Clock Synchronization Accuracy

C37.118 IRIG-B:	10 µs
IRIG-B:	5 ms
DNP3:	2 s

Unsynchronized Clock Drift

Control Powered:	26.5 minutes per year, typical

Routine Dielectric Strength

AC Current Inputs:	2500 Vac for 10 s

Weight

SEL-2431 Controller:	< 4.5 kg (10.0 lb)
Enclosure With Controller:	16.6 kg (36.5 lb)

Dimensions

SEL-2431 Controller:	15.00" x 8.62" x 4.29"
Enclosure:	25.00" x 12.00" x 10.96"

Enclosure

IP Rating:	IP55
Material:	Marine-Grade Aluminum
Color:	ANSI 61 Gray

Type Tests

Environmental Tests

Cold:	IEC 60068-2-1:2007 Test Ad; 16 hr at –40°C
Damp Heat Cyclic:	IEC 60068-2-30:2005 Test Db; 25° to 55°C, 6 cycles, 95% humidity
Dry Heat:	IEC 60068-2-2:2007 Test Bd: 16 hr at +85°C
Enclosure Protection:	CEI/IEC 60529:2013 IP55

Dielectric Strength and Impulse Tests

Dielectric:	IEC 60255-5:2000 IEEE C37.90-2005, Section 8—Insulation Tests 3100 Vdc on general contact outputs and CT input; 2200 Vdc on EIA-485 communications port; 2000 Vdc on all other connectors
Impulse:	IEC 60255-5:2000 IEEE 37.90-2005 0.5 J, 5000 V

Electrostatic Discharge Test

ESD:	IEC 60255-22-2:2008 IEC 61000-4-2:2008 IEEE C37.90.3-2001 2, 4, 6, 8 kV contact discharge 2, 4, 6, 8, 15 kV air discharge

RFI and Interference Tests

Fast Transient Disturbance:	IEC 60255-22-4:2008 IEC 61000-4-4:2011, Class A, 4 kV
Radiated RFI:	IEC 61000-4-3:2010, 10 V/m IEC 60255-22-3:2007, 10 V/m IEEE C37.90.2-2004, 20 V/m
Radiated Radio Frequency (1.89 GHz):	ENV 50204:1995, 10 V/m
Surge Withstand:	IEEE C37.90.1-2002 2.5 kV oscillatory; 4 kV fast transient IEC 60255-22-1:2007 2.5 kV peak common mode, 1.0 kV peak differential mode
Surge Immunity:	IEC 61000-4-5:2005 IEC 60255-22-5:2008 2 kV line-to-line and 6 kV line-to-earth for an SEL-2431 equipped with a surge protection accessory
Conducted Immunity:	IEC 61000-4-6:2008 IEC 60255-22-6:2001 10 Vrms Installed RF Ferrite Choke (Fair Rite part #0443164151) on copper Ethernet cables. Contact the SEL factory for this complimentary part if needed.
Power Frequency Magnetic Field Immunity:	IEC 61000-4-8:2009 100 A/m (60 sec), 1000 A/m (3 sec)
Pulse Magnetic Field Immunity:	IEC 61000-4-9:2001 1000 A/m
Damped Oscillatory Magnetic Field Immunity:	IEC 61000-4-10:2001 100 A/m
Power Supply Variation and Interruption:	IEC 60255-11:2008 IEC 6100-4-11:2004 IEC 61000-4-17:2002 IEC 61000-4-29:2000

Vibration and Shock Tests

Shock and Bump:	IEC 60255-21-2:1988 Class 1: Shock Withstand, Bump Class 2: Shock Response IEC 60255-21-3:1993 Class 2
Sinusoidal Vibration:	IEC 60255-21-1:1988 Class 1: Endurance Class 2: Response

Object Penetration

Object Penetration:	IEC 60529:2001 IP 20, excluding terminal blocks

Processing Specifications

Analog Data Acquisition:	32 samples per power system cycle, frequency tracking
Control Processing Rate:	Once per power system cycle, frequency tracking
Data Filtering:	Full-cycle cosine filter after low-pass analog filtering
Filtered Data Averaging (voltage and currents):	10 cycles (except for fault overcurrent element)

Control Accuracies

Voltage Control Accuracy—Steady State (V secondary)

Measured Channels:	± 0.3% (–40° to + 85°C, 108–132 Vac) (IEEE C57.15-1999)
Calculated Values:	± 1.0% (–40° to + 85°C, 108–132 Vac)

Overcurrent Accuracy—Steady State (A secondary)

General Overcurrent Elements:	± 0.3% ± 500 µA (0.002–0.700 A)
Fault Overcurrent Element:	± 0.3% ± 500 µA (0.4–2.0 A)

Overcurrent Element Response (Applied Current > 2x Pickup Setting)

General Overcurrent Elements:	<10 cycles
Fault Overcurrent Element:	<3 cycles

Metering Accuracy

Load Current:	±0.3% ±500 µA (0.001–2.000 A) and ±0.5° (0.020–2.000 A)
Harmonics (2nd–15th):	Current: ±5% of fundamental (0.02–0.64 A)
Voltages:	±0.3% and ±0.5° (80–145 Vac)

Synchrophasor Accuracy

Maximum Data Rate in Messages per Second

IEEE C37.118 Protocol:	60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
IEEE C37.118 Accuracy:	Level 1 at maximum message rate when frequency-based phasor compensation is enabled (PHCOMP = Y) PMDOK bit will deassert due to inclusion of out-of-band interfering signal.
Nominal Current:	450 mA
Current Range:	45 mA to 540 mA
Frequency Range:	±5 Hz of nominal (50 to 60 Hz)
Voltage Range:	80 V to 145 V (Voltage range is limited by power supply ratings)
Phase Angle Range:	–180° to +180°

SECTION 2

PC Software

Overview

SEL provides many PC software solutions (applications) that support the SEL-2431 Voltage Regulator Control and other SEL devices. SEL-2431 software solutions are listed in *Table 2.1*.

Table 2.1 SEL Software Solutions

Product Name	Description
SEL Compass	This application provides an interface for web-based notification of product updates and automatic software updating.
SEL-5010 Relay Assistant Software	This application uses a database to manage a connection directory and settings of multiple devices.
ACSELERATOR QuickSet SEL-5030 Software	QuickSet is a powerful setting, event analysis, and measurement tool that aids in applying and using the relay. See *Table 2.2* for information about the various QuickSet applications.
	Licensed versions of this software allow you to customize relay settings to particular applications, instead of dealing with all settings in the device. These custom settings are stored in QuickSet Design Templates. You can lock settings to match your standards or lock and hide settings that are not used. This makes installation of a new device simple and helps ensure that new devices are applied according to your organization's standards.
ACSELERATOR Architect SEL-5032 Software	Use this application to design and commission SEL IEDs in IEC 61850 substations, create and map GOOSE messages, use predefined reports, create and edit datasets, and read in SCD, ICD, and CID files.
ACSELERATOR TEAM SEL-5045 Software	The TEAM system provides custom data collection and movement of a wide variety of device information. The system provides tools for device communication, automatic collection of data, and creation of reports, warnings and alarms.
ACSELERATOR Analytic Assistant SEL-5601 Software	Converts SEL Compressed ASCII event reports files to oscillography
Cable Selector SEL-5801 Software	Selects the proper SEL cables for your application.

This section describes how to get started with the SEL-2431 and QuickSet. QuickSet is a powerful setting, event analysis, and measurement tool that aids in setting, applying, and using the SEL-2431. *Table 2.2* shows the suite of QuickSet applications provided for the SEL-2431.

Table 2.2 QuickSet Applications (Sheet 1 of 2)

Application	Description
Terminal	Provides a direct connection to the SEL device. Use this feature to ensure proper communications and directly interface with the device.
Rules-Based Settings Editor	Provides on-line or offline device settings that include interdependency checks. Use this feature to create and manage settings for multiple devices in a database.

Table 2.2 QuickSet Applications (Sheet 2 of 2)

Application	Description
USB Flash Drive	Provides an interface to send settings from the Rules-Based Settings Editor to a USB flash drive to be used in setting the SEL-2431. Provides the interface to create a USB authentication key to provide user authentication via a USB flash drive. Provides a means of copying digitally signed firmware files (.zds files) to the USB flash drive.
Event Analysis	Provides oscillography and other event analysis tools.
Meter and Control	Provides HMI for metering and control features.
Settings Database Management	QuickSet uses a database to manage the settings of multiple devices.
Help	Provides general QuickSet and device-specific QuickSet context sensitive help.

Setup

Follow the steps outlined in the *SEL-2431 Voltage Regulator Control Field Reference Guide* to prepare the SEL-2431 for use. Perform the following steps to initiate communications:

Step 1. Connect the appropriate communications cable between the SEL-2431 and the PC.

Step 2. Apply power to the SEL-2431.

Step 3. Start QuickSet.

Communications

QuickSet uses relay communications **Port 1**, **Port 2**, or **Port F** (front panel) to communicate with the SEL-2431. Perform the following steps to configure QuickSet to communicate effectively with the relay.

Step 1. Select **Communications** from the QuickSet main menu bar.

Step 2. Select the **Parameters** submenu to display the screen shown in *Figure 2.1*.

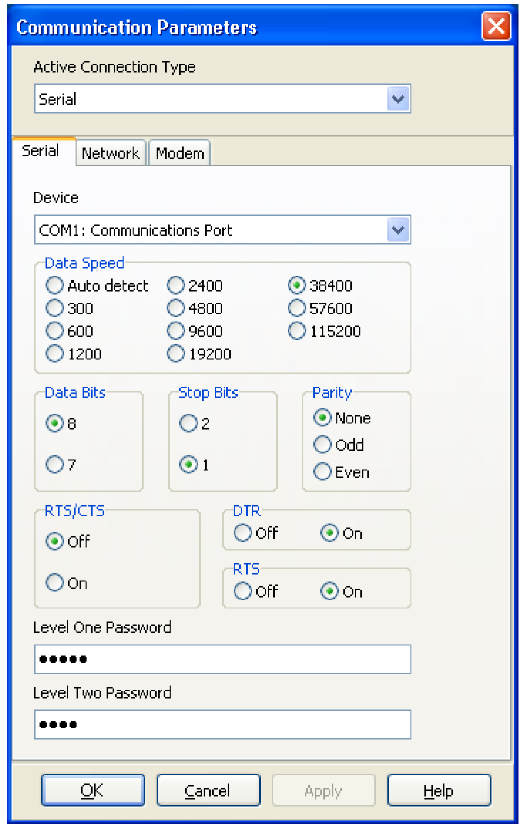

Figure 2.1 Communication Parameters Dialog Box

Step 3. Configure the PC port to match the relay communications settings.

Step 4. Configure QuickSet to match the SEL-2431 default settings by entering Access Level 1 and Access Level 2 passwords in the respective text boxes.

Step 5. If a telephone modem is chosen from the device text box, enter the dial-up telephone number in the **Phone Number** text box.

Step 6. For network communications, check the **Use Network** check box and enter the network parameters.

Step 7. Exit the menus by selecting **OK** when finished.

Terminal

Terminal Window

Select **Communications > Terminal** on the QuickSet main menu bar, or press **<Ctrl+T>**, to open the terminal window (shown in *Figure 2.2*).

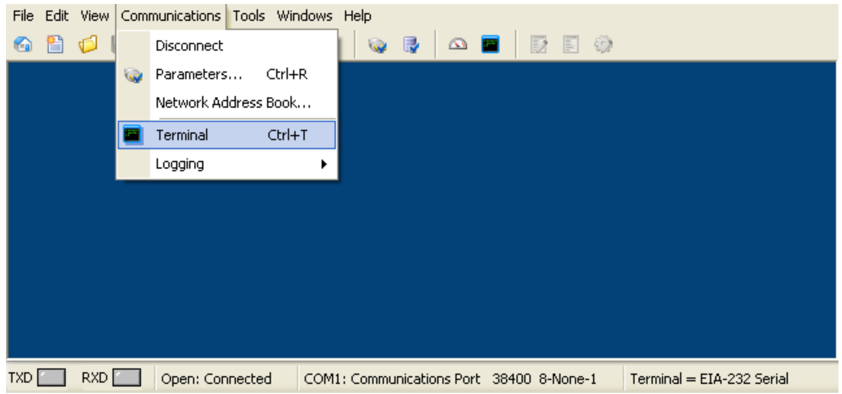

Figure 2.2 Communications Menu

The terminal window is an ASCII interface with the relay. This is a basic terminal emulation, not including file transfer capabilities. Many third-party terminal emulation programs are available with file transfer encoding schemes. Verify proper communications with the relay by pressing **<Enter>** a few times, and making sure that a prompt is received. If a prompt is not received, ensure proper setup.

Terminal Logging

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

Drivers and Part Number

After selecting **Communications > Terminal**, access the relay at Access Level 1. Issue the **ID** command to receive an identification report, as shown in *Figure 2.3*.

```
=ID <Enter>
"FID=SEL-2431-Rxxx-V0-Z001001-D2007xxxx","xxxx"
"BFID=SLBT-2431-Rxxx-V0-Z001001-D2007xxxx","xxxx"
"CID=9C2C","026E"
"DEVID=SEL-2431","03F4"
"DEVCODE=68","0315"
"PARTNO=24310X11X1131XXXXXXX","07BB"
"CONFIG=10000000","03E4"
=
```

Figure 2.3 Device Response to the ID Command

Locate and record the Z number (Z001001) in the FID string. The first portion of the Z number (Z001…) determines the settings version. The settings version used by QuickSet must be the same settings version as that used in the firmware of the SEL-2431. Using the Device Editor driver version is discussed in more detail in *Settings Editor (Editor Mode)* on page 2.9.

Settings Database Management and Drivers

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

Active Database

Change the active database to the one that you need to modify by selecting **File > Active Database** on the main menu bar.

Database Manager

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

Settings Database

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

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

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

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

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

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

Copy/Move Settings Between Databases

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

Step 2. Select the **Open B** option button to open a device database.

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

a. Highlight a device or setting in the **A** database

b. Select **Copy** or **Move**, and select the **>** button to create a new device or setting in the **B** database.

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

Create a New Database, Copy an Existing Database

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

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

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

Step 3. Select **OK**.

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

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

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

Step 2. Select the **Open B** button. QuickSet prompts you for a file location.

Step 3. Create a new empty database.

a. Type a new database name.

b. Select the **Open** button.

c. Select **Yes**.

Load devices into the new database as in *Copy/Move Settings Between Databases* on page 2.5.

Settings

QuickSet offers the capability of creating settings for one or more SEL-2431 controls. Store existing relay settings downloaded from SEL-2431 controls with QuickSet, creating a library of relay settings, then modify and upload these settings from the settings library to an SEL-2431. QuickSet makes setting the relay easy and efficient. However, you do not have to use QuickSet to configure the SEL-2431; you can use an ASCII terminal or a computer running terminal emulation software. QuickSet provides the advantages of rules-based settings checks, SELOGIC control equation Expression Builder, operator control and metering HMI, event analysis, and help.

If your SEL-2431 is equipped with a Type A USB port on the front, it can receive settings that are stored on a USB flash drive. Use the **USB Flash Drive** feature in QuickSet to store settings to a USB flash drive.

Settings Editor

The Settings Editor shows the relay settings in easy-to-understand categories. The SEL-2431 settings structure makes setting the relay easy and efficient. Settings are grouped logically, and relay elements that are not used in the selected control scheme are not accessible. For example, if the relay is used in a locked-forward regulation mode, you only need to set the forward regulator settings. Settings for the other control operation modes (such as reverse settings) are dimmed (grayed) in the QuickSet menus. QuickSet shows all of the settings categories in the settings tree view. The settings tree view remains constant whether settings categories are enabled or disabled. However, any disabled settings are dimmed when accessed by selecting an item in the tree view.

If your SEL-2431 is equipped with a Type A USB port on the front, it can receive settings that are stored on a USB flash drive. Use the **USB Flash Drive** feature in QuickSet to store settings to a USB flash drive.

Settings Menu

QuickSet uses a database to store and manage SEL device settings. Each unique device has its own record of settings. Use the **File** menu to open an existing record, create and open a new record, or read relay settings from a connected SEL-2431 and then create and open a new record. Use the **Tools > Settings > Convert** menu to convert and open an existing record. The record will be opened in the **Setting Editor** as a Setting Form (template) or in Editor Mode.

Table 2.3 File/Tools Menus

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

File > New

Selecting **New** creates new settings files. QuickSet makes the new settings files from the driver that you specify in the **Settings Editor Selection** dialog box. QuickSet uses the Z number in the FID string to create a particular settings version. To get started making SEL-2431 settings with the **Settings Editor** in the Editor Mode, select **File > New** from the main menu bar, then SEL-2431 from the left list box and the Z number from the right list box as shown in *Figure 2.4*.

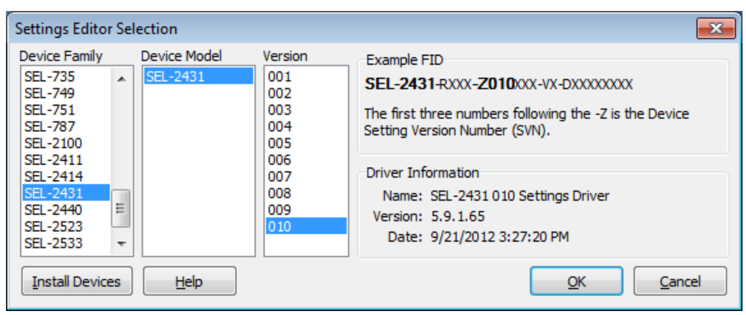

Figure 2.4 Selection of Drivers

After the relay model and settings driver selection, QuickSet presents the **Device Part Number** dialog box. Use this dialog box to configure the Device Editor to produce settings for a device with options determined by the part number, as shown in *Figure 2.5*. Press **OK** when finished.

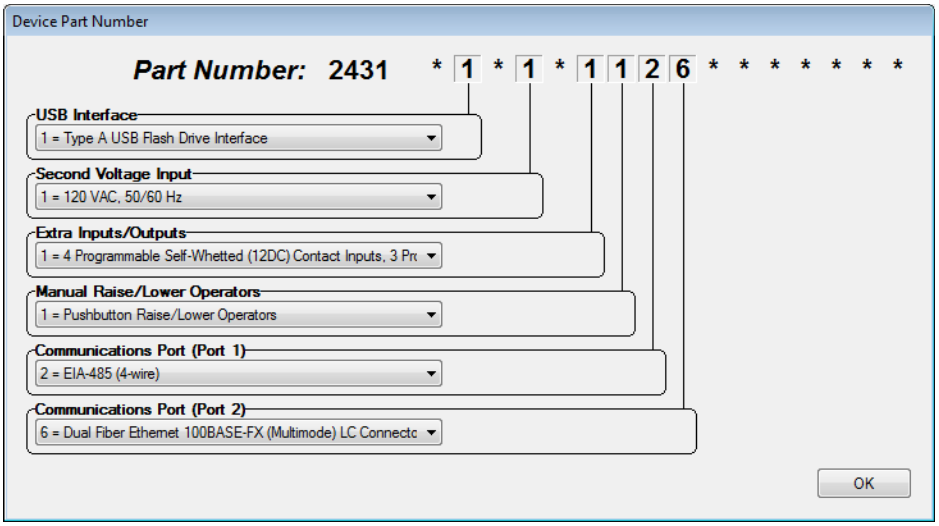

Figure 2.5 Device Part Number Screen

Figure 2.6 shows the **Settings Editor** screen. View the bottom of the window to check the **Settings Driver** number. Compare the QuickSet Settings Driver number and the first portion of the Z number in the FID string (select **Tools > HMI > HMI > Status**). These numbers must match. QuickSet uses this first portion of the Z number to determine the correct settings to display.

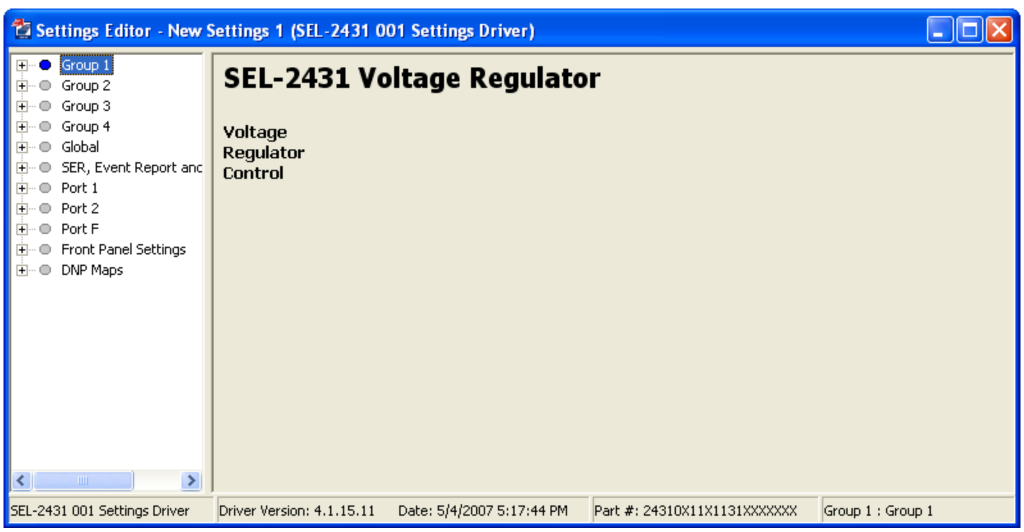

Figure 2.6 New Settings Screen

File > Open

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

File > Read

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

Tools > Settings > Convert

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

Settings Editor (Editor Mode)

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

Entering Settings

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

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

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

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

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

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

Expression Builder

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

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

Access the Expression Builder

Use the ellipsis button ... in the settings dialog boxes of **Settings Editor** windows to create expressions, as shown in *Figure 2.8*.

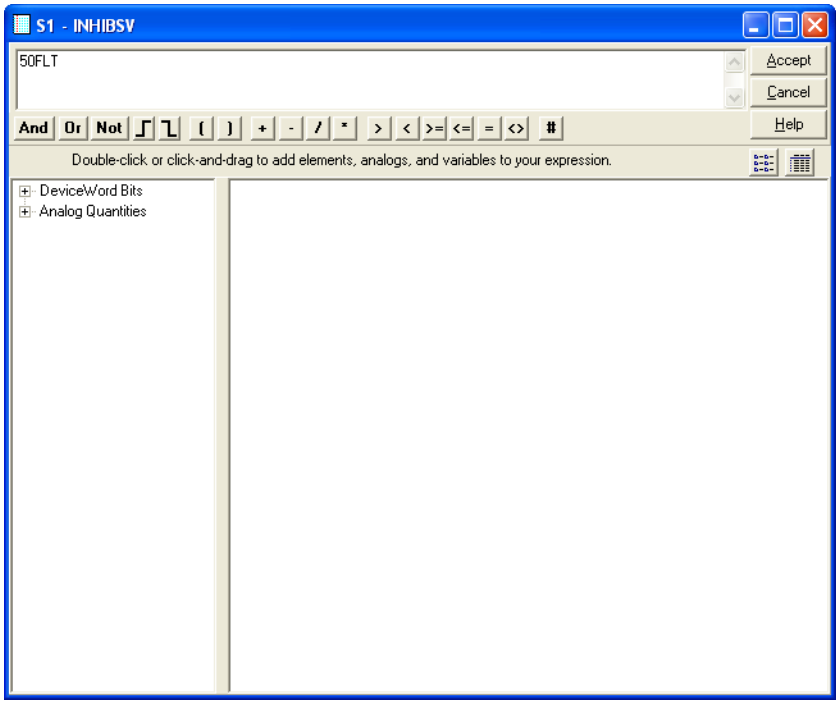

Figure 2.7 Create Expressions With Expression Builder

Expression Builder Organization

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

Using the Expression Builder

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

File > Save

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

File > Send

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

Edit > Part Number

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

Text Files

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

USB Flash Drive

QuickSet provides the functionality to interface with a Type A USB flash drive that you can use to interact with the SEL-2431. To access this feature, open a setting file for the SEL-2431 in the Settings Editor. The USB flash drive is under the **Front Panel** section of the tree-view list, as shown in *Figure 2.8*.

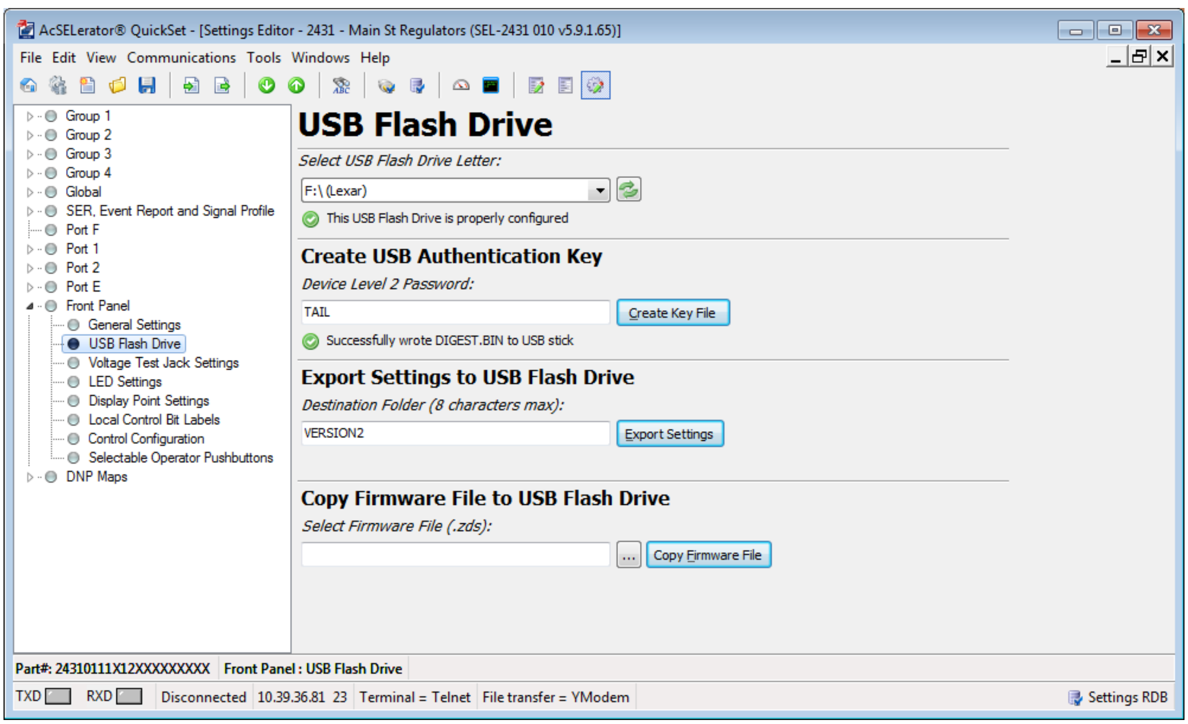

Figure 2.8 USB Flash Drive Menu in Settings Editor

Select USB Flash Drive Letter

Select the drive letter of the connected USB flash drive. You must do this before any other functions in this section.

Create USB Authentication Key

Enter the Level 2 (**2AC**) password of the SEL-2431 to create the encrypted USB authentication key. Press **Create Key File** to copy the USB authentication key onto the USB flash drive.

Export Settings to USB Flash Drive

Type a destination folder name, then press **Export Settings**. This will create a folder with the specified name to store the settings files. You will select the specified name on the HMI of the SEL-2431 when the settings are applied.

Copy Firmware File to USB Flash Drive

Select the firmware file, then press **Copy Firmware File**. The firmware file will be copied to the USB flash drive. You will select this firmware filename on the HMI of the SEL-2431 when the firmware upgrade is applied.

Event Analysis

QuickSet has integrated analysis tools that help you retrieve information about device operations quickly and easily. Use the event information that the SEL-2431 stores to evaluate the performance of a system (select **Tools > Events > Get Event Files**). *Figure 2.9* shows the screen for retrieving events.

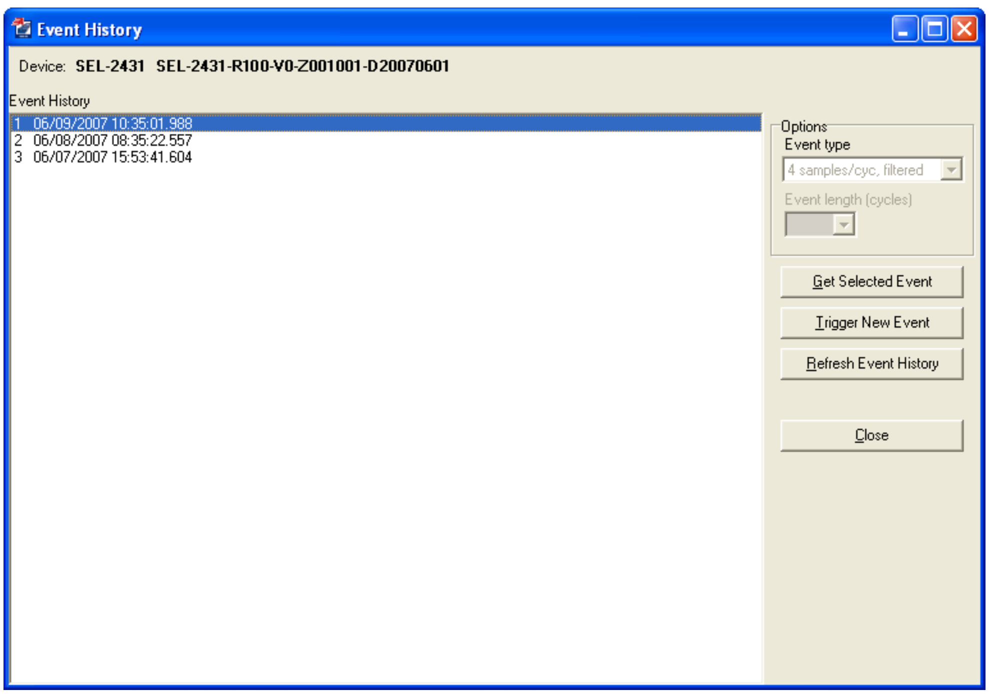

Figure 2.9 Retrieving Events

Event Waveforms

The device provides event reports that use 4 samples/cycle filtered data. See *Section 11: Analyzing Events* for information on recording events.

View Event History

You can retrieve event files stored in the device and transfer these files to a computer. For information on the types of event files and data capture, see *Event Reporting* on page 11.2. To download event files from the device, select **Tools > Events > Get Event Files**. The **Event History** dialog box appears, as shown in *Figure 2.9*.

Get Event

Highlight the event you want to view (e.g., Event 1 in *Figure 2.9*) and select the **Get Selected Event** button. When the download is complete, QuickSet queries whether to save the file on your computer, as shown in *Figure 2.10*.

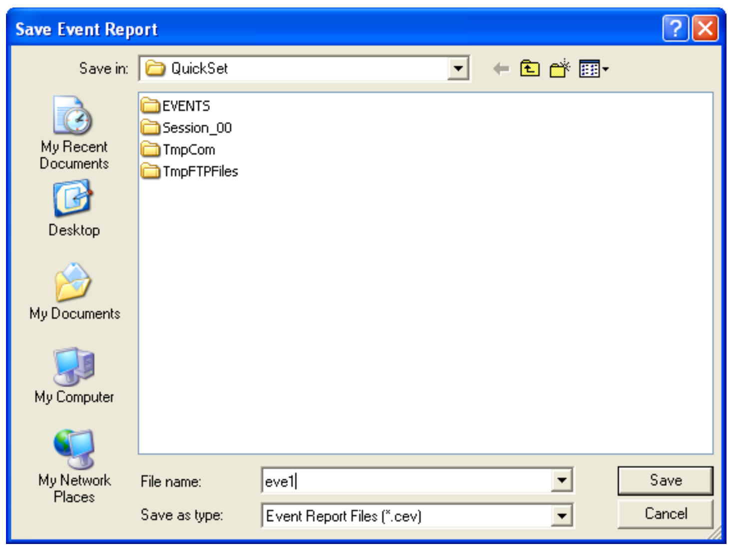

Figure 2.10 Saving the Retrieved Event

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

View Event Files

To view the saved events, you need the SEL-5601 software package. Use the **View Event Files** function from the **Tools > Events** menu to select the event you want to view (QuickSet remembers the location where you stored the previous event record). Use **View Combined Event Files** to simultaneously view as many as three separate events.

Meter and Control

Select **Tools > HMI > HMI** to bring up the screen shown in *Figure 2.11*. The HMI tree view shows all the functions available from the HMI function.

Device Overview

The device overview screen provides an overview of the device. The metering portion of the window shows the primary and secondary line current, source and load voltage, compensation voltage, power quantities, and frequency. The **Contact I/O** portion of the window displays the status of the contact inputs and outputs.

You can assign any Device Word bits to the 16 user-defined Target LEDs. To change the present assignment, perform the following steps:

Step 1. Double-click on the text above the square you want to change.

After double-clicking on the text, a box with available Device Word bits appears in the lower left corner of the screen.

Step 2. Select the appropriate Device Word bit.

Step 3. Select the **Update** button to assign the Device Word bit to the LED.

Step 4. To change the color of the LED, click in the square and make your selection from the color palette.

The front-panel portion of the window shows the eleven operation and indication LEDs, the control configuration indication LEDs, and the operator control indication LEDs.

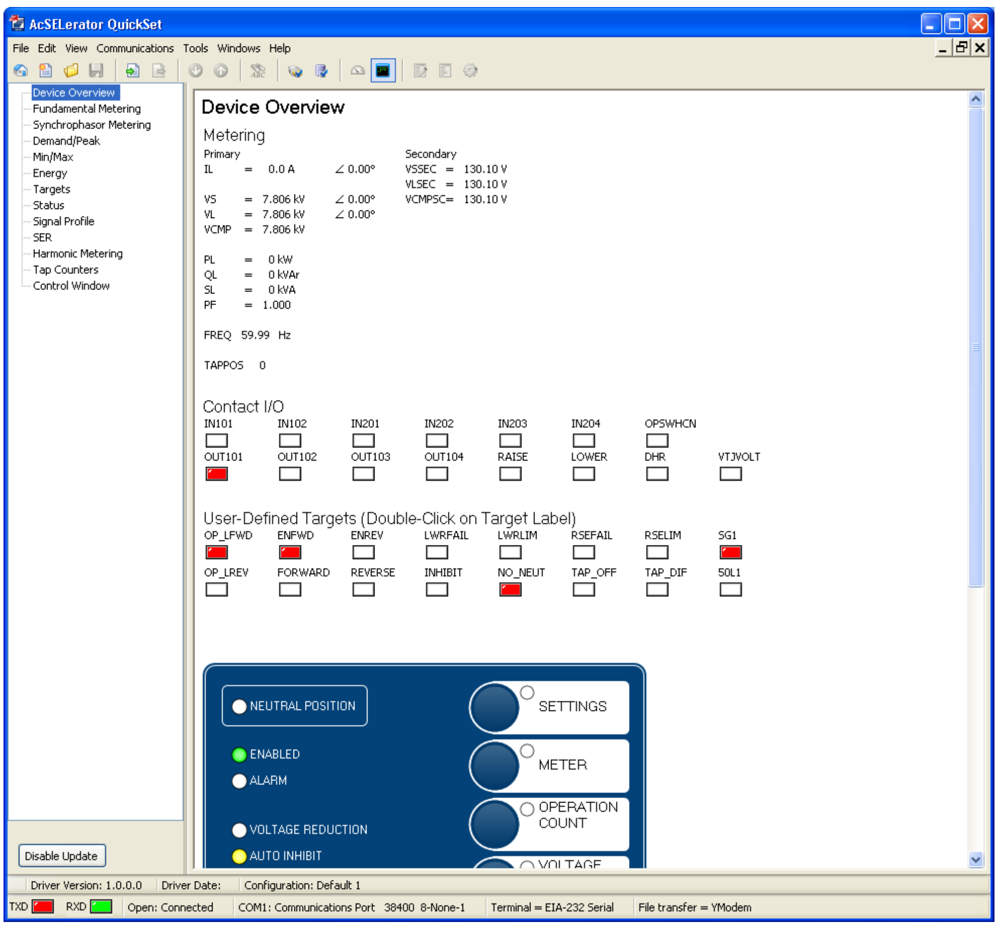

Figure 2.11 Device Overview Screen

The **Fundamental Metering** screen displays the corresponding instantaneous metering values.

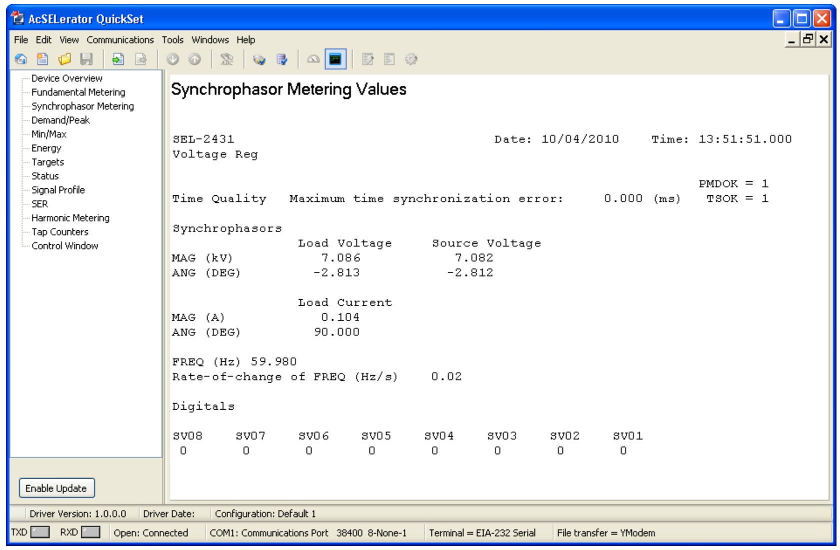

Figure 2.12 Synchrophasor Metering Screen

Figure 2.12 shows the **Synchrophasor Metering** screen. This screen displays the phasor measurement values.

Similarly, the **Demand/Peak** screen shows the demand and peak demand meter values, the **Max/Min** screen shows the max/min meter values, and the **Energy** screen shows the energy meter values.

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

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

Figure 2.13 shows the **Control** window. From here you can clear the Event History, SER, trigger events, and reset metering data. You can also set the time and date.

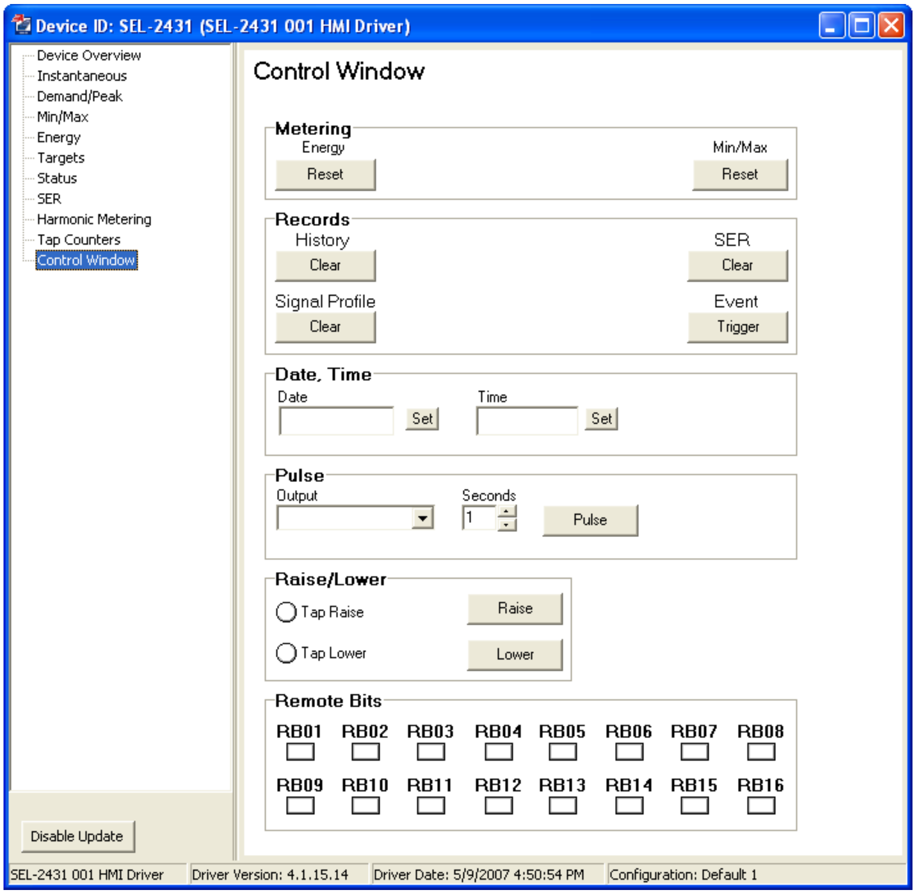

Figure 2.13 Control Window

To control the Remote Bits, select the appropriate square, then select the operation from the box shown in *Figure 2.14*.

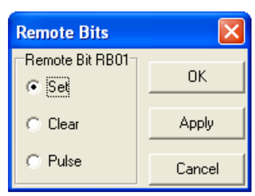

Figure 2.14 Remote Operation Selection

Help

Various forms of QuickSet help are available, as shown in *Table 2.4*. Press **<F1>** to open a context-sensitive help file with the appropriate topic as the default.

Table 2.4 Available Help Types

Help	Description
General QuickSet	Select **Help** from the main menu bar.
SEL-2431 Settings	Select **Settings Help** from the **Help** menu bar while the **Settings Editor** is open.
Database Manager	Select **Help** from the bottom of the **Database Manager** window.

SECTION 3

Control Algorithms

Line-Drop Compensation (LDC)

NOTE: A recommended, classic reference for understanding line-drop compensation is Distribution Systems - Electric Utility Engineering Reference Book, Volume 3, Electric Utility Engineers of the Westinghouse Electric Corporation, 1965 (Chapter 7: System Voltage Regulation, subchapter X. Line Drop Compensation).

The following examples use *forward* direction values, though the same principles are applicable for *reverse* direction values, too.

Line-drop compensation attempts to keep a point on the distribution system (deemed the *regulation point* as shown in *Figure 3.1*) at a constant voltage. This regulation point may be an important load center on the distribution feeder. To keep the regulation point at a constant voltage requires the voltage regulator to change its output voltage V_L as load changes—the voltage drop across the distribution system line impedance (R_{pri} + jX_{pri} in *Figure 3.1*) is compensated for.

NOTE: If LDC is turned off (group setting ELDC := N, or group SETLDCO := N and the voltage reduction scheme is active), then voltage V_{CMP} becomes the input voltage V_L as shown in *Figure 3.1*.

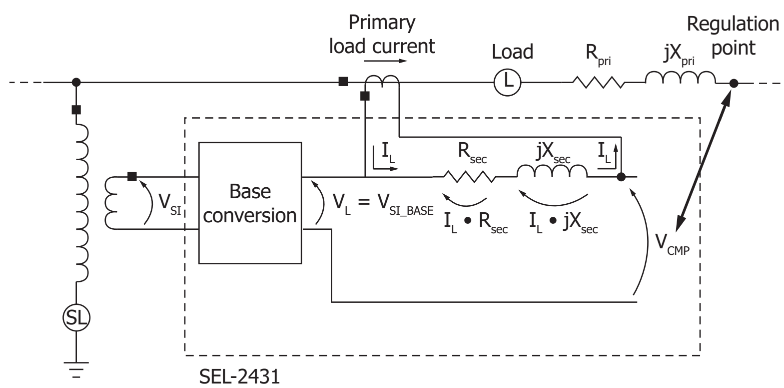

Figure 3.1 Line-Drop Compensation Performed to Keep Voltage Constant at the Regulation Point

Looking further at *Figure 3.1*, the SEL-2431 mimics the primary system in the implementation of the line-drop compensation feature:

- V_L corresponds to the voltage output of the voltage regulator
- R_{sec} and jX_{sec} (secondary impedance values) correspond to R_{pri} and jX_{pri} (primary impedance values)
- V_{CMP} corresponds to the desired, calculated voltage at the regulation point

OPEN- OR CLOSED-DELTA INSTALLATIONS
No angle adjustment of the load-drop compensation settings is needed for open-delta or closed-delta voltage regulator installations. Global settings CONFIG, DELTA, D_LAG, and D_LEAD handle any necessary angle adjustments. However, the 1.73 multiplier discussed below still needs to be applied by the user when making load-drop compensation settings for open-delta or closed-delta installations.

Secondary voltage values V_L (voltage regulator load-side voltage) and V_{CMP} (compensated voltage) and load current I_L can be observed in metering. The SEL-2431 does not literally have a mimic circuit as shown in *Figure 3.1*—this is just a functional representation.

As an intermediate step toward making line-drop compensation settings, derive the secondary impedance values R_{sec} and jX_{sec} using Global settings values BASE_SEC, BASE_PRI, and CTPRIM (0.2 A is the current transformer secondary rating):

$$R_{sec} = R_{pri} \bullet (BASE\_SEC/BASE\_PRI) \bullet (CTPRIM/0.2)$$

$$X_{sec} = X_{pri} \bullet (BASE\_SEC/BASE\_PRI) \bullet (CTPRIM/0.2)$$

SETTING APPLICATION
See *Table 4.2* and *Table 4.3* for the application of control and LDC settings, respectively, depending on the operating mode (setting OPMODE).

The line-drop compensation settings (for forward direction) are set in terms of the voltage drop across the R_{sec} and X_{sec} impedance values for rated current transformer secondary current (I_L = 0.2 A):

VLDCFWR = Forward Resistive LDC voltage

= 0.2A • R_{sec}

= R_{pri} • (BASE_SEC/BASE_PRI) • CTPRIM

VLDCFWX = Forward Reactive LDC voltage

= 0.2A • X_{sec}

= X_{pri} • (BASE_SEC/BASE_PRI) • CTPRIM

The above VLDCFWR and VLDCFWX settings can be used directly if the voltage regulator is connected line-to-neutral on a three-phase circuit.

If a voltage regulator is connected line-to-line on a three-phase circuit (open-delta or closed-delta installations), adjust settings VLDCFWR and VLDCFWX by the following factor:

➤ Multiply by 1.73 (= $\sqrt{3}$)

If the circuit is single-phase, adjust settings VLDCFWR and VLDCFWX by the following appropriate factor:

➤ Multiply by 2 if the voltage regulator is applied on a single-phase (two-wire) circuit (there is voltage drop in both wires)
➤ Multiply by 1.67 if the voltage regulator is applied on a single-phase (two-wire) circuit and one of the two wires is a neutral wire that is grounded every so often (there is voltage drop in both wires, but the neutral wire has less effective voltage drop because of the parallel ground path)

Figure 3.2 shows voltage V_{CMP} being maintained constant at the regulation point, while the voltage V_L at the voltage regulator location varies with load. The desired voltage at the regulation point is setting:

F_CNBND (Forward Center Band)

This desired voltage at the regulation point is not exact because of a voltage bandwidth allowance provided by setting:

F_BNDWD (Forward Band Width)

Voltage bandwidth prevents continual hunting (tap operation) by the voltage regulator control. See the combined application of settings F_CNBND and F_BNDWD in *Figure 3.8*.

Keep in mind that voltage V_{CMP} at the regulation point is a *calculated* value, per *Figure 3.1* and *Figure 3.3*. Voltage V_L is adjusted by the voltage regulator in an attempt to keep calculated voltage V_{CMP} at constant value F_CNBND (within bandwidth allowance F_BNDWD) at the regulation point.

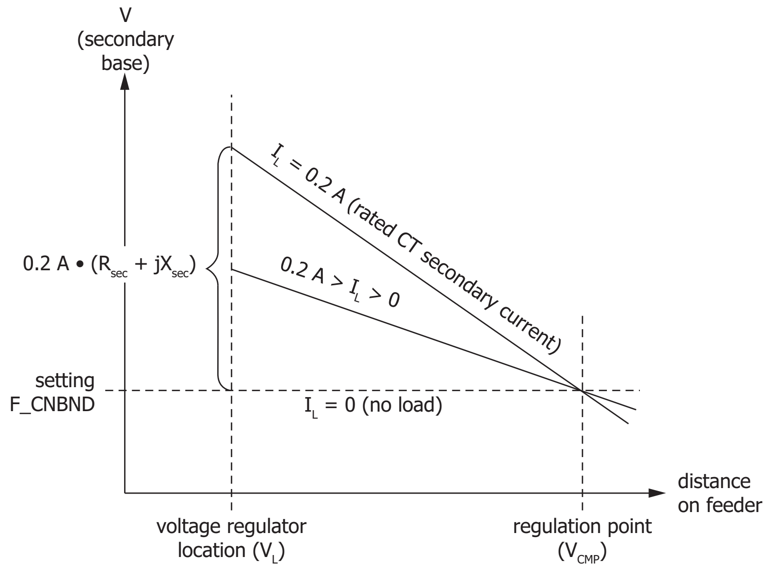

Figure 3.2 Line-Drop Compensation Keeps Voltage V_{CMP} Constant at the Regulation Point

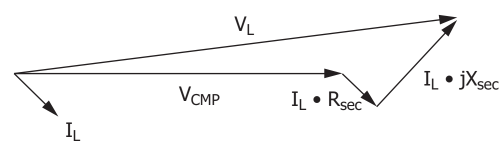

Figure 3.3 Vectorial Representation of Line-Drop Compensation Keeping Voltage V_{CMP} Constant at the Regulation Point

LDC Limits

In some specialized applications, utilities want to limit the influence that line-drop compensation has on V_L. This can be done using the four settings listed here.

SETTING APPLICATION
See *Table 4.3* for the application of these four settings, depending on the operating mode (setting OPMODE).

Setting:	Description:
VLDCFWMP	Forward LDC Voltage—Positive Maximum
VLDCFWMN	Forward LDC Voltage—Negative Maximum
VLDCRVMP	Reverse LDC Voltage—Positive Maximum
VLDCRVMN	Reverse LDC Voltage—Negative Maximum

The settings described as “Positive Maximum” will limit the influence of line-drop compensation when applied for $|V_{CMP}| \leq |V_L|$, as shown in *Figure 3.4*. This is the traditional application of line-drop compensation, where forward power flow results in voltage drop between the measured point and the regulation point.

Figure 3.4 shows V_{CMP} right at the ($|V_L|$ – VLDCFWMP) boundary. If $|V_{CMP}|$ < ($|V_L|$ – VLDCFWMP), then ($|V_L|$ – VLDCFWMP) effectively replaces V_{CMP} as the regulation point voltage. Otherwise, V_{CMP} continues as the standard regulation point voltage (see *Figure 3.1* and *Figure 3.2*). Setting VLDCFWMP limits the influence that V_{CMP} can have on increasing V_L when I_L increases. Setting VLDCRVMP operates similarly.

The settings described as “Negative Maximum” will limit the influence of line-drop compensation when applied for $|V_{CMP}| > |V_L|$, as shown in *Figure 3.5*. This is used in advanced applications where the traditional use of line drop compensation is not being applied.

Figure 3.5 shows V_{CMP} right at the ($|V_L|$ – VLDCFWMN) boundary (VLDCFWMN is a negative value). If $|V_{CMP}| >$ ($|V_L|$ – VLDCFWMN), then ($|V_L|$ – VLDCFWMN) effectively replaces V_{CMP} as the regulation point voltage. Otherwise, V_{CMP} continues as the standard regulation point voltage (see *Figure 3.1* and *Figure 3.2*). Setting VLDCFWMN limits the influence that V_{CMP} can have on decreasing V_L when I_L increases. Setting VLDCRVMN operates similarly.

Notice that the settings described in *Over- and Undervoltage Limits* on page 3.7 will limit the absolute value of V_{CMP}, whereas the settings described in this section limit the relative difference between V_{CMP} and V_L.

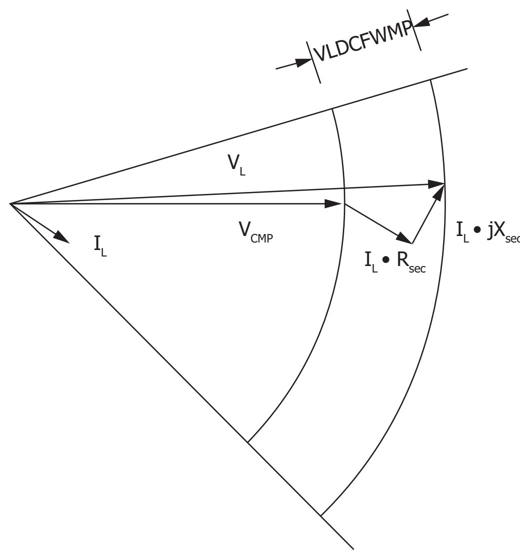

Figure 3.4 Application of VLDCFWMP When $|V_{CMP}| \leq |V_L|$

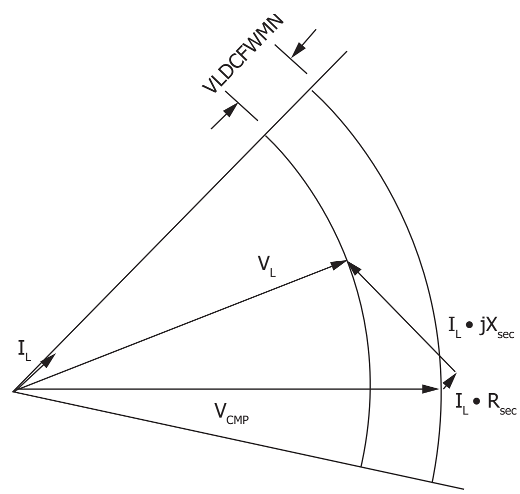

Figure 3.5 Application of VLDCFWMN When $|V_{CMP}| > |V_L|$

Adjust LDC Settings for Conductor Changes and Tapped Load

Figure 3.1 assumes a constant conductor type with no load tapped off between the voltage regulator and the regulation point. This is usually not the case. A more realistic scenario is conductor size change (toward smaller conductor the farther out one goes on the feeder) and load tapped off along the way. To derive adequate VLDCFWR and VLDCFWX settings in such a scenario:

➤ Presume that the entire length of line section is the conductor type of the majority conductor type of the same line section. Using the impedance values (ohms/unit length) of the majority conductor type, calculate the R_{pri} and jX_{pri} primary impedance values for the line section between the voltage regulator and the regulation point.

➤ Calculate the VLDCFWR and VLDCFWX settings with these R_{pri} and jX_{pri} primary impedance values, respectfully (use the VLDCFWR and VLDCFWX equations following *Figure 3.1*). Lower these new VLDCFWR and VLDCFWX settings values some (but keep the same VLDCFWR/VLDCFWX ratio) to account for tapped load (voltage drop to the end of the line section will not be as great as calculated—not all the load flows to the end of the line section). Some experimentation with these VLDCFWR and VLDCFWX settings may be required to optimize them.

Utility Voltage Regulator LDC Setting Sheets

Some utilities have their own voltage regulator LDC settings sheets. For such, keep in mind that voltage base conversion is already accounted for in the SEL-2431 (as shown in *Figure 3.1* with the output voltage converting from V_{S1} to $V_L = V_{S1\_BASE}$; see *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*).

Simplified LDC Settings: Directly Increase the Output Voltage as Load Increases

If the distribution feeder power factor is fairly consistent throughout the day, then LDC settings can be set to directly increase the output voltage as load increases. *Figure 3.6* shows the increased output voltage at the voltage regulator as the load increases:

➤ Setting F_CNBND (Forward Center Band, V sec.) is set for the desired output voltage during light load conditions (0 A primary load current, effectively, for the graph in *Figure 3.6*)

➤ V_{FL} (output voltage at full load, V sec.) corresponds to I_{FL} (primary current at full load)

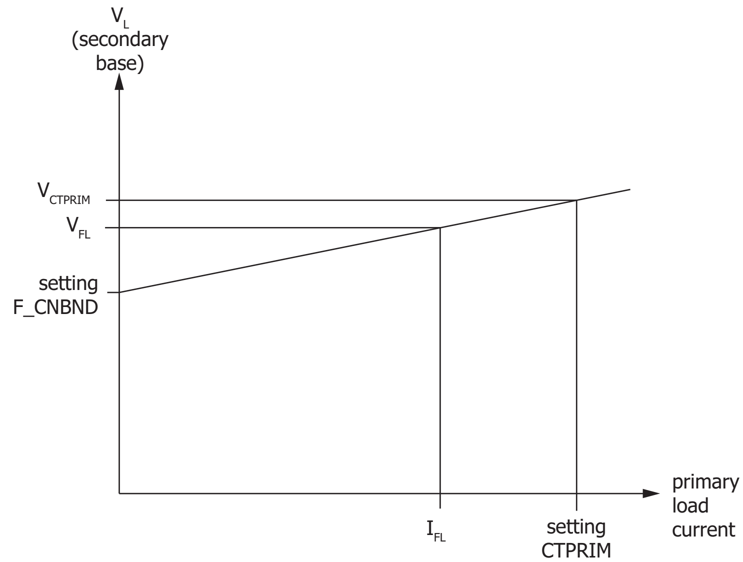

Figure 3.6 Line-Drop Compensation Configured to Directly Increase the Output Voltage (VL) as Load Increases

From the graphed slope in *Figure 3.6*:

$$(V_{FL} – F\_CNBND) / I_{FL} = (V_{CTPRIM} – F\_CNBND)/CTPRIM$$

Quantity (V_{CTPRIM} – F_CNBND) is the voltage drop across the R_{sec} and X_{sec} impedance values for rated current transformer secondary current (I_L = 0.2A; see *Figure 3.1* and *Figure 3.2*)

$$(V_{CTPRIM} – F\_CNBND) = (CTPRIM/I_{FL}) \bullet (V_{FL} – F\_CNBND)$$

Power factor angle = θ = (system voltage angle – system current angle). The LDC settings (for forward direction) are then:

VLDCFWR = Forward Resistive LDC voltage

= (VCTPRIM – F_CNBND) • cosθ

= (CTPRIM/I_{FL}) • (V_{FL} – F_CNBND) • cosθ

VLDCFWX = Forward Reactive LDC voltage

= (VCTPRIM – F_CNBND) • sinθ

= (CTPRIM/I_{FL}) • (V_{FL} – F_CNBND) • sinθ

For a feeder that operates close to unity power factor (= 1.00; power factor angle = θ = 0 degrees), by proper application of capacitors, the following LDC settings simplifications are made:

VLDCFWD = (CTPRIM/I_{FL}) • (V_{FL} – F_CNBND)

VLDCFWX = 0

For internal V_{CMP} calculations (see *Figure 3.7*):

R_{sec} = VLDCFWR / 0.2A

X_{sec} = VLDCFWX / 0.2A

Keep in mind that voltage V_{CMP} in *Figure 3.7* is still a *calculated* value, but is no longer the projected voltage at a regulation point (as in the traditional LDC scheme portrayed in *Figure 3.1* and *Figure 3.2*). In this application, voltage V_{CMP} is just the *light load* voltage value (= F_CNBND). Voltage V_L is adjusted by the voltage regulator in an attempt to keep calculated voltage V_{CMP} at constant value F_CNBND (within bandwidth allowance F_BNDWD).

Figure 3.7 shows voltages V_{CMP} and V_L “in line,” with no angle between them. This is because of:

$\tan^{-1}(X_{sec}/R_{sec}) = \tan^{-1}$ (VLDCFWX / VLDCFWR)

$= \theta$ (power factor angle)

This power factor angle congruency realizes the greatest V_L value (for a given load value). Any deviation from this power factor angle congruency results in V_{CMP} and V_L being *not* “in line” and V_L being somewhat diminished in magnitude. Thus, the desired voltage at a given current, shown optimally by the graphed slope in *Figure 3.6*, may be somewhat lower than shown, because of power factor deviations.

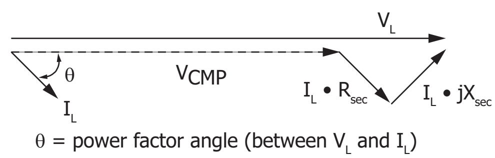

Figure 3.7 Vectorial Representation of Line-Drop Compensation Configured to Directly Increase the Output Voltage (V_L) as Load Increases

Over- and Undervoltage Limits

The following examples use *forward* direction values (e.g., Forward Center Band setting F_CNBND), though the same principles are applicable for reverse direction values, too. The following over- and undervoltage limits are operational only in the automatic mode (**AUTO** LED illuminated).

Maximum and Minimum Voltage Limits

The SEL-2431 causes a voltage regulator to automatically tap to keep the regulation point voltage (V_{CMP}) in *Figure 3.8* within its range. Setting limits VMAX and VMIN shown in *Figure 3.8* attempt to prevent the voltage regulator from automatically tapping too high or too low and causing abnormally high or low voltage at the voltage regulator location. The priority is to prevent voltage V_L (a real measurement) from exceeding its range, while V_{CMP} (a calculated value) is allowed to go out of its range if need be.

A conceivable scenario is one where line-drop compensation is in use (top part of *Figure 3.8*; compare to *Figure 3.2*) and load is increasing. Thus, the slope of the line in *Figure 3.8* (like that in *Figure 3.2*) also increases. Conceivably, the voltage at the voltage regulator location (V_L) could get too high (above VMAX) while trying to maintain the regulation point voltage (V_{CMP}) within its range. To prevent customers near the voltage regulator output from seeing high voltage as a result of automatic tapping, such tapping is suspended when voltage V_L is within 1 volt of setting VMAX (effective VMAX – 1 threshold). Voltage V_{CMP} is then allowed to slip underneath effective setting F_CNBND – 1/2 (F_BNDWD), if need be (V_{CMP} is allowed to go out of its range).

A similar low voltage scenario has a VMIN + 1 threshold (automatic tapping is suspended when voltage V_L is within 1 volt of setting VMIN).

Figure 3.8 is a combination of *Figure 3.1* and *Figure 3.2*.

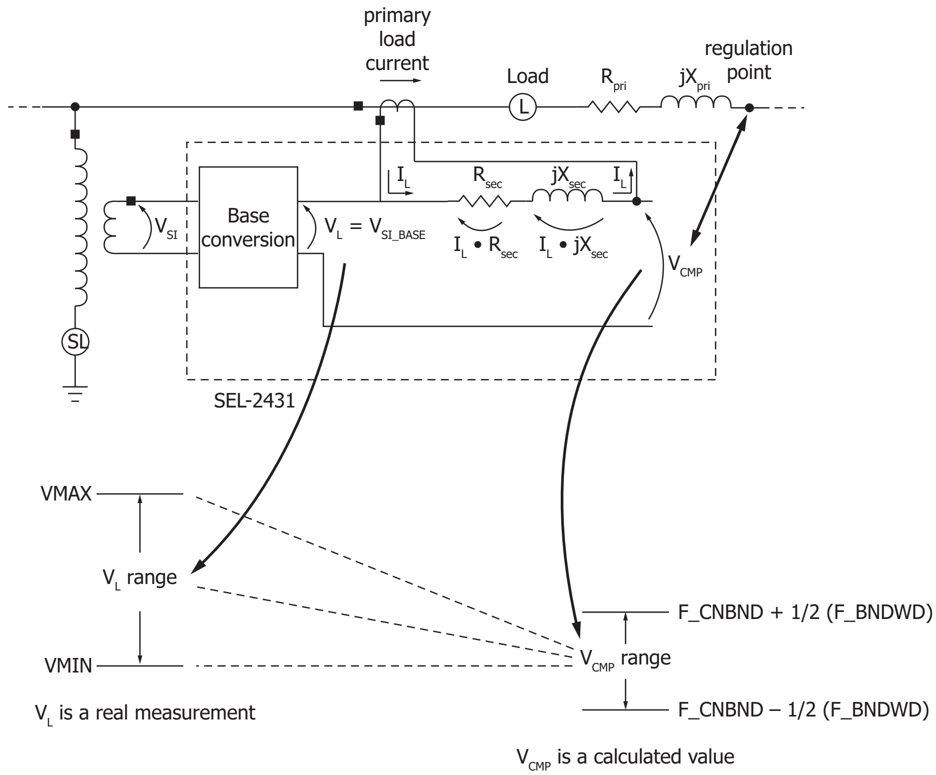

Figure 3.8 Maximum and Minimum Voltage Limits VMAX and VMIN

Voltage Limit Example

In the forward direction operation, if VMAX is exceeded, the SEL-2431 prevents further raise tap operations, but does not block lower tap operations. If an automatic lower operation takes place (either from the definite-time characteristic or from the runback feature), the SEL-2431 will perform additional lower operations if necessary (separated by the Group setting TD2 time delay) until the terminal voltage falls below VMAX.

NOTE: The example applies to reverse direction operation, except the raise and lower actions must be swapped in the description.

Similarly, if the voltage is less than VMIN, the control prevents further lower tap operations, but does not block raise tap operations. If an automatic raise operation takes place, the SEL-2431 will perform additional raise operations if necessary (separated by the Group setting TD2 time delay) until the terminal voltage goes above VMIN.

Runback High- and Low-Voltage Limits

As discussed in the preceding subsection, VMAX and VMIN limits prevent further automatic tapping out of the normal range of V_L (forward direction example).

Additional runback (high and low) limits VMAX + DBNDH and VMIN – DBNDL, respectively, will instigate automatic tapping to bring voltage VL back within its normal range. These runback limits are portrayed in *Figure 3.9* as lying beyond the VMAX/VMIN limits, but can be at the same level if respective runback settings DBNDH and DBNDL are set to zero (0).

Runback timer setting RUNBKPU qualifies voltage beyond runback limits VMAX + DBNDH or VMIN – DBNDL, then instigates automatic tapping in the direction to bring voltage V_L back within its normal range. After the first tap, if additional tapping is needed to bring voltage V_L back within its normal range, the timing reverts to setting TD2 (Time Delay 2 for Subsequent Taps). Setting TD2 is the same time setting that is reverted to after the first tap for regular automatic tapping.

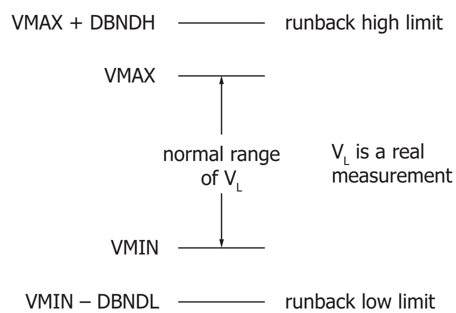

Figure 3.9 Runback High and Low Voltage Limits

VMAX and VMIN setting limits may still function to bring voltages back within normal limits (with subsequent timer TD2 timing and taps), even if the runback scheme is turned off (Group setting ENRUNBK := N, DBNDH := OFF, or DBNDL := OFF). See *Voltage Limit Example* for more information.

Runback Example Cases

A runback condition may be caused by several actions, some of which are listed below.

- A large change in system load causes the voltage to change quickly (perhaps from just below VMAX to just above VMAX + DBNDH, or from just above VMIN to just below VMIN – DBNDL). Such a load change may be either on the regulated feeder or on another feeder supplied by the same substation transformer.
- When the power is restored after a prolonged power outage, sometimes called “cold-load pickup”, the SEL-2431 initializes and immediately sees voltage that is higher than VMAX + DBNDH or lower than VMIN – DBNDL, and starts the runback timer.
- When the regulator is operated in manual mode and is then switched back to automatic mode, and the present tap position causes either a voltage greater than VMAX + DBNDH or lower than VMIN – DBNDL.
- When the regulator control changes setting groups, and the new setting group has different VMAX, VMIN, DBNDH, or DBNDL settings.

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SECTION 4

Control Operating Modes

Overview

The automatic operation of the voltage regulator has several automatic modes of operation to accommodate different operating conditions and applications. These automatic modes of operation dictate whether the voltage regulator will regulate voltage in the forward or the reverse direction. The automatic modes of operation are:

- Locked Forward Mode
- Locked Reverse Mode
- Idle Reverse Mode
- Bidirectional Mode
- Cogeneration Mode
- Flexible Distributed Generation

This section of the manual describes the method for selecting voltage for automatic operations, the forward/reverse power element used for automatic operations, and the automatic modes of operation listed above. This section also describes the voltage reduction logic.

Voltage Selection and Correspondence to Metering

Refer to *Figure B.1–Figure B.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*. Using the following information in the figure titles determine the appropriate figure to use:

- Tap changer type: SIEMENS, HOWARD, COOPER, or GE (Global setting TAPCHNGR)
- Regulator type: A or B (Global setting TYPE)

Using the appropriate figure, determine which voltage (V_{S1} or V_{S2}) is:

- the normal load-side voltage (right side of figure)
- the normal source-side voltage (left side of figure)

If the figure is *Figure B.1*, the normal load-side voltage (right side of the figure) is V_{S2} and it is:

- a measured voltage, if Global setting 2ND_PT := Y (an internal potential transformer is installed, as shown in the figure)
- a calculated voltage, if Global setting 2ND_PT := N (an internal potential transformer is not installed. In this case, voltage V_{S2} is calculated internally from normal source-side [left] voltage V_{S1}, known tap position, and load)

If the figure is *Figure B.2*, *Figure B.3*, or *Figure B.4*, the normal source-side voltage (left side of figure) is V_{S2} and it is:

- ➤ a measured voltage, if Global setting 2ND_PT := Y (an external potential transformer should be installed, as shown in the figure)
- ➤ a calculated voltage, if Global setting 2ND_PT := N (an external potential transformer is not installed. In this case, voltage V_{S2} is calculated internally from normal load-side [right] voltage V_{S1}, known tap position, and load)

These normal load-side and source-side voltages can be observed in metering (see *Table 7.1* and *Figure 7.1*):

- ➤ VL = normal load-side voltage
- ➤ VS = normal source-side voltage
- ➤ VCMP = voltage at the regulation point, based on either VL or VS, depending on power flow and enabled operating mode (see *Table 4.1* and *Figure 4.2* and accompanying text)

See *Figure 3.1* and *Figure 3.2* for a regulated voltage example (forward power flow perspective —power flowing toward normal load side; VCMP corresponds to regulated voltage VL).

If line-drop compensation is disabled (Group setting ELDC := N, or Group setting SETLDC0 := Y and the voltage reduction scheme is active), then VCMP = VL or VS, directly.

Forward/Reverse Power Flow, Operating Mode, and Regulated Voltage Selection

Forward/Reverse Power Flow

In *Figure B.1–Figure B.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*, forward power flow is in the normal load-side (right) direction. Reverse power flow is in the normal source-side (left) direction. Forward and reverse power flow is determined from the current and normal load-side voltage.

Only one of the following Device Word bits (see *Figure 4.1*) asserts at any one time for power flow determination:

- ➤ FORWARD—forward power flow in the normal load-side direction
- ➤ REVERSE—reverse power flow in the normal source-side direction
- ➤ NO_TORK—neither FORWARD nor REVERSE is asserted

NO TORK (“no torque”) indicates that no power flow direction can be determined because:

- ➤ not enough current or voltage signal is available (e.g., “no load” condition)
- ➤ or the load is nearly purely capacitive (e.g., big capacitor bank to the load-side of the voltage regulator) or inductive

Notice the separate current thresholds for the further refined forward and reverse power regions (Group settings 50FWDP and 50REVP, respectively) at the bottom of *Figure 4.1*.

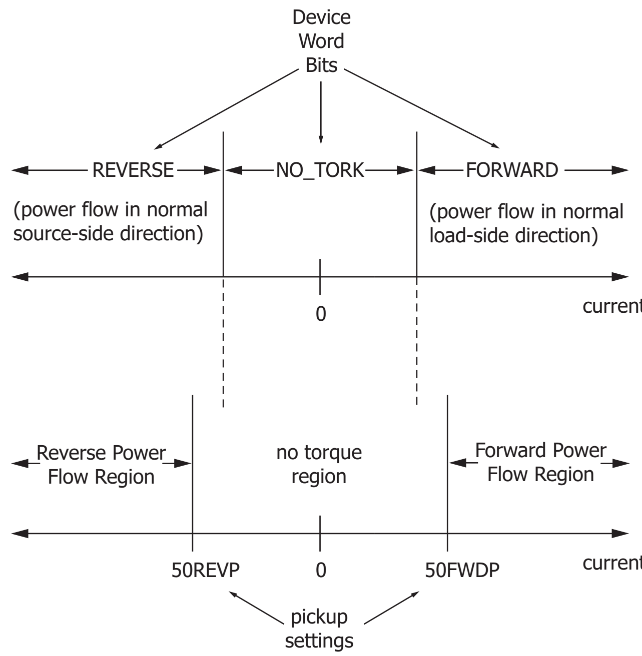


Figure 4.1 Derivation of Power Flow Regions

Operating Mode

Group setting OPMODE selects the power flow regions that the voltage regulator should operate in when in AUTO mode, as shown in *Figure 4.2* and *Figure 4.8*. Use Group setting OPMODE to select the operation mode according to the conditions listed in *Table 4.1*.

Table 4.1 Selections for Group Setting OPMODE

OPMODE Selection	Operating Mode: Scenario
LOCKFWD	Locked Forward: Power flow expected to always be in the forward (normal load-side) direction
LOCKREV	Locked Reverse: Power flow expected to always be in the reverse (normal source-side) direction
IDLEREV	Idle Reverse: Power flow expected to always be in the forward (normal load-side) direction, but no voltage regulation should occur if power flow is indeterminate (e.g., “no load” condition)
BIDIR	Bidirectional: Power flow direction varies due to multiple electric power system interfaces and the control alternately operates the regulator in the forward (normal load-side) and reverse (normal source-side) directions depending on power flow
COGEN	Cogeneration: Power flow direction varies due to distributed energy resources on the normal load side, and during reverse power flow, voltage is still regulated from a forward direction perspective (at the normal load-side terminal).
FLEXDG	Power flow direction varies and can be due to distributed energy resources or feeders with multiple electric power system interfaces. Since regulation direction cannot be determined by power flow alone, the control determines regulation direction based on the resultant voltage regulation effectiveness of the issued tap changes. See *Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG)* on page 4.8.

DIRECTION OF VOLTAGE REGULATION

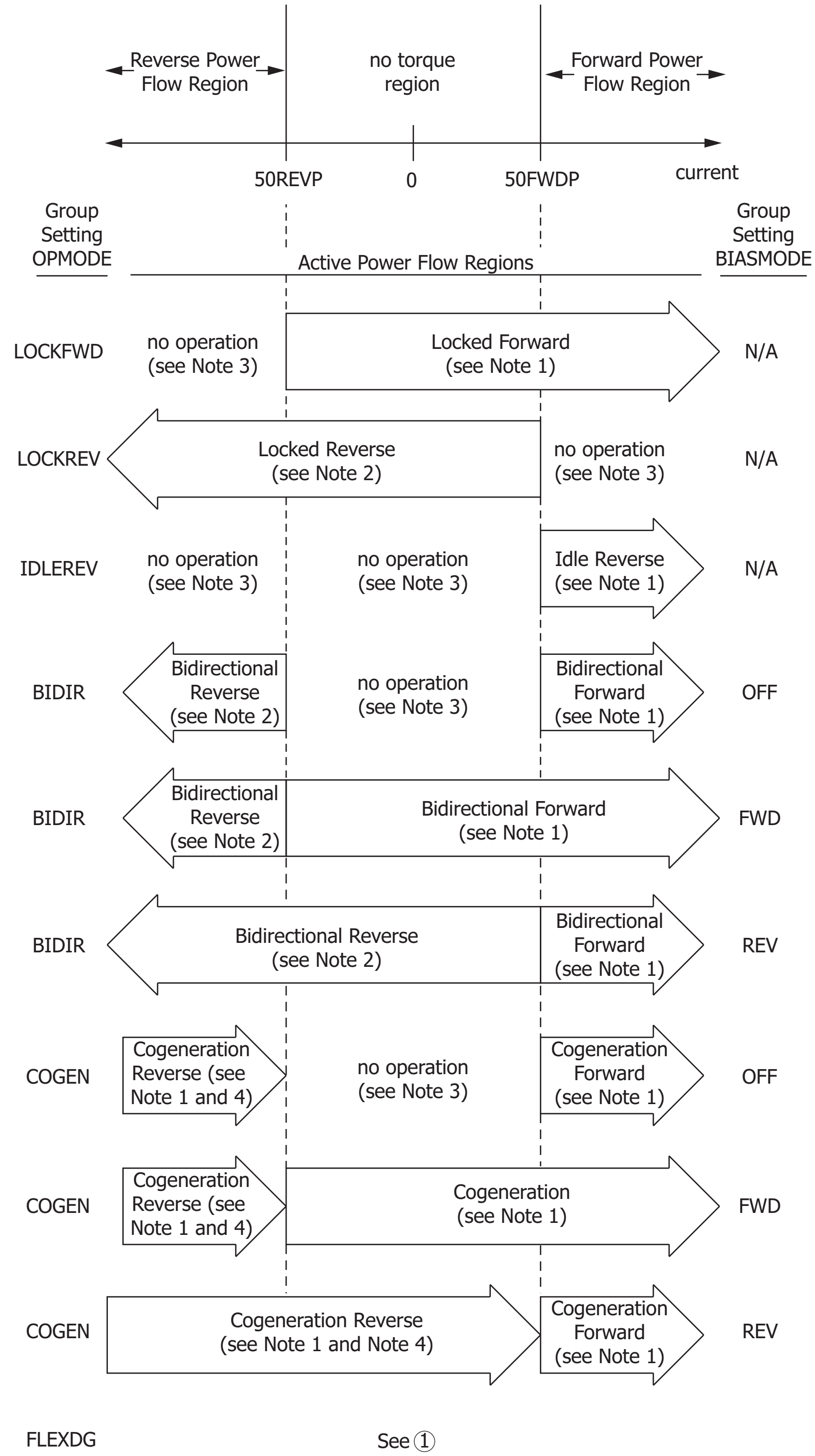
The arrows in *Figure 4.2* indicate the direction of voltage regulation: Right-pointing (forward): normal load-side voltage V_L is regulated. Left-pointing (reverse): normal source-side voltage V_S is regulated. Corresponding forward and reverse: controller settings and line-drop compensation (LDC) settings are also used (Note 4 discusses an exception). See *Table 4.2* and *Table 4.3*.

BIASMODE SETTING

See *BIASMODE Setting* on page 4.6.

Notice that the Locked Forward operating mode in *Figure 4.2* (which does not have the BIASMODE setting available) has voltage regulation in the forward power flow direction for the small current zone, similar to the Bidirectional Forward submode (BIASMODE = FWD).

Similarly, the Locked Reverse operating mode in *Figure 4.2* (which does not have the BIASMODE setting available) has voltage regulation in the reverse power flow direction for the small current zone, similar to the Bidirectional Reverse submode (BIASMODE = REV).



① *Figure 4.8*.

Figure 4.2 Active Power Flow Regions for the Different Operating Modes

The following notes further describe the active power flow regions depicted in *Figure 4.2*.

Note 1: Device Word bit ENFWD (enable forward control) = logical 1 if *both* the following are true:

- ➤ One of the "see Note 1" areas in *Figure 4.2* is active (for the given Group settings OPMODE and BIASMODE)
- ➤ SELOGIC setting INHIBSV (Inhibit Conditions) evaluates to logical 0

Note 2: Device Word bit ENREV (enable reverse control) = logical 1 if *both* the following are true:

- ➤ One of the "see Note 2" areas in *Figure 4.2* is active (for the given Group settings OPMODE and BIASMODE)
- ➤ SELOGIC setting INHIBSV (Inhibit Conditions) evaluates to logical 0

Note 3: Device Word bit INHIBIT = logical 1 if *any* of the following are true:

- ➤ Device Word bit MODEINH is asserted when the operating mode (for the given Group settings OPMODE and BIASMODE) is in the "no operation" zone shown in *Figure 4.2*.
- ➤ SELOGIC setting INHIBSV (Inhibit Conditions) evaluates to logical 1. Device Word bit INHIBSV is asserted when its SELOGIC control equation asserts (see *Group Settings* on page SET.5)

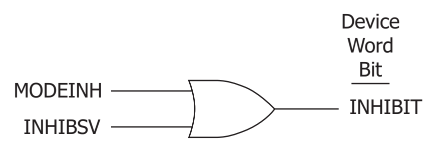


Figure 4.3 INHIBIT Logic Diagram

No automatic tap changing occurs when Device Word bit INHIBIT = logical 1, even if the SEL-2431 is in the AUTO mode (front-panel **AUTO** LED illuminated).

MORE COMPLEX SYSTEMS

For systems (usually containing cogeneration/distributed generation) where voltage regulation direction cannot be reliably determined by power flow, see *Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG)* on page 4.8.

Note 4: This Cogeneration mode region is unique in that it regulates voltage in the forward direction but uses reverse line-drop compensation (LDC) settings. Following are considerations for making reverse LDC settings for this particular Cogeneration mode region:

- ➤ Set VLDCRVR := 0 and VLDCRVX := 0. The voltage regulator maintains normal load-side voltage V_L at a constant output (F_CNBND setting level). As reverse current through the voltage regulator increases (e.g., supplied by the cogeneration/distributed generation on the normal load side), voltage out on the normal load-side circuit increases.
- ➤ Set VLDCRVR and VLDCRVX to positive values. The voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the normal load-side circuit at the F_CNBND setting level. As reverse current through the voltage regulator increases (e.g., supplied by the cogeneration/distributed generation on the normal load side), V_L decreases (LDC voltage regulation perceives regulation point voltage as being too high and thus adjusts V_L down). To prevent V_L from going too low for increased reverse current, LDC settings VLDCRVR and VLDCRVX can be set to smaller positive values (or to negative values).

The normal source-side voltage of the voltage regulator (farthest from the cogeneration/distributed generation source unit) is still the "stiffest bus," so to speak. The cogeneration/distributed generation source is not going to influence this normal source-side voltage of the voltage regulator. Thus, the voltage regulator is still able to regulate its normal load-side voltage (closest to the cogeneration/distributed generation source unit).

BIASMODE Setting

The BIASMODE setting in *Figure 4.2* and *Figure 4.8* allows for automatic voltage regulator tapping in the small current zone (includes zero current flow):

- ➤ Reverse Current ≤ setting 50REVP
- ➤ Forward Current ≤ setting 50FWDP

This prevents a voltage regulator from being “stranded” (not being able to tap) when current is at or near zero in magnitude.

An optimum application example [using the Bidirectional operating mode (OPMODE = BIDIR) and BIASMODE = FWD] is for customers between the normal load-side of a voltage regulator and a farther away normally-open switch on the primary system (see *Figure 4.4(a)*). The minimal load due to the relatively few customers on this normal load-side primary system section results in the voltage regulator operating in the small current zone. However, normal load-side voltage is adequately regulated because BIASMODE = FWD and the Bidirectional Forward submode is active (see *Figure 4.2*).

Similarly, OPMODE = BIDIR and BIASMODE = REV applies for customers between the normal source-side of a voltage regulator and a farther away normally-open switch on the primary system (see *Figure 4.4(b)*). Normal source-side voltage is adequately regulated for these relatively few customers on this normal source-side primary system section (voltage regulator operating in the small current zone) because BIASMODE = REV and the Bidirectional Reverse submode is active (see *Figure 4.2*).

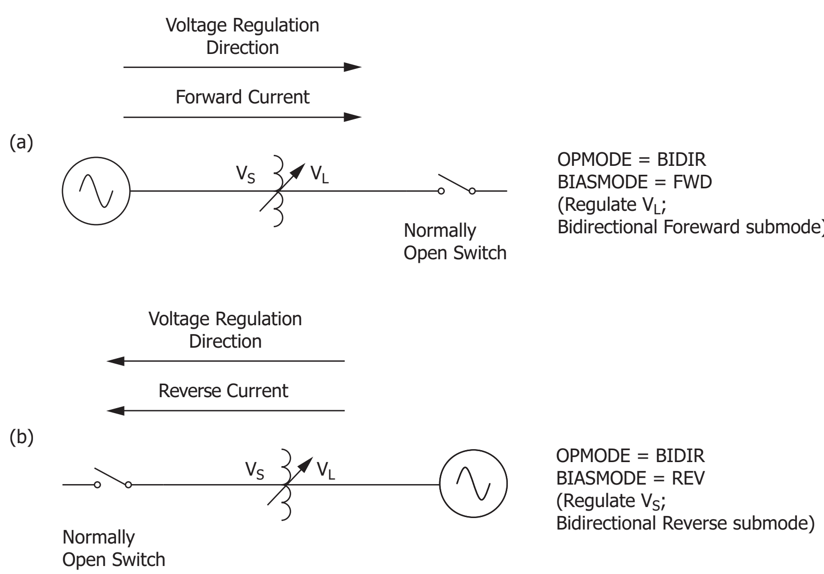


Figure 4.4 Applications for BIASMODE Setting

Control and LDC Settings Per Operating Mode

FORWARD OR REVERSE
See *Figure 4.2* for greater detail on direction of voltage regulation (reverse or forward).

Table 4.2 Active Control Settings (Forward or Reverse) for the Different Operating Modes

Control Settings:	Reverse	Forward
	R_CHAR R_CNBND R_BNDWD R_TD1 R_DISC R_DLYRS	F_CHAR F_CNBND F_BNDWD F_TD1 F_DISC F_DLYRS
Operating Modes wherein Control Settings are used:		Locked Forward (OPMODE = LOCKFWD)
	Locked Reverse (OPMODE = LOCKREV)	
		Idle Reverse (OPMODE = IDLEREV)
	Bidirectional Reverse submode (OPMODE = BIDIR)	Bidirectional Forward submode (OPMODE = BIDIR)
		Cogeneration Reverse and Cogeneration Forward submodes (OPMODE = COGEN)
	Flexible Distributed Generation (OPMODE = FLEXDG) (see *Table 4.4*)	

LINE-DROP COMPENSATION
See *Line-Drop Compensation (LDC)* on page 3.1 for more information on the LDC settings in *Table 4.3*.

Table 4.3 Active LDC Settings (Forward or Reverse) for the Different Operating Modes

LDC Settings (enabled with setting ELDC = Y):	Reverse	Forward
	VLDCRVR VLDCRVX VLDCRVMP VLDCRVMN	VLDCFWR VLDCFWX VLDCFWMP VLDCFWMN
Operating Modes wherein LDC Settings are used:		Locked Forward (OPMODE = LOCKFWD)
	Locked Reverse (OPMODE = LOCKREV)	
		Idle Reverse (OPMODE = IDLEREV)
	Bidirectional Reverse submode (OPMODE = BIDIR)	Bidirectional Forward submode (OPMODE = BIDIR)
	Cogeneration Reverse submode (OPMODE = COGEN)	Cogeneration Forward submode (OPMODE = COGEN)
	Flexible Distributed Generation (OPMODE = FLEXDG) (see *Table 4.5*)	

Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG)

Distributed Generation Voltage Regulation Challenges (Without OPMODE = FLEXDG)

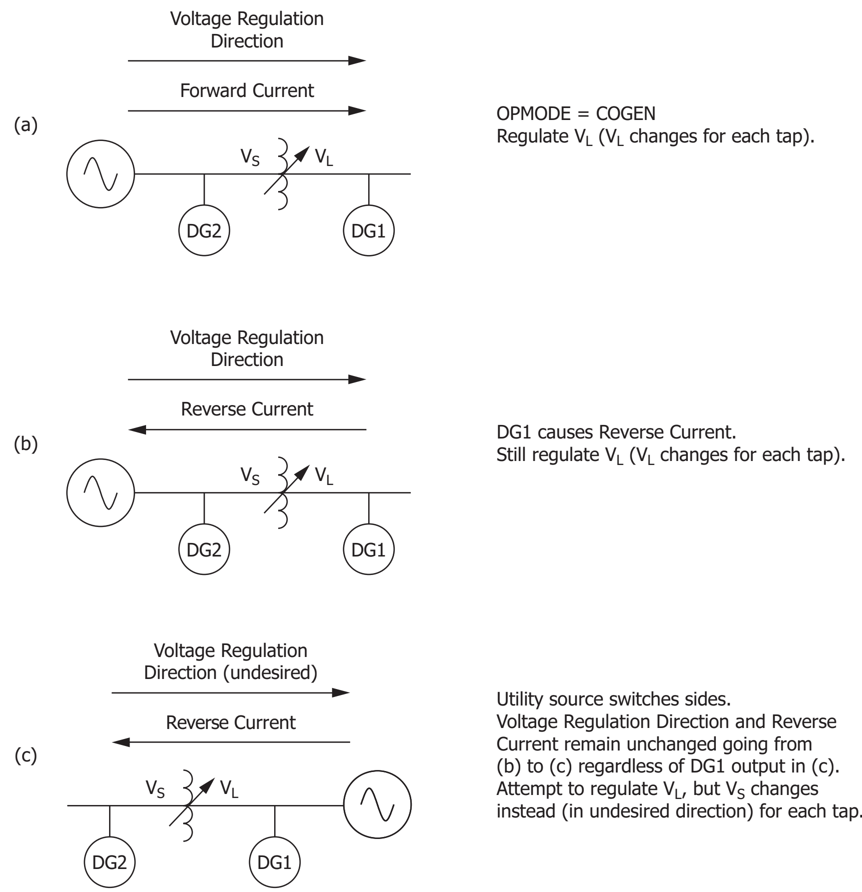


Figure 4.5 Operating in Cogeneration Voltage Regulation Mode (OPMODE = COGEN) but Utility Source Reversal Then Occurs

NOTE: Device Word Bit OP_FLEX asserts (= logical 1) when OPMODE = FLEXDG.

In *Figure 4.5(a),* distributed generation (DG) is found on both sides of the voltage regulator, which operates with the cogeneration voltage regulation mode (setting OPMODE = COGEN). With the indicated voltage regulation direction, the voltage regulator control regulates the normal load-side voltage V_L. The utility source is on the normal source side (left side) of the voltage regulator. Any tapping of the voltage regulator causes normal load-side voltage V_L to change in magnitude while normal source-side voltage V_S at the voltage regulator remains relatively unchanged. Even if DG1 causes reverse current to flow through the voltage regulator, as shown in *Figure 4.5(b)*, any tapping of the voltage regulator still causes voltage V_L to change in magnitude while voltage V_S remains relatively unchanged. This is because the utility source is much stronger/stiffer than any DG.

Figure 4.5(c) shows the utility source suddenly switched to the normal load side (right side) of the voltage regulator. The new utility source for this feeder portion could even be from a different substation. Voltage regulation direction and reverse current flow through the regulator (even with no DG1 output) match what is shown in *Figure 4.5(b)*. Now any tapping of the voltage regulator causes normal source-side voltage V_S at the voltage regulator to change in magnitude while normal load-side voltage V_L remains relatively unchanged. With the indicated voltage regulation direction in *Figure 4.5(c)* (the voltage regulator control regulates voltage V_L for OPMODE = COGEN), the control continues to ask for voltage regulator tapping in an attempt to control voltage V_L. If the voltage regulator control attempts to raise voltage V_L, the result is voltage V_S being lowered instead.

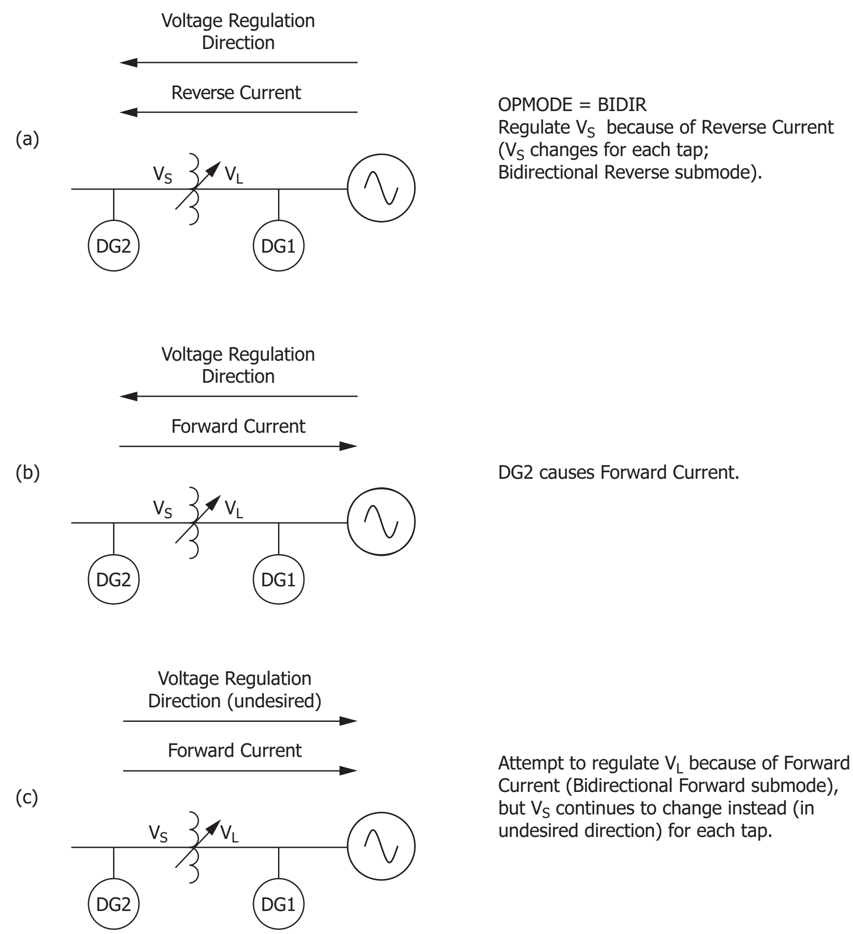


Figure 4.6 Operating in Bidirectional Reverse Voltage Regulation Submode (OPMODE = BIDIR) but Current Reversal Then Occurs

Figure 4.6(a) is the same as *Figure 4.5(c)*, except that the voltage regulation direction is changed (the voltage regulator control regulates the normal source-side voltage V_S, instead of normal load-side voltage V_L) because the operating mode is changed to the bidirectional voltage regulation mode (OPMODE = BIDIR). The bidirectional reverse voltage regulation submode is operative with reverse current flowing through the voltage regulator.

If DG2 causes forward current to flow through the voltage regulator (*Figure 4.6(b)*), the bidirectional forward voltage regulation submode is operative (*Figure 4.6(c)*) and the voltage regulator control now regulates the normal load-side voltage V_L, instead of normal source-side voltage V_S. The stronger/stiffer utility source is still on the right side so this bidirectional forward voltage regulation submode will not function properly in *Figure 4.6(c)*. If the voltage regulator control attempts to raise voltage V_L, the result is voltage V_S being lowered instead.

Distributed Generation Voltage Regulation Challenges Are Handled With OPMODE = FLEXDG

ONLY SOURCE-SIDE VOLTAGE

If only normal source-side voltage V_S is available, the OPMODE = FLEXDG scheme can operate even with the conditions detailed in the second NOTE for Figure B.1 of the SEL-2431 Field Reference Guide. Tap delta voltage for V_S changes in the opposite manner compared to V_L for a given tap operation (see discussion accompanying *Figure 4.5* and *Figure 4.6*). OPMODE = FLEXDG scheme logic adjusts accordingly for this difference (analog value DLT_VSS is monitored instead of DLT_VLS; see *Table F.1*).

Current direction through the voltage regulator is not a reliable indicator of change in strong/stiff source from one side of the voltage regulator to the other when DGs are interspersed on the circuit. The change in normal load-side voltage V_L due voltage regulator tapping is a better indicator:

- If voltage V_L changes sufficiently in magnitude due to tapping, operate in the cogeneration voltage regulation mode (*Figure 4.5(a)* and *Figure 4.5(b)*).
- If voltage V_L does not change much (if at all) in magnitude due to tapping, operate in the bidirectional reverse voltage regulation submode (*Figure 4.6(a)*) but allow the bidirectional reverse voltage regulation submode to continue to operate (continue regulating the normal source-side voltage V_S) for forward current flow through the voltage regulator (*Figure 4.6(b)*).

This combination scheme of the cogeneration voltage regulating mode and a modified bidirectional reverse voltage regulation mode is realized with OPMODE = FLEXDG (flexible distributed generation voltage regulation mode). To switch between these resulting submodes for OPMODE = FLEXDG, the difference in voltage V_L due to a single tap operation of the voltage regulator (tap delta voltage) has to be analyzed.

Tap Delta Voltage Settings and Analysis (OPMODE = FLEXDG)

Analog value DLT_VLS (see *Table F.1*) is the difference in normal load-side voltage V_L due to a single tap operation of the voltage regulator (tap delta voltage; mV secondary).

A full-value tap delta voltage (mV secondary) for V_L is determined as:

(VADJUST/16) • BASE_SEC • (1000 mV sec./V sec.)

Where:

- VADJUST is the per unit voltage adjustment global setting in per unit of full voltage (factory default is VADJUST = 0.100 per unit for nominal 10% full raise voltage regulator; some Type B designs need a different VADJUST value (e.g., VADJUST = 0.111); see *Table 8.7*)
- Denominator value 16 is the number of voltage regulator taps (from neutral position) to realize full raise voltage (or full lower voltage) out of the voltage regulator (see *Figure 5.1* and *Figure 5.2*). VADJUST/16 is the per unit voltage change for one voltage regulator tap operation (e.g., 0.00625 per unit = 0.100 per unit/16; often referred to as a 0.625% voltage change)
- BASE_SEC is the Base Secondary Voltage global setting (factory default of BASE_SEC = 120.0 V sec.)

With the preceding default settings, a full-value tap delta voltage for V_L evaluates to:

0.75 V sec. = 750 mV sec. = (0.100/16) • (120.0 V sec.) • (1000 mV sec./V sec.)

The following group settings:

- TAPDELTL (Low Tap Delta Voltage Threshold Per Unit; factory default is 0.50 per unit)
- TAPDELTH (High Tap Delta Voltage Threshold Per Unit; factory default is 0.60 per unit)

respectively determine if:

- Voltage V_L does not change much (if at all) in magnitude due to tapping (hereafter referred to as low tap delta voltage)
- Voltage V_L changes in magnitude due to tapping (hereafter referred to as high (normal) tap delta voltage)

per the following threshold calculations:

- TAP_DELTA_LO = TAPDELTL • (VADJUST/16) • BASE_SEC • (1000 mV sec./V sec.)
- TAP_DELTA_HI = TAPDELTH • (VADJUST/16) • BASE_SEC • (1000 mV sec./V sec.)

With the preceding default settings, these threshold calculations evaluate to:

- TAP_DELTA_LO = 0.375 V sec. = 375 mV sec. = 0.5 • 750 mV sec. (50% of full-value tap delta voltage)
- TAP_DELTA_HI = 0.450 V sec. = 450 mV sec. = 0.6 • 750 mV sec. (60% of full-value tap delta voltage)

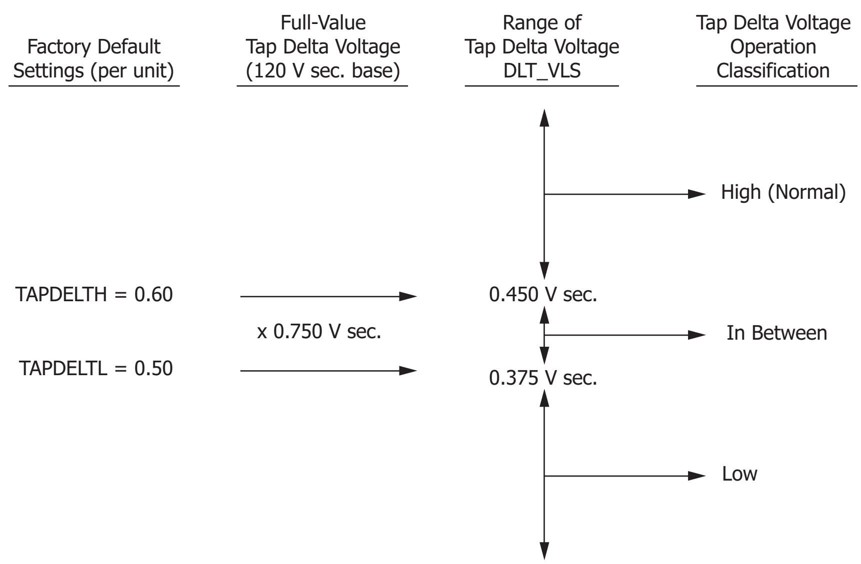


Figure 4.7 Tap Delta Voltage Operation Classification per Resultant Tap Delta Voltage DLT_VLS

Threshold comparisons result in the following operation classifications (see *Figure 4.7*):

- If analog value DLT_VLS ≤ TAP_DELTA_LO for a given tap operation, then the tap operation is deemed a **low tap delta voltage operation**.
- If analog value DLT_VLS > TAP_DELTA_HI for a given tap operation, then the tap operation is deemed a **high (normal) tap delta voltage operation**.
- If neither of the preceding comparisons for a given tap operation are satisfied (TAP_DELTA_LO < analog value DLT_VLS ≤ TAP_DELTA_HI), then the tap operation is deemed an **in between tap delta voltage operation**.

Tap Operations Determine Active Voltage Regulation Submode (OPMODE = FLEXDG)

The latest three tap operations are evaluated as follows (see *Figure 4.8*):

- In the cogeneration forward operation or the cogeneration reverse operation submode, if 2 out of 3 tap operations are low tap delta voltage operations, this is deemed a **qualified low tap delta voltage transition** and the following occur:
  - Qualified low tap delta voltage transition results in bidirectional reverse operation becoming the active voltage regulation submode.
  - Device Word bit DVLOW changes from logical 0 to logical 1.
  - Note: If the first two tap operations are low tap delta voltage operations, there is no waiting for a third tap operation and a qualified low tap delta voltage transition proceeds immediately.
- In the bidirectional reverse operation submode, if 2 out of 3 tap operation counts are high (normal) tap delta voltage operations, this is deemed a **qualified high (normal) tap delta voltage transition** and the following occur:
  - Qualified high (normal) tap delta voltage transition results in either the cogeneration forward operation or the cogeneration reverse operation becoming the active voltage regulation submode.
  - Device Word bit DVLOW changes from logical 1 to logical 0.
  - Note: If the first two operations are high (normal) tap delta voltage operations, there is no waiting for a third tap operation and a qualified high (normal) tap delta voltage transition proceeds immediately.

AUTOMATIC MODE

If the SEL-2431 is not in automatic mode (front-panel **AUTO** LED extinguished; Device Word bit AUTO = logical 0), then no automatic voltage regulation tapping occurs and Device Word bit DVLOW = logical 0.

When the SEL-2431 goes from manual to automatic mode (front-panel **AUTO** LED illuminated; Device Word bit AUTO = logical 1), then the OPMODE = FLEXDG scheme starts out in the Cogeneration voltage regulation submode (see *Figure 4.8*) with Device Word bit DVLOW = logical 0.

Once a qualified low tap delta voltage or qualified high (normal) tap delta voltage transition is made (see *Figure 4.8*), these latest three tap operation results are erased and tap operation evaluation is started anew. Cogeneration voltage regulation is the default mode on startup (with Device Word bit DVLOW = logical 0).

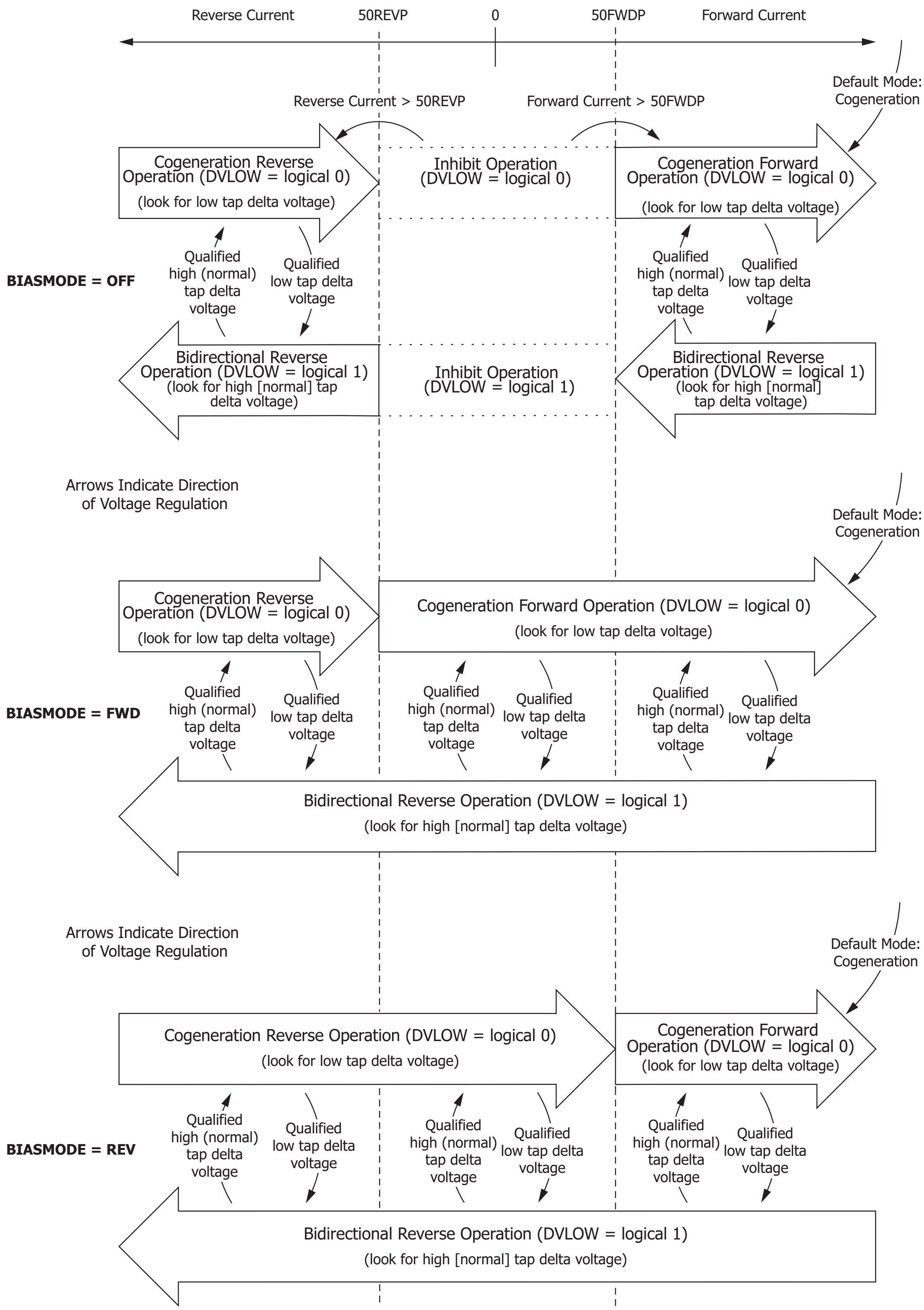


Figure 4.8 Operation Submodes of the Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG; Variation per BIASMODE Setting)

Figure 4.9 shows the BIASMODE = FWD layout, but it is generally applicable to all the scheme variations (per BIASMODE setting) in *Figure 4.8*. Different quadrants of *Figure 4.9* are extensively referenced in *Table 4.6* through *Table 4.9* in the consideration of center band settings (F_CNBND and R_CNBND; see *Table 4.4*) and line-drop compensation settings (see *Table 4.5*).

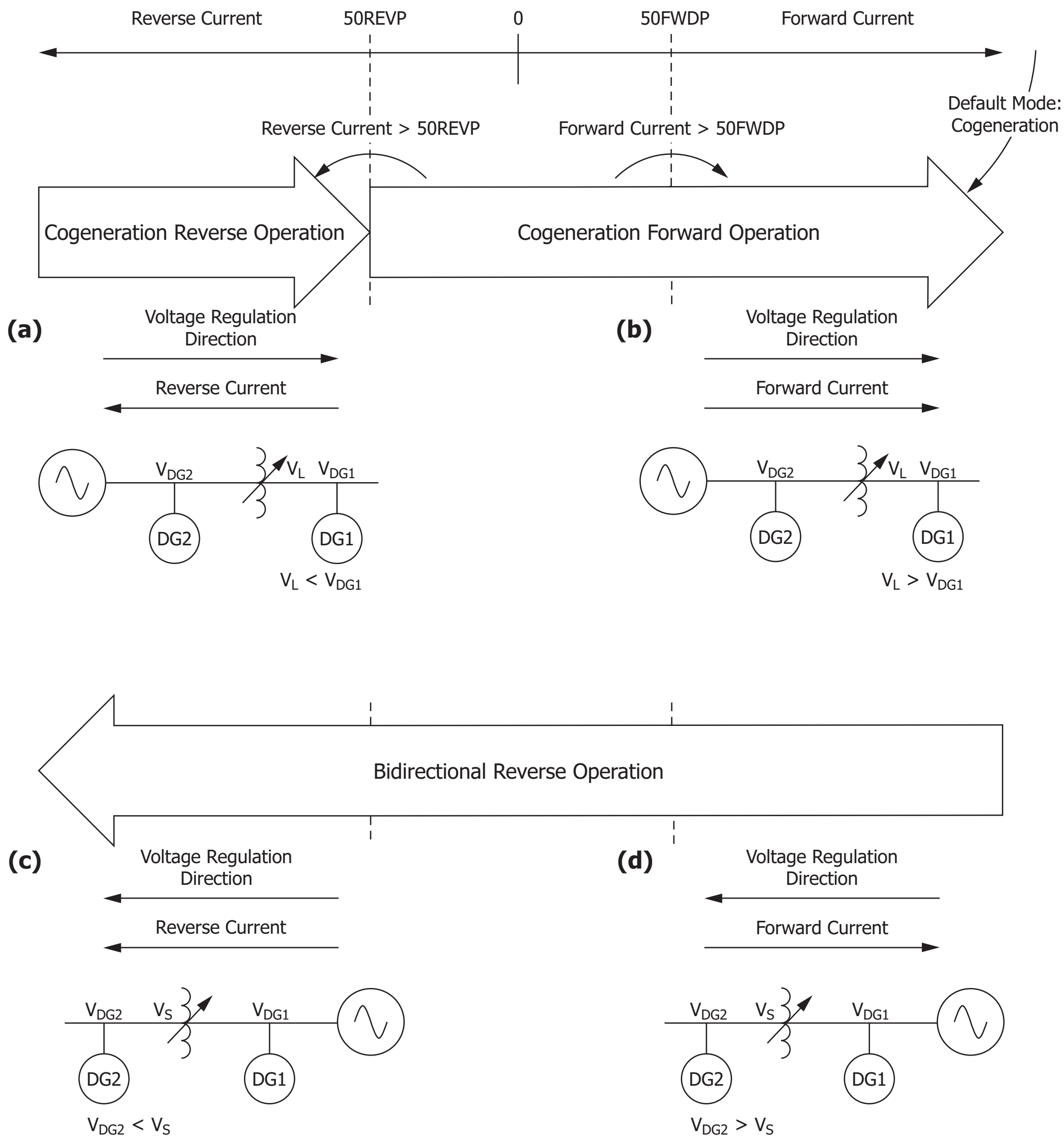


Figure 4.9 Correlation of the Operation Submodes of the Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG) With Primary System Sources

Voltage Regulation Settings Guidelines (OPMODE = FLEXDG)

Table 4.4 Active Control Settings (Forward or Reverse) for the Operation Submodes of the Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG)

Operation Submode:	Cogeneration Reverse	Cogeneration Forward	Bidirectional Reverse
	Forward	Forward	Reverse
Active Control Settings:	F_CHAR F_CNBND F_BNDWD F_TD1 F_DISC F_DLYRS	F_CHAR F_CNBND F_BNDWD F_TD1 F_DISC F_DLYRS	R_CHAR R_CNBND R_BNDWD R_TD1 F_DISC F_DLYRS

NOTE: Settings F_TD1 and R_TD1 can be set differently because their respective source-side voltage regulators (which they have to time-coordinate with) could have different time delay settings. The adjacent paragraphs discuss the different stronger/stiffer source arrangements that impact such settings.

The Forward Control settings in *Table 4.4* are used for both the Cogeneration Forward and Cogeneration Reverse Operation submodes because the stronger/stiffer source remains the same (normal source side of the voltage regulator), regardless of cogeneration (distributed generation) output which can cause reverse current through the voltage regulator; see *Figure 4.5(a)* and *Figure 4.5(b)*. The next source-side voltage regulator should be time coordinated with the Forward Time Delay 1 for First Tap setting F_TD1 (time delay for the next source-side voltage regulator set shorter than setting F_TD1).

The Reverse Control settings in *Table 4.4* are used for the Bidirectional Reverse Operation submode because the stronger/stiffer source is now on the normal load side of the voltage regulator. Such a change is usually due to primary system switching; see *Figure 4.5(c)* and *Figure 4.6(a)*. The Reverse Time Delay 1 for First Tap setting R_TD1 needs to be time coordinated with the next source-side voltage regulator on this new source. This new source could even be connected to a different substation (time delay for the next source-side voltage regulator on this new source set shorter than setting R_TD1).

The Enable Line-Drop Compensation setting ELDC in *Table 4.5* provides four different allotments of LDC settings for the three separate operation submodes.

The Forward and Reverse Line-Drop Compensation (LDC) settings in *Table 4.5* are correspondingly the same type of setting (e.g., Forward Resistive LDC Voltage setting VLDCFWR has the same settings range as Reverse Resistive LDC Voltage setting VLDCRVR). Thus, a forward LDC setting can be applied in a reverse LDC calculation/voltage regulation algorithm. A reverse LDC setting can also be applied in a forward LDC calculation/voltage regulation algorithm. Forward and Reverse are just labels and do not limit the application of the forward and reverse LDC settings to strictly respective forward and reverse operation submodes.

ELDC DEFAULT

If group setting OPMODE is not set to FLEXDG (e.g., OPMODE = LOCKFWD and ELDC = Y) and later OPMODE is changed to OPMODE = FLEXDG, group setting ELDC initially defaults to ELDC = Y1 (because previously ELDC = Y).

If OPMODE is set to FLEXDG (e.g., OPMODE = FLEXDG and ELDC = Y1, Y2, Y3, or Y4) and later OPMODE is changed (e.g., OPMODE = BIDIR), ELDC initially defaults to ELDC =Y (because previously ELDC = Y1, Y2, Y3, or Y4).

In the preceding two scenarios, if ELDC = N instead, it continues as ELDC = N for initial default value after the OPMODE settings change.

Table 4.5 Active Line-Drop Compensation (LDC) Settings (Forward or Reverse) for the Operation Submodes of the Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG)

<table>
<tr><th>Active LDC Settings for:</th><th>Cogeneration Reverse Operation Submode</th><th>Cogeneration Forward Operation Submode</th><th>Bidirectional Reverse Operation Submode</th></tr>
<tr><td rowspan="2">ELDC = Y1
(see Table 4.6)</td><td rowspan="2">no LDC</td><td>Forward</td><td>Reverse</td></tr>
<tr><td>VLDCFWR
VLDCFWX
VLDCFWMP
VLDCFWMN</td><td>VLDCRVR
VLDCRVX
VLDCRVMP
VLDCRVMN</td></tr>
<tr><td rowspan="2">ELDC = Y2
(see Table 4.7)</td><td>Reverse</td><td>Forward</td><td rowspan="2">no LDC</td></tr>
<tr><td>VLDCRVR
VLDCRVX
VLDCRVMP
VLDCRVMN</td><td>VLDCFWR
VLDCFWX
VLDCFWMP
VLDCFWMN</td></tr>
<tr><td rowspan="2">ELDC = Y3
(see Table 4.8)</td><td>Reverse</td><td>Forward</td><td>Reverse</td></tr>
<tr><td>VLDCRVR
VLDCRVX
VLDCRVMP
VLDCRVMN</td><td>VLDCFWR
VLDCFWX
VLDCFWMP
VLDCFWMN</td><td>VLDCRVR
VLDCRVX
VLDCRVMP
VLDCRVMN</td></tr>
<tr><td rowspan="2">ELDC = Y4
(see Table 4.9)</td><td>Forward</td><td>Forward</td><td>Reverse</td></tr>
<tr><td>VLDCFWR
VLDCFWX
VLDCFWMP
VLDCFWMN</td><td>VLDCFWR
VLDCFWX
VLDCFWMP
VLDCFWMN</td><td>VLDCRVR
VLDCRVX
VLDCRVMP
VLDCRVMN</td></tr>
<tr><td>ELDC = N</td><td>no LDC</td><td>no LDC</td><td>no LDC</td></tr>
</table>

The following tables explain the submode operations for the ELDC settings in *Table 4.5*. Line-drop compensation settings (VLDCFWR, VLDCFWX, VLDCRVR, and VLDCRVX) initially set with positive values are used in these examples.

➤ Settings ELDC = Y1 (see *Table 4.6*) and ELDC = Y2 (see *Table 4.7*) **probably satisfy most LDC applications**.

➤ Settings ELDC = Y3 (see *Table 4.8*) and ELDC = Y4 (see *Table 4.9*) provide more LDC settings variation.

Table 4.6 Voltage Regulation Effects and Considerations for Setting ELDC = Y1 (OPMODE = FLEXDG)

Cogeneration Reverse Operation (*Figure 4.9(a)*)
There is no LDC voltage regulation (see *Table 4.5*). The voltage regulator maintains normal load-side voltage V_L at the F_CNBND setting level (see *Table 4.4*). As reverse current through the voltage regulator increases (e.g., supplied by DG1), voltage out on the circuit (DG1 side) increases.
Cogeneration Forward Operation (*Figure 4.9(b)*)
Voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG1 side) at F_CNBND setting level (see *Table 4.4*). This is just standard voltage regulation for a forward submode operating with forward current.
Bidirectional Reverse Operation (*Figure 4.9(c)*)
Voltage regulator adjusts normal source-side voltage V_S to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG2 side) at R_CNBND setting level (see *Table 4.4*). This is just standard voltage regulation for a reverse submode operating with reverse current.
Bidirectional Reverse Operation (*Figure 4.9(d)*)
The voltage regulator adjusts normal source-side voltage V_S to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG2 side) at the R_CNBND setting level (see *Table 4.4*). As forward current through the voltage regulator increases (e.g., supplied by DG2), V_S decreases (LDC voltage regulation perceives regulation point voltage as being too high and thus adjusts V_S down).

Table 4.7 Voltage Regulation Effects and Considerations for Setting ELDC = Y2 (OPMODE = FLEXDG)

Cogeneration Reverse Operation (*Figure 4.9(a)*)
The voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG1 side) at the F_CNBND setting level (see *Table 4.4*). As reverse current through the voltage regulator increases (e.g., supplied by DG1), V_L decreases (LDC voltage regulation perceives regulation point voltage as being too high and thus adjusts V_L down). To prevent V_L from going too low for increased reverse current, LDC settings VLDCRVR and VLDCRVX can be set to smaller positive values (or to negative values). For ELDC = Y2, LDC settings VLDCRVR and VLDCRVX are not shared with any other Operation mode (see *Table 4.5*) and thus such settings variations can be made.
Cogeneration Forward Operation (*Figure 4.9(b)*)
Voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG1 side) at F_CNBND setting level (see *Table 4.4*). This is just standard voltage regulation for a forward submode operating with forward current.
Bidirectional Reverse Operation (*Figure 4.9(c)*)
There is no LDC voltage regulation (see *Table 4.5*). The voltage regulator maintains normal source-side voltage V_S at the R_CNBND setting level (see *Table 4.4*). As reverse current through the voltage regulator increases, voltage out on the circuit (DG2 side) decreases. This is just standard primary system voltage drop.
Bidirectional Reverse Operation (*Figure 4.9(d)*)
There is no LDC voltage regulation (see *Table 4.5*). The voltage regulator maintains normal source-side voltage V_S at the R_CNBND setting level (see*Table 4.4*). As forward current through the voltage regulator increases (e.g., supplied by DG2), voltage out on the circuit (DG2 side) increases.

Table 4.8 Voltage Regulation Effects and Considerations for Setting ELDC = Y3 (OPMODE = FLEXDG)

Cogeneration Reverse Operation (*Figure 4.9(a)*) The voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG1 side) at the F_CNBND setting level (see *Table 4.4*). As reverse current through the voltage regulator increases (e.g., supplied by DG1), V_L decreases (LDC voltage regulation perceives regulation point voltage as being too high and thus adjusts V_L down). To prevent V_L from going too low for increased reverse current, LDC settings VLDCRVR and VLDCRVX can be set to smaller positive values (or to negative values). But, LDC settings VLDCRVR and VLDCRVX are shared with Bidirectional Reverse Operation (see *Table 4.5*), so compromise settings have to be made.
Cogeneration Forward Operation (*Figure 4.9(b)*) Voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG1 side) at F_CNBND setting level (see *Table 4.4*). This is just standard voltage regulation for a forward submode operating with forward current.
Bidirectional Reverse Operation (*Figure 4.9(c)*) Voltage regulator adjusts normal source-side voltage V_S to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG2 side) at R_CNBND setting level (see *Table 4.4*). This is just standard voltage regulation for a reverse submode operating with reverse current. Remember that LDC settings VLDCRVR and VLDCRVX are shared with Cogeneration Reverse Operation (see *Table 4.5*), so compromise settings have to be made.
Bidirectional Reverse Operation (*Figure 4.9(d)*) The voltage regulator adjusts normal source-side voltage V_S to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG2 side) at the R_CNBND setting level (see *Table 4.4*). As forward current through the voltage regulator increases (e.g., supplied by DG2), V_S decreases (LDC voltage regulation perceives regulation point voltage as being too high and thus adjusts V_S down). Remember that LDC settings VLDCRVR and VLDCRVX are shared with Cogeneration Reverse Operation (see *Table 4.5*), so compromise settings have to be made.

Table 4.9 Voltage Regulation Effects and Considerations for Setting ELDC = Y4 (OPMODE = FLEXDG)

Cogeneration Reverse Operation (*Figure 4.9(a)*) The voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG1 side) at the F_CNBND setting level (see *Table 4.4*). As reverse current through the voltage regulator increases (e.g., supplied by DG1), V_L decreases (LDC voltage regulation perceives regulation point voltage as being too high and thus adjusts V_L down). To prevent V_L from going too low for increased reverse current, LDC settings VLDCFWR and VLDCFWX can be set to smaller positive values (or to negative values). But, LDC settings VLDCFWR and VLDCFWX are shared with Cogeneration Forward Operation (see *Table 4.5*), so compromise settings have to be made.
Cogeneration Forward Operation (*Figure 4.9(b)*) Voltage regulator adjusts normal load-side voltage V_L to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG1 side) at F_CNBND setting level (see *Table 4.4*). This is just standard voltage regulation for a forward submode operating with forward current. Remember that LDC settings VLDCFWR and VLDCFWX are shared with Cogeneration Reverse Operation (see *Table 4.5*), so compromise settings have to be made.
Bidirectional Reverse Operation (*Figure 4.9(c)*) Voltage regulator adjusts normal source-side voltage V_S to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG2 side) at R_CNBND setting level (see *Table 4.4*). This is just standard voltage regulation for a reverse submode operating with reverse current.
Bidirectional Reverse Operation (*Figure 4.9(d)*) The voltage regulator adjusts normal source-side voltage V_S to maintain regulation point voltage (see *Figure 3.2*) out on the circuit (DG2 side) at the R_CNBND setting level (see *Table 4.4*). As forward current through the voltage regulator increases (e.g., supplied by DG2), V_S decreases (LDC voltage regulation perceives regulation point voltage as being too high and thus adjusts V_S down).

Optional Current-Based Transitions Between Voltage Regulation Submodes (OPMODE = FLEXDG)

NOTE: The listed 5 second qualification times in *Figure 4.10* (Forward Current > 50FWDP) and *Figure 4.11* (Reverse Current > 50REVP) can be as long as 6 seconds due to the parallel 1 second qualification of forward or reverse power flow (see FORWARD and REVERSE Device Word bits in *Figure 4.1*).

If forward current through the voltage regulator is only possible with an actual reversal of the stiff source (transition from lower left to upper right of *Figure 4.9*), then consider making setting FLEX_50 = FWD (see *Figure 4.10*) to speed up the process of switching from Bidirectional Reverse Operation to Cogeneration Forward Operation (do not have to wait for a qualified high (normal) tap delta voltage transition; see *Figure 4.8*).

If reverse current through the voltage regulator is only possible with an actual reversal of the stiff source (transition from upper right to lower left of *Figure 4.9*), then consider making setting FLEX_50 = REV (see *Figure 4.11*) to speed up the process of switching from Cogeneration Operation to Bidirectional Reverse Operation (do not have to wait for a qualified low tap delta voltage transition; see *Figure 4.8*).

FACTORY DEFAULT
FLEX_50 = OFF

For example, if:

- such a setting is made (e.g., FLEX_50 = FWD; see *Figure 4.10*)
- and such a transition occurs (e.g., Reverse Current ≤ 50REVP for 5 s for BIASMODE = FWD and FLEX_50 = FWD)

then the SEL-2431 control operates in the Cogeneration Forward Operation submode (after previously operating in the Bidirectional Reverse Operation submode). In this submode change example, Device Word bit DVLOW changes, too, from logical 1 to logical 0 (just like what happens with a qualified high (normal) tap delta voltage transition in *Figure 4.8*).

But even if:

- Reverse Current ≤ 50REVP continues to be true (e.g., Forward Current is appreciable)
- after the preceding example BIASMODE = FWD and FLEX_50 = FWD transition in *Figure 4.10* is made,

the qualified low tap delta voltage transition logic is still active (see *Figure 4.8*). Continuing with this example, current can then change to Reverse Current > 50REVP (resulting in transitioning from Cogeneration Forward Operation to Cogeneration Reverse Operation) and the qualified low tap delta voltage transition logic is still active. A qualified low tap delta voltage transition brings the SEL-2431 control back to the Bidirectional Reverse Operation submode if subsequent tap delta voltage measurements indicate that the stiffer utility source did not change sides (e.g., the Reverse Current ≤ 50REVP for 5 s transition was due to an occasional reverse to forward current flow caused by a DG unit).

Similar holds true for FLEX_50 = REV transitions (*Figure 4.11*) and corresponding qualified high (normal) tap delta voltage transition logic still being active (see *Figure 4.8*). A qualified high (normal) tap delta voltage transition can bring the SEL-2431 control back to the Cogeneration Reverse Operation or Cogeneration Forward Operation submode.

The monitoring of tap delta voltage in *Figure 4.8* is continual, regardless of the rational for making setting FLEX_50. Setting FLEX_50 only accelerates the transition between submodes. The FLEX_50 setting controls nothing else, nor has any lingering effect if its transition condition continues to be true after the current-based transition (in *Figure 4.10* or *Figure 4.11*) is made.

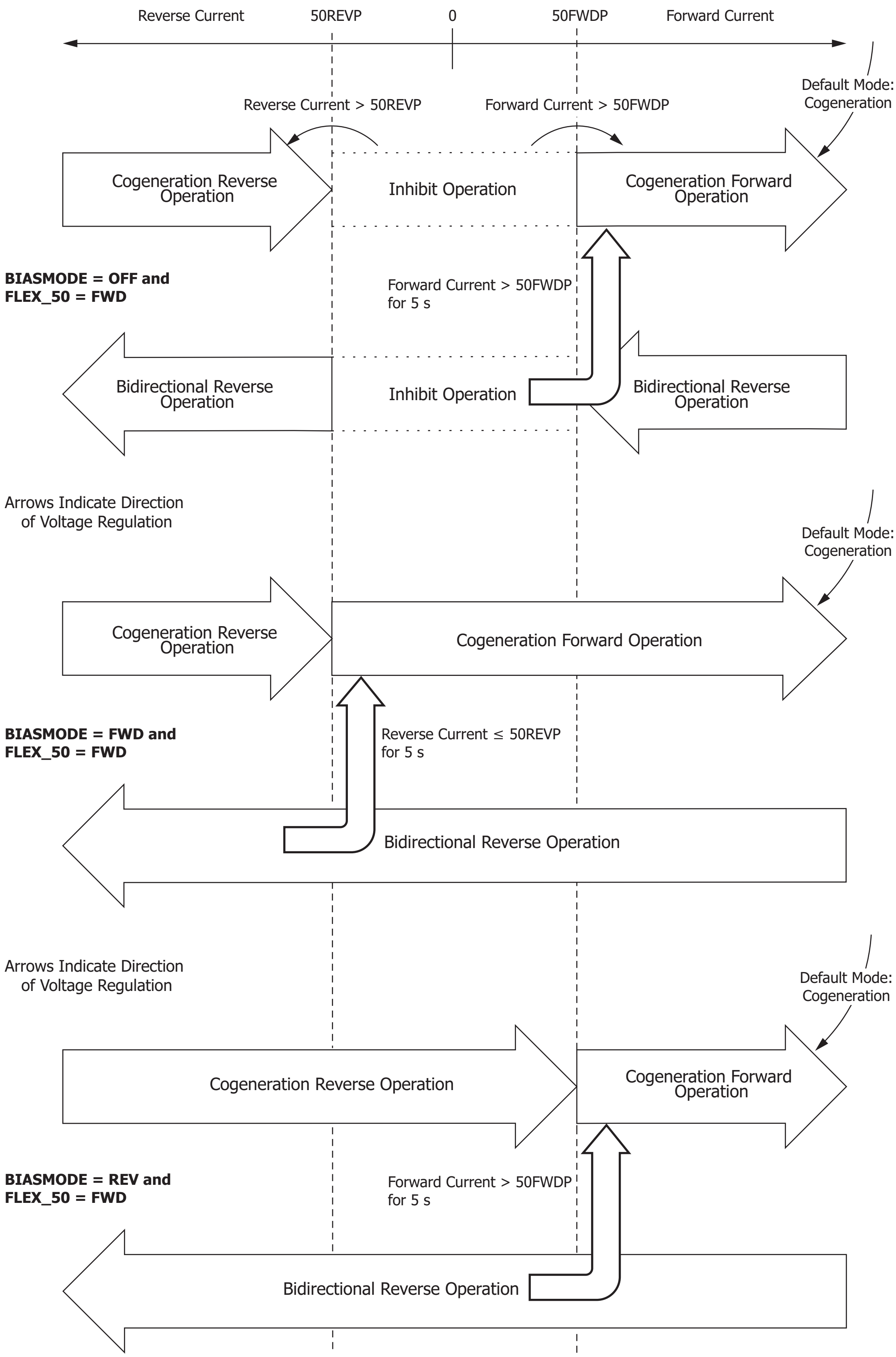


Figure 4.10 Transition from Bidirectional Reverse Operation Submode to Cogeneration Forward Operation Submode for FLEX_50 = FWD (OPMODE = FLEXDG)

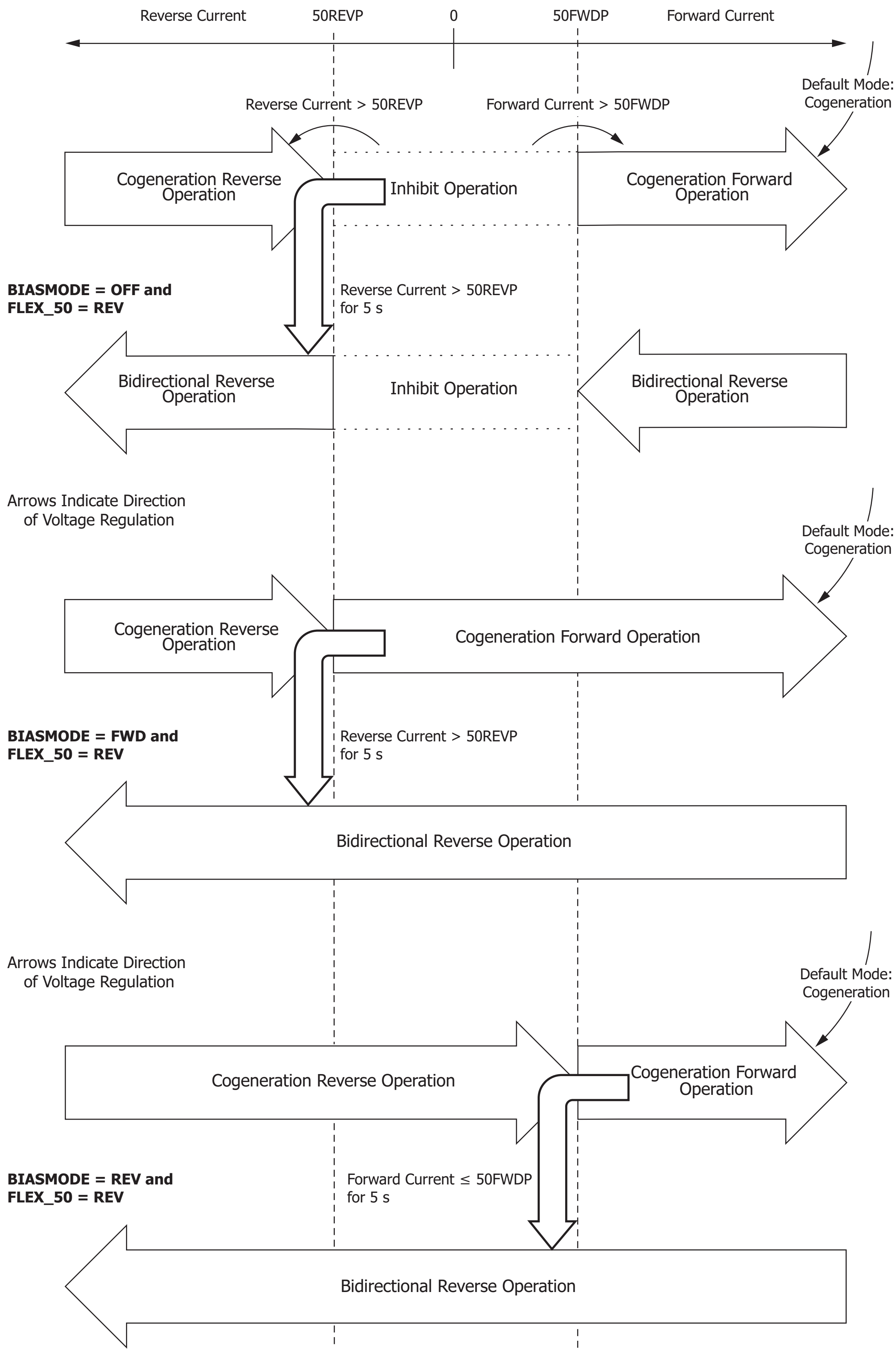


Figure 4.11 Transition from Cogeneration Operation Submode to Bidirectional Reverse Operation Submode for FLEX_50 = REV (OPMODE = FLEXDG)

NOTE: The listed 5 second qualification times in *Figure 4.12* (Forward Current > 50FWDP; Reverse Current > 50REVP) can be as long as 6 seconds due to the parallel 1 second qualification of forward or reverse power flow (see FORWARD and REVERSE Device Word bits in *Figure 4.1*).

The transitions in *Figure 4.12* (for FLEX_50 = BOTH) are a combination of:

- *Figure 4.10* (for FLEX_50 = FWD)
- and *Figure 4.11* (for FLEX_50 = REV)

Use FLEX_50 = BOTH (when OPMODE = FLEXDG) for applications that traditionally require a Bidirectional operation mode (OPMODE = BIDIR; see *Figure 4.2*), where:

- forward current is from a utility source (see *Figure 4.5(a)*)
- and reverse current is from a utility source (see *Figure 4.6(a)*)

but occasionally current flow from a DG unit could cause:

- a forward to reverse current transition when in Bidirectional forward mode (similar to the transition from *(a)* to *(b)* in *Figure 4.5*; utility source did not change sides)
- or a reverse to forward current transition when in Bidirectional reverse mode (similar to the transition from *(a)* to *(b)* in *Figure 4.6*; utility source did not change sides)

For example, if:

- BIASMODE = FWD and FLEX_50 = BOTH; see *Figure 4.12*
- and a transition occurs (e.g., Reverse Current ≤ 50REVP for 5 s) because a DG unit caused a reverse to forward current flow through the voltage regulator (stiffer utility source did not change sides)

then the SEL-2431 control operates in the Cogeneration Forward Operation submode (after previously operating in the Bidirectional Reverse Operation submode). In this submode change example, Device Word bit DVLOW changes, too, from logical 1 to logical 0 (just like what happens with a qualified high (normal) tap delta voltage transition in *Figure 4.8*).

But even if:

- Reverse Current ≤ 50REVP continues to be true (e.g., Forward Current is appreciable)
- after the preceding example BIASMODE = FWD and FLEX_50 = BOTH transition in *Figure 4.12* is made,

the qualified low tap delta voltage transition logic is still active (see *Figure 4.8*). A qualified low tap delta voltage transition brings the SEL-2431 control back to the Bidirectional Reverse Operation sub-mode if subsequent tap delta voltage measurements indicate that the stiffer utility source did not change sides (e.g., the Reverse Current ≤ 50REVP for 5 s transition was due to an occasional reverse to forward current flow caused by a DG unit).

Similarly, for a Reverse Current > 50REVP transition (BIASMODE = FWD and FLEX_50 = BOTH; *Figure 4.12*) and corresponding qualified high (normal) tap delta voltage transition logic is still active (see *Figure 4.8*) and can bring the SEL-2431 control back to the Cogeneration Reverse Operation submode.

The monitoring of tap delta voltage in *Figure 4.8* is continual, regardless of the rational for making setting FLEX_50. Setting FLEX_50 only accelerates the transition between submodes (like for traditional Bidirectional operation mode). The FLEX_50 = BOTH setting controls nothing else, nor has any lingering effect if its transition condition continues to be true after the current-based transition in *Figure 4.12* is made.

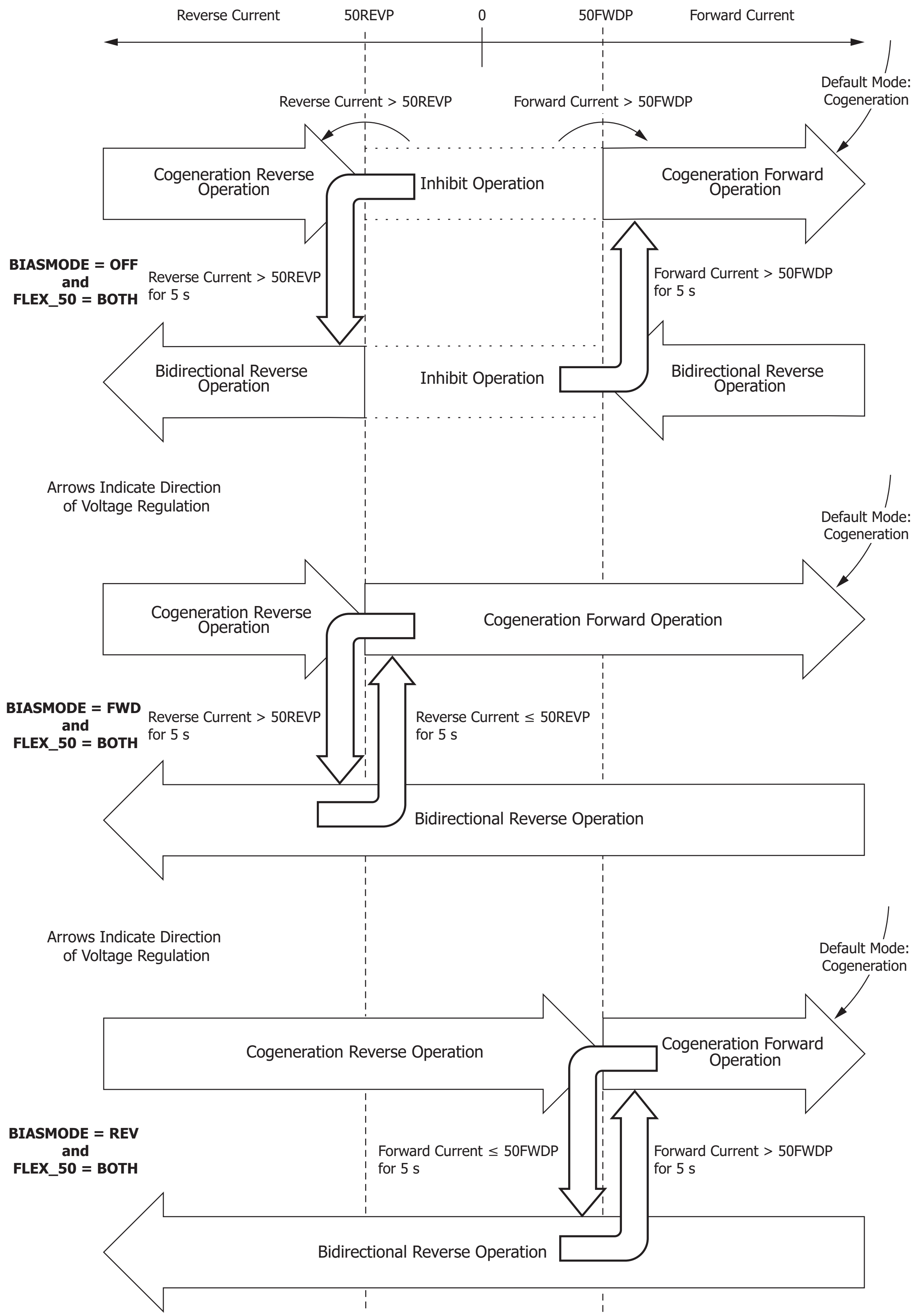


Figure 4.12 Transition from Bidirectional Reverse Operation Submode to Cogeneration Forward Operation Submode (or Vice Versa) For FLEX_50 = BOTH (OPMODE = FLEXDG)

Voltage Reduction

Voltage reduction is the deliberate lowering of the system voltage when the power demand exceeds the supply. This reduction in voltage is achieved by lowering the existing center band setting by a predefined percentage. *Figure 4.13* (a) shows the system voltage in the low voltage out-of-band area. After changing the center band (and the upper and lower band edges), the same system voltage is now in the out-of-band (high voltage) area and the regulator issues a **LOWER** command.

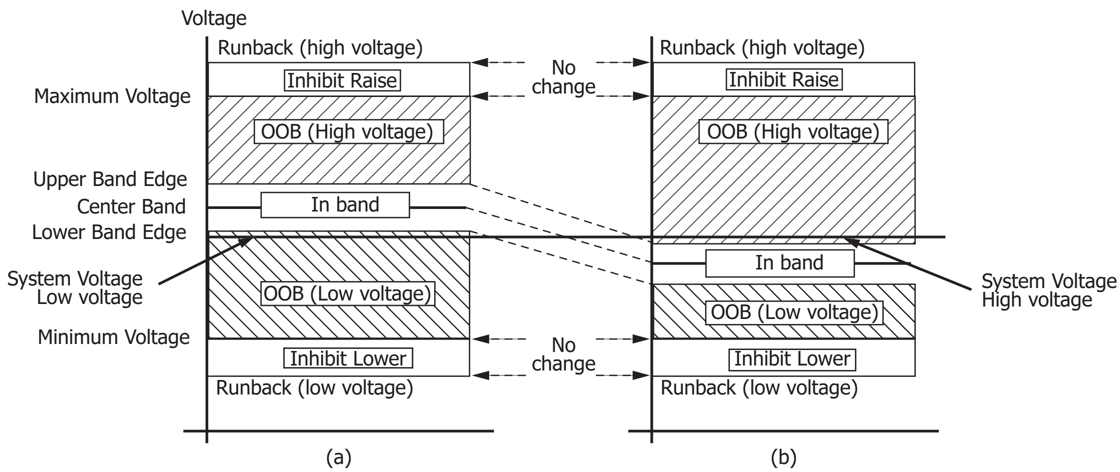


Figure 4.13 Voltage Characteristics (a) Before Voltage Reduction and (b) After Voltage Reduction

You can enable three separate levels of voltage reduction. Three levels of separate voltage reduction percentages can be chosen for forward or reverse voltage regulation. Legacy SCADA voltage reduction schemes are supported with the pulse or latch voltage reduction modes. Also, you can enable voltage reduction via programmable SELOGIC equations set to such quantities as load current level in the control voltage reduction mode. Refer to *Section 8: Settings* for more information on the Group settings used for voltage reduction.

When voltage reduction is enabled, the VRIPROG Device Word bit is enabled.

Latch Mode Voltage Reduction

Figure 4.14 shows the logic for latch mode voltage reduction (Group setting VREDMODE := LATCH). This mode of voltage reduction is used with legacy SCADA systems where a binary to decimal input is decoded to determine the level or stage of voltage reduction (level 1, level 2, or level 3).

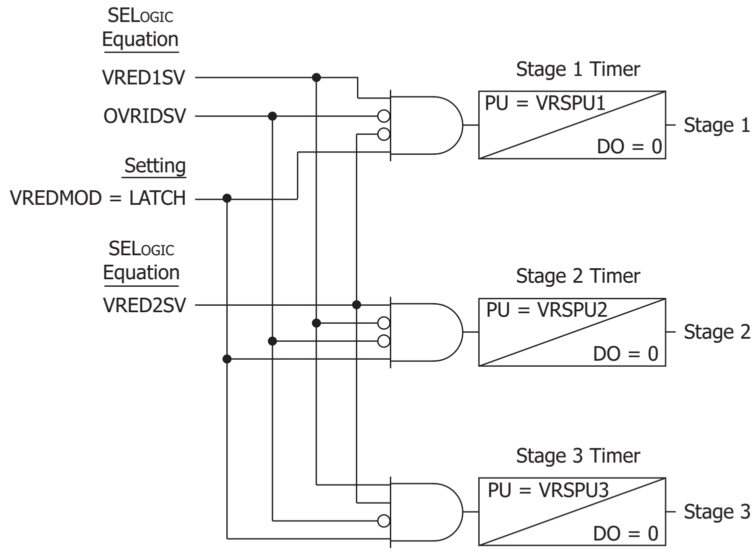


Figure 4.14 Latch Mode Voltage Reduction Logic

Group setting SELOGIC equations VRED1SV and VRED2SV are typically set to contact inputs as shown in the example below.

For this example, two stages of voltage reduction are desired for the latch mode voltage reduction. Stage 1 forward voltage reduction will reduce the center band (system) voltage by 2 percent. Stage 2 voltage reduction will reduce the center band voltage by 4 percent.

- ➤ ENREDUC := Y
- ➤ VREDMOD := LATCH
- ➤ VREDFP1 := 2
- ➤ VREDFP2 := 4

A third stage of forward voltage reduction is not desired, nor is voltage reduction in the reverse direction desired.

- ➤ VREDFP3 := OFF
- ➤ VREDRP1 := OFF
- ➤ VREDRP2 := OFF
- ➤ VREDRP3 := OFF

Stage 1 voltage reduction is time qualified for 30 seconds. Stage 2 voltage reduction is time qualified for 60 seconds.

- ➤ VRSPU1 := 30
- ➤ VRSPU2 := 60

Voltage reduction is accomplished by the binary to decimal conversion of contact inputs IN101 and IN102. Stage 1 voltage reduction is accomplished when IN101 is asserted and IN102 is deasserted. Stage 2 voltage reduction is accomplished when IN101 deasserted and IN102 asserted. Stage 3 voltage reduction is not desired and no voltage reduction takes place when both IN101 and IN102 are asserted.

- ➤ VRED1SV := IN101
- ➤ VRED2SV := IN102

Voltage reduction should not take place when the voltage regulator control is in the LOCAL or MANUAL mode of operation.

Line-drop compensation could also be disabled when voltage reduction is in progress.

➤ OVRIDSV := LOCAL OR MANUAL

➤ SETLDC0 := Y

Note that if voltage reduction goes from stage 1 to stage 2, there is a period of time equal to the time qualification of stage 2 (VRSPU2 setting) when no voltage reduction is enabled. Similarly when voltage goes from stage 2 to stage 3, no voltage reduction is enabled for VRSPU3 time.

Pulse-Mode Voltage Reduction

Figure 4.15 and *Figure 4.16* show the logic for pulse-mode voltage reduction (Group setting VREDMOD := PULSE). This mode of voltage reduction is used with legacy SCADA systems where an input is momentarily pulsed to advance voltage reduction to a certain level (stage).

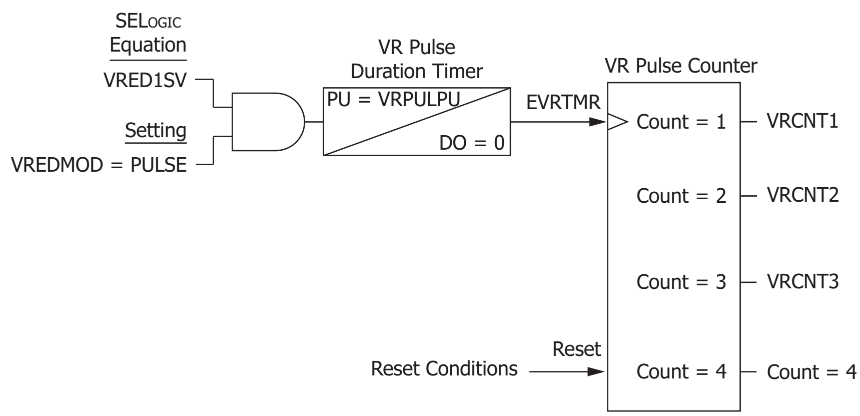


Figure 4.15 Pulse-Mode Voltage Reduction Logic

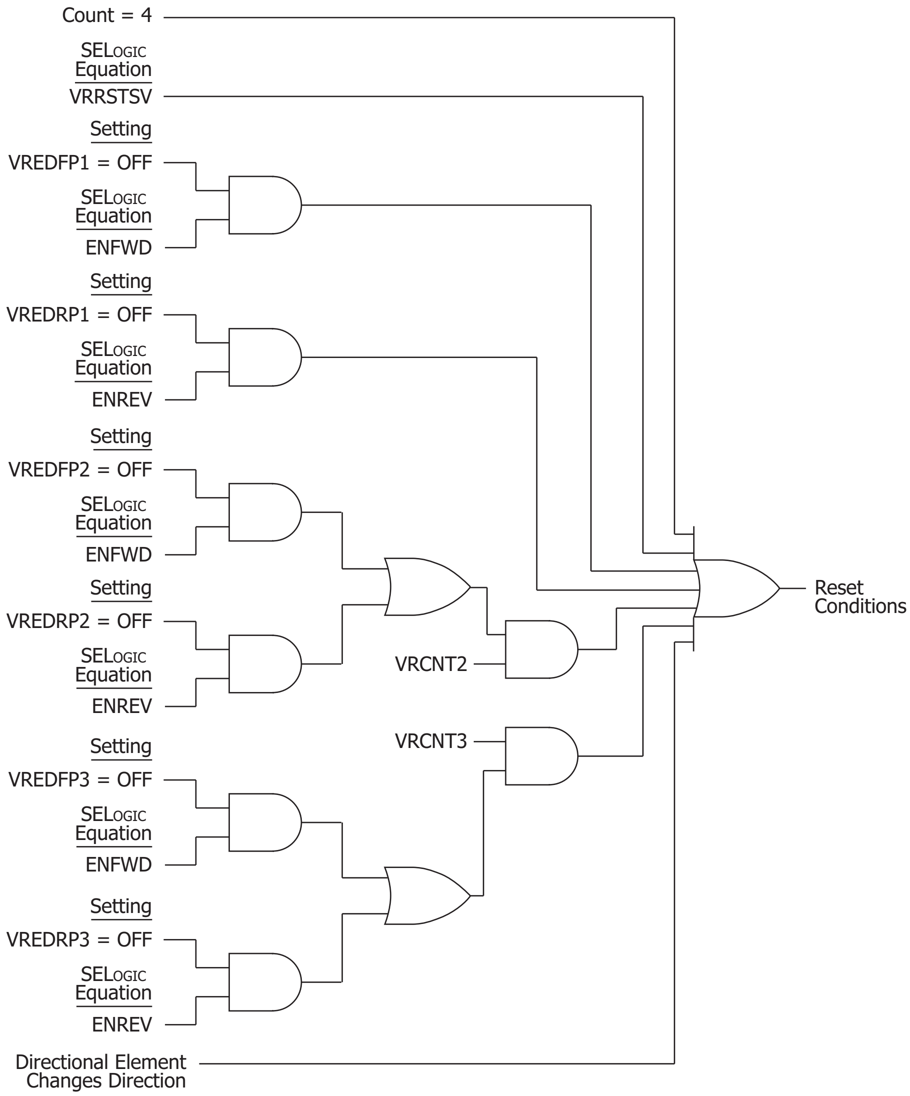


Figure 4.16 Reset Conditions for Pulse-Mode Voltage Reduction

Control-Mode Voltage Reduction

Figure 4.17 shows the logic for control-mode voltage reduction.

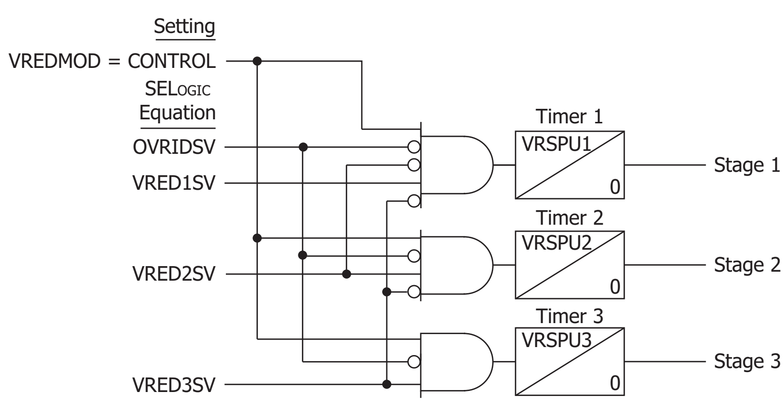


Figure 4.17 Control-Mode Voltage Reduction

The control mode of voltage reduction is useful for automatic control of voltage reduction based on order of precedence inputs such as load current levels, signals from control centers, etc.

Stage 1 voltage reduction is enabled when Group setting SELOGIC equation VRED1SV is asserted and VRED2SV and VRED3SV are deasserted. Similarly, stage 2 voltage reduction is enabled when VRED2SV is asserted and VRED3SV is deasserted, and voltage reduction stage 3 is enabled when VRED3SV is asserted.

An example of control mode voltage reduction would be to set each voltage reduction SELOGIC input equation to increasing levels of load current.

- E50L := 3
- 50L1P := 0.1
- 50L2P := 0.15
- 50L3P := 0.2
- ENREDUC := Y
- VREDMOD := CONTROL
- VREDFP1 := 1.5
- VREDFP2 := 3.0
- VREDFP3 := 4.5
- VREDRP1 := OFF
- VREDRP2 := OFF
- VREDRP3 := OFF
- VRSPU1 := 30
- VRSPU2 := 60
- VRSPU3 := 90
- VRED1SV := 50L1
- VRED2SV := 50L2
- VRED3SV := 50L3

Stage 1 voltage reduction (1.5 percent in forward direction only) is enabled when load current is above 0.1 A sec. and below 0.15 A sec. Stage 2 voltage reduction (3.0 percent in forward direction only) is enabled when load current is above 0.15 A sec. and below 0.2 A sec. Stage 3 voltage reduction (4.5 percent in forward direction only) is enabled when load current is above 0.2 A sec.

Note that if voltage reduction goes from stage 1 to stage 2, there is a period of time equal to the time qualification of stage 2 (VRSPU2 setting) when no voltage reduction is enabled. Similarly when voltage goes from stage 2 to stage 3, no voltage reduction is enabled for VRSPU3 time.

SECTION 5

Tap Operations

Overview

NOTE: The Raise/Lower (reversing) switch in *Figure 5.1* and *Figure 5.4* is automatically controlled by the voltage regulator, not the SEL-2431 Voltage Regulator Control. The reversing switch changes position as the regulator passes through the neutral position (Tap = 0 or N) as shown in *Figure 5.1–Figure 5.6*. The reason for switching becomes clear in the following example.

Figure 5.1, *Figure 5.4*, and accompanying figures show a full-raise sequence and a full-lower sequence, respectively. *Figure 5.1* and *Figure 5.4* are derived from *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*, though they do not show as much detail as *Figure B.3* (e.g., shunt winding detail is not shown). Refer also to this *Figure B.3* when working through the following detailed tapping examples for *Figure 5.1* and *Figure 5.4*. The polarity marks on both the series and shunt windings allow the corresponding voltages to be added or subtracted, depending on the position of the Raise/Lower (reversing) switch. This becomes more clear in the following detailed tapping examples.

Full-Raise Sequence Example

Figure 5.1, with corresponding *Figure 5.2*, goes through an entire raise sequence, starting from the maximum lower position (Tap = –16). This is not necessarily a realistic scenario (going continually from the maximum lower position to the maximum raise position), but it illustrates the full range of operation of a voltage regulator.

The actual raise and lower outputs of the SEL-2431 are shown in *Figure C.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* (notice the dedicated output contacts for automatic operations and the optional toggle switch/pushbuttons; notice that the pushbutton outputs are effectively through the same output contacts used for automatic operation). The raise and lower outputs interface to the voltage regulators (*Figure B.5–Figure B.8* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*) via wiring harnesses (*Figure 2.5–Figure 2.9* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*).

Figure 5.2 and *Figure 5.3* show the voltage rising smoothly from left to right. The voltage actually changes in stair-step fashion as each Tap progresses. Similar is true for the falling voltage in *Figure 5.5* and *Figure 5.6*.

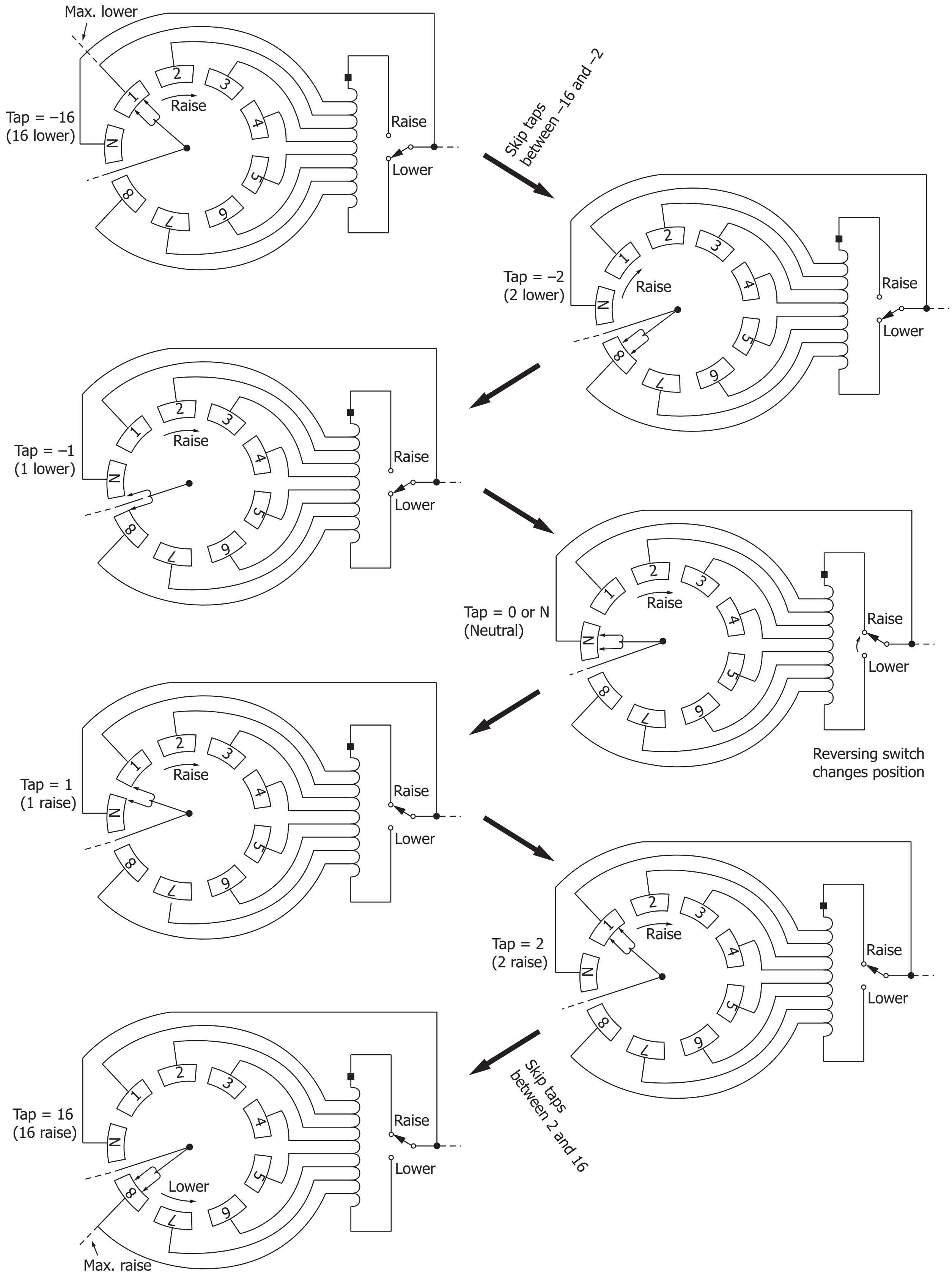


Figure 5.1 Voltage Regulator Mechanics of Tapping From Tap –16 to 16 (Raise)

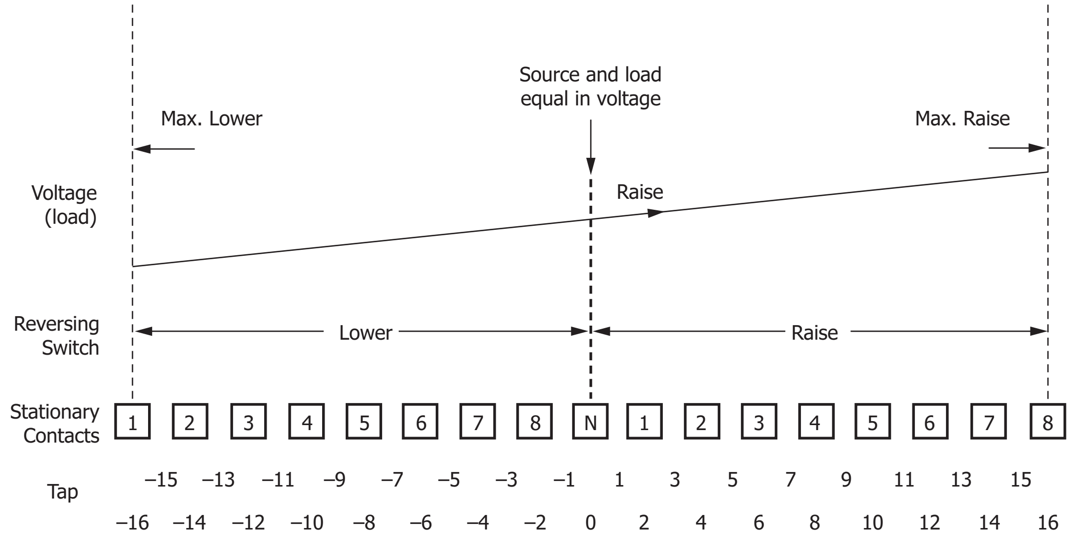


Figure 5.2 Plot of a Continual Raise Operation (Tap –16 to 16)

"Tap = –16" Position

Analyzing the "Tap = –16" position in the upper left corner of *Figure 5.1* (going from left to right, source to load; also refer to *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*):

- ➤ Start at the source terminal (S) and trace through the tap fingers on stationary contact 1 to the top of the series winding
- ➤ Because of the position of the Raise/Lower switch, trace down the series winding then out through the Raise/Lower switch in the Lower position
- ➤ Then trace out to the load terminal (L) with the shunt winding effectively below it

The preceding tracing exercise at the "Tap = –16" position shows that the entire series winding is traversed and actively in the circuit. With the polarity markings on the series and shunt windings, the source terminal (S) is at a higher voltage than the load terminal (L)—higher by the amount of voltage drop across the entire series winding. This makes sense at this maximum lower position (Tap = –16)—the load voltage is lowest, compared to the source voltage, by the amount of voltage drop across the entire series winding (see *Figure 5.2*).

From the upper left of *Figure 5.1*, following the progression of the drawing, the taps between "Tap = –16" and "Tap = –2" are not shown and the next tap changer is in the "Tap = –2" position (the tap fingers rotate through many positions, from stationary contact 1 to stationary contact 8).

"Tap = –2" Position

Analyzing the "Tap = –2" position in the upper right of *Figure 5.1* (going from left to right, source to load; also refer to *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*):

- Start at the source terminal (S) and trace through the tap fingers on stationary contact 8 to nearly the bottom of the series winding
- Because of the position of the Raise/Lower switch, trace down this small portion of the series winding then out through the Raise/Lower switch in the Lower position
- Then trace out to the load terminal (L), with the shunt winding effectively below it

The preceding tracing exercise at the "Tap = –2" position shows that a small portion of the series winding is traversed and actively in the circuit. With the polarity markings on the series and shunt windings, the source terminal (S) is at a higher voltage than the load terminal (L)—higher by the amount of voltage drop across the small portion of the series winding that was traversed. So, with respect to the source voltage, the load voltage is getting higher as the regulator taps from "Tap = –16" to "Tap = –2" (see *Figure 5.2*).

Following the progression of the drawing in *Figure 5.1*, the next tap changer is in the "Tap = –1" position (the tap fingers rotate from stationary contact 8 to a "bridging" position, straddling both stationary contacts 8 and N; see a voltage regulator instruction manual for more detailed explanation on this "bridging" position).

"Tap = –1" Position

Analyzing the "Tap = –1" position in *Figure 5.1* (going from left to right, source to load; also refer to corresponding *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*):

- Start at the source terminal (S) and trace through the tap fingers; one of these goes to stationary contact 8, and the other goes to stationary contact N. With the windings in the tap fingers (again, see a voltage regulator instruction manual for more detailed explanation), this creates an effective series winding voltage in between "Tap = –2" and "Tap = 0 or N (Neutral)" for the Raise/Lower switch in the Lower position (the smallest effective subdivision of the series winding)
- Because of the position of the Raise/Lower switch, trace down this smallest portion of the series winding then out through the Raise/Lower switch in the Lower position
- Then trace out to the load terminal (L), with the shunt winding effectively below it

The preceding tracing exercise at the "Tap = –1" position shows that the smallest effective subdivision of the series winding is traversed and actively in the circuit. With the polarity markings on the series and shunt windings, the source terminal (S) is at a higher voltage than the load terminal (L)—higher by the amount of voltage drop across the smallest effective subdivision of the series winding that was traversed. So, with respect to the source voltage, the load voltage is getting higher and is almost equal to the source voltage at "Tap = –1" (see *Figure 5.2*).

Following the progression of the drawing in *Figure 5.1*, the next tap changer is in the "Tap = 0 or N (Neutral)" position (the tap fingers rotate from the "bridging" position, straddling both stationary contacts 8 and N, to just stationary contact N).

"Tap = 0 or N (Neutral)" Position

Analyzing the "Tap = 0 or N (Neutral)" position in *Figure 5.1* (going from left to right, source to load; also refer to corresponding *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*):

- Start at the source terminal (S) and trace through the tap fingers on stationary contact N
- Notice that the series winding is completely bypassed
- With the tap fingers newly at stationary contact N (going in the raise direction), the position of the Raise/Lower (reversing) switch changes from the Lower position to the Raise position in anticipation of subsequent taps in the raise direction
- Then trace out to the load terminal (L), with the shunt winding effectively below it

The preceding tracing exercise at the "Tap = 0 or N (Neutral)" position shows that the source terminal (S) is at the same voltage as the load terminal (L) (see *Figure 5.2*).

Following the progression of the drawing in *Figure 5.1*, the next tap changer is in the "Tap = 1" position (the tap fingers rotate from stationary contact N to a "bridging" position, straddling both stationary contacts N and 1; see a voltage regulator instruction manual for more detailed explanation on this "bridging" position).

"Tap = 1" Position

Analyzing the "Tap = 1" position in the middle of *Figure 5.1* (going from left to right—source to load; also refer to corresponding *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*):

- Start at the source terminal (S) and trace through the tap fingers; one of these goes to stationary contact N, and the other goes to stationary contact 1. With the windings in the tap fingers (see a voltage regulator instruction manual for more detailed explanation), this creates an effective series winding voltage in between "Tap = N" and "Tap = 1" for the Raise/Lower switch in the Raise position (the smallest effective subdivision of the series winding)
- Because of the position of the Raise/Lower switch, trace up this smallest portion of the series winding then out through the Raise/Lower switch in the Raise position
- Then trace out to the load terminal (L) with the shunt winding effectively below it

The preceding tracing exercise at the "Tap = 1" position shows that the smallest effective subdivision of the series winding is traversed and actively in the circuit. With the polarity markings on the series and shunt windings, the source terminal (S) is at a lower voltage than the load terminal (L)—lower by the amount of voltage drop across the smallest effective subdivision of the series winding that was traversed. So, with respect to the source voltage, the load voltage is getting higher and is slightly higher than the source voltage at "Tap = 1" (see *Figure 5.2*).

Following the progression of the drawing in *Figure 5.1*, the next tap changer is in the "Tap = 2" position (the tap fingers rotate from the "bridging" position, straddling both stationary contacts N and 1, to just stationary contact 1).

“Tap = 2” Position

Analyzing the “Tap = 2” position in the lower right corner of *Figure 5.1* (going from left to right—source to load; also refer to corresponding *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*):

- ➤ Start at the source terminal (S) and trace through the tap fingers on stationary contact 1 to nearly the top of the series winding
- ➤ Because of the position of the Raise/Lower switch, trace up this small portion of the series winding then out through the Raise/Lower switch in the Raise position
- ➤ Then trace out to the load terminal (L), with the shunt winding effectively below it

The preceding tracing exercise at the “Tap = 2” position shows that a small portion of the series winding is traversed and actively in the circuit. With the polarity markings on the series and shunt windings, the source terminal (S) is at a lower voltage than the load terminal (L)—lower by the amount of voltage drop across the small portion of the series winding that was traversed. So, with respect to the source voltage, the load voltage is getting even higher as the regulator taps from “Tap = 1” to “Tap = 2” (see *Figure 5.2*).

From the lower right corner of *Figure 5.1*, following the progression of the drawing, the taps between “Tap = 2” and “Tap = 16” are not shown and the next subfigure is for the “Tap = 16” position (the tap fingers rotate through many positions, from stationary contact 1 to stationary contact 8).

“Tap = 16” Position

Analyzing the “Tap = 16” position in the lower left of *Figure 5.1* (going from left to right, source to load; also refer to corresponding *Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*):

- ➤ Start at the source terminal (S) and trace through the tap fingers on stationary contact 8 to the bottom of the series winding
- ➤ Because of the position of the Raise/Lower switch, trace up the series winding then out through the Raise/Lower switch in the Raise position
- ➤ Then trace out to the load terminal (L), with the shunt winding effectively below it

The preceding tracing exercise at the “Tap = 16” position shows that the entire series winding is traversed and actively in the circuit. With the polarity markings on the series and shunt windings, the source terminal (S) is at a lower voltage than the load terminal (L)—lower by the amount of voltage drop across the entire series winding. This makes sense at this maximum raise position (Tap = 16)—the load voltage is highest, compared to the source voltage, by the amount of voltage boost across the entire series winding (see *Figure 5.2*).

TAPMAX/TAPMIN Values Constrain Regulator Operation

Figure 5.3 is the same as *Figure 5.2* (discussed in the preceding example), with TAPMAX and TAPMIN settings applied. In the *Figure 5.3* example, the voltage regulator is constrained within the bounds of:

➤ "Tap = –8" (Device Word bit MINTAP asserts to logical 1 when the tap is at the TAPMIN setting or a lower tap value; TAPMIN not set to OFF)

➤ "Tap = 12" (Device Word bit MAXTAP asserts to logical 1 when the tap is at the TAPMAX setting or a higher tap value; TAPMAX not set to OFF)

If the SEL-2431 found the present tap value:

➤ outside the TAPMAX/TAPMIN bounds (e.g., a settings change was made to TAPMAX or TAPMIN; not set to OFF)

➤ *and* it was in the automatic mode (**AUTO** LED illuminated)

then (with factory-default settings for SELOGIC setting RAISESV and LOWERSV) it would issue taps to the voltage regulator to bring the tap value back within the TAPMAX/TAPMIN bounds (see SELOGIC settings RAISESV and LOWERSV in *Other Raise/Lower Methods* on page 5.11).

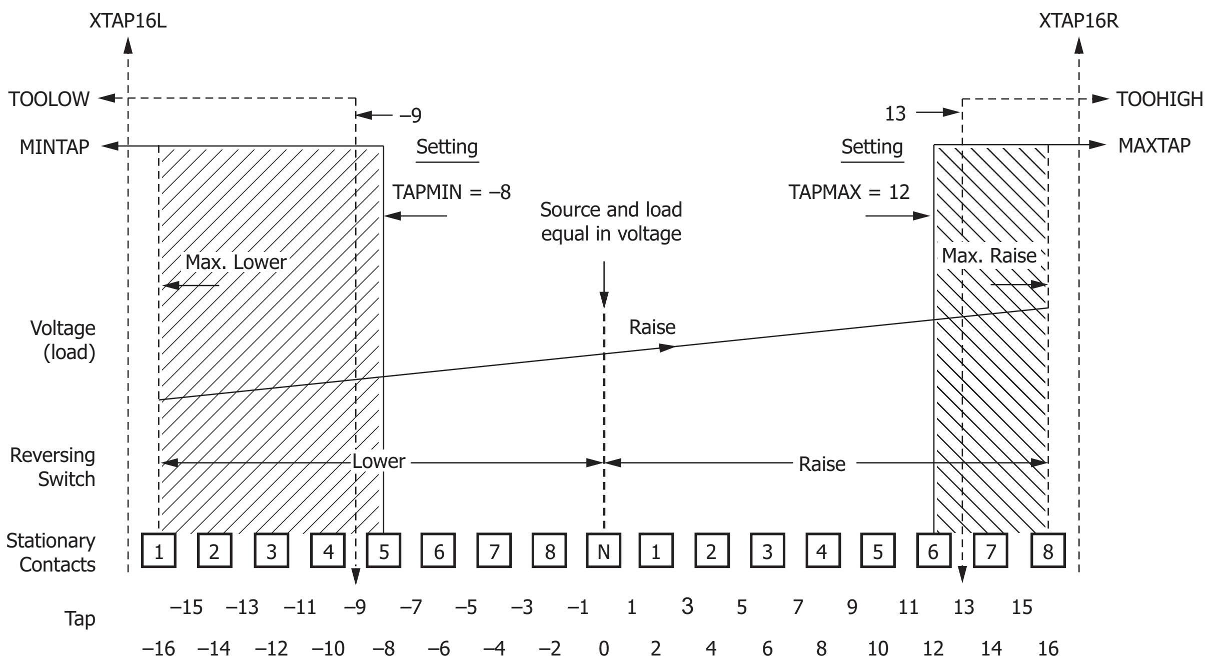


Figure 5.3 Settings TAPMAX and TAPMIN Constrain a Continual Raise Operation

The other Device Word bits shown in *Figure 5.3* operate as follows:

➤ Device Word bit TOOLOW asserts to logical 1 when the tap is at a "TAPMIN – 1" or lower tap value)

➤ Device Word bit TOOHIGH asserts to logical 1 when the tap is at a "TAPMAX + 1" or higher tap value)

➤ Device Word bit XTAP16L asserts momentarily to logical 1 when the tap value attempts to go to a tap value lower than "Tap = –16" (this might occur when the SEL-2431 gets "off tap" and finds itself at "Tap = –16" internally, but the voltage regulator is actually at a higher tap). A lower tap is still made (if no other setting condition prevents it), but the tap value is not decremented beyond "Tap = –16".

- ➤ Device Word bit XTAP16R asserts momentarily to logical 1 when the tap value attempts to go to a tap value higher than “Tap = 16” (this might occur when the SEL-2431 gets “off tap” and finds itself at “Tap = 16” internally, but the voltage regulator is actually at a lower tap). A higher tap is still made (if no other setting condition prevents it), but the tap value is not decremented beyond “Tap = 16”.

With factory settings, Device Word bits XTAP16L and XTAP16R route to the front-panel **ALARM** LED and the alarm output contact OUT101.

Full-Lower Sequence Example

Figure 5.4, with corresponding *Figure 5.5*, goes through an entire lower sequence, starting from the maximum raise position (Tap = 16). A step-by-step example is not given for *Figure 5.4*, but the procedure/analysis would be similar to that given for *Figure 5.1*.

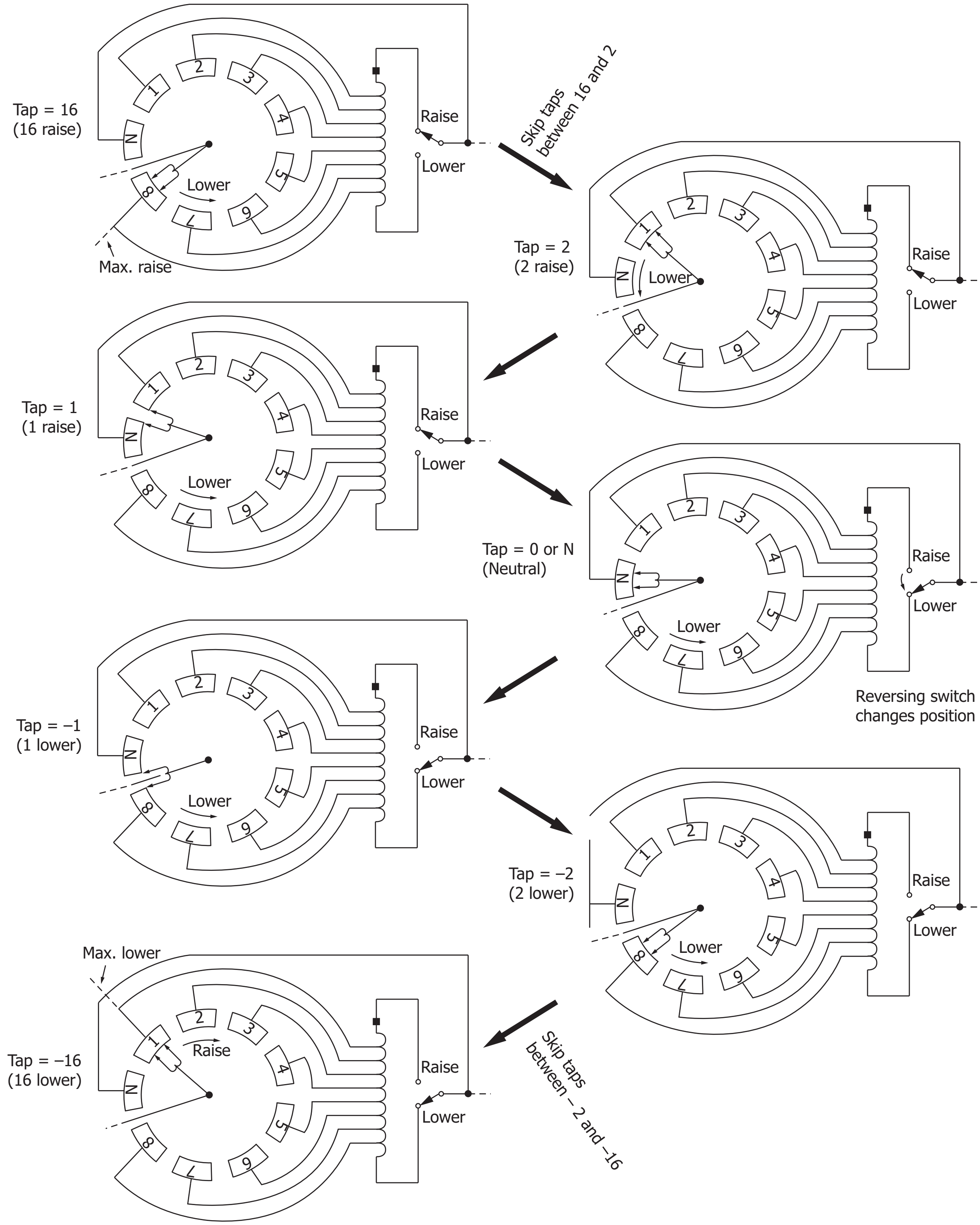


Figure 5.4 Voltage Regulator Mechanics of Tapping From Tap 16 to –16 (Lower)

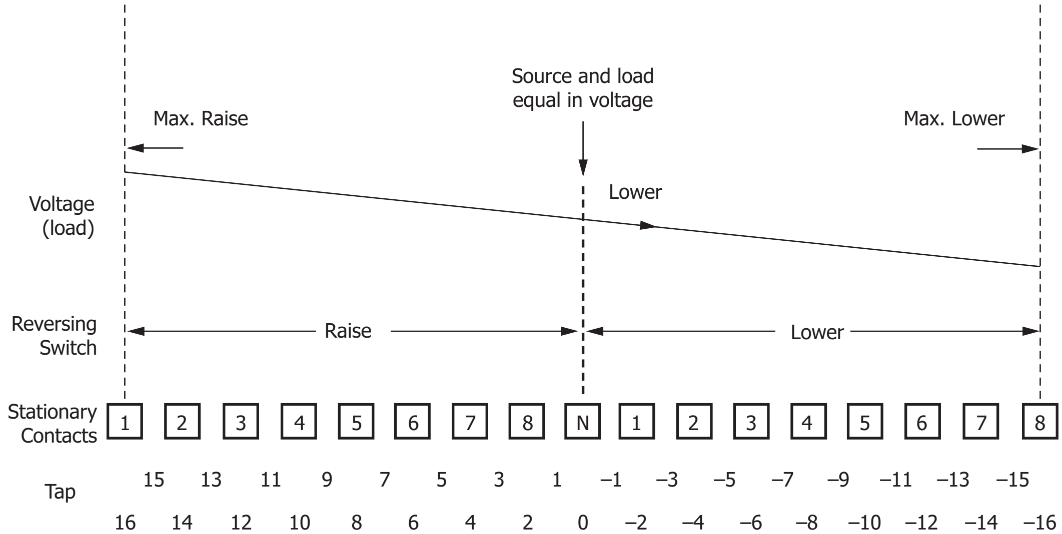


Figure 5.5 Plot of a Continual Lower Operation (Tap 16 to –16)

Figure 5.6 is the same as *Figure 5.5* with TAPMAX and TAPMIN settings applied. An analysis is not given for *Figure 5.6*, but it would be similar to that given for *Figure 5.3*.

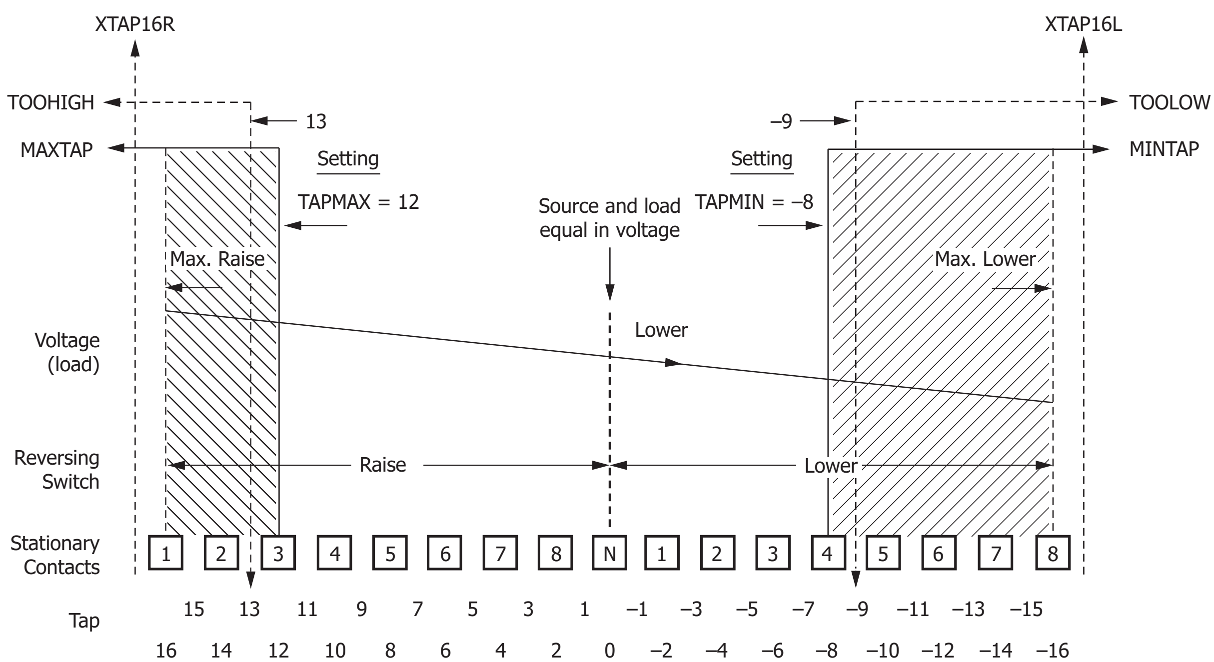


Figure 5.6 Settings TAPMAX and TAPMIN Constrain a Continual Lower Operation

Inhibiting/Blocking Then Resuming Tap Operation

If voltage is out-of-band and SELOGIC Group setting INHIBSV asserts (= logical 1; no tapping) then deasserts (= logical 0; tapping allowed), timing to tap restarts from the beginning.

If voltage is out-of-band and SELOGIC Group setting BLOCKSV asserts (= logical 1; no tapping), timing to tap continues with the present timer, but no tapping occurs when the timer times out (a "pending tap" condition exists). Then, if voltage is still out-of-band when BLOCKSV deasserts (= logical 0; tapping allowed), a tap occurs immediately for this "pending tap" condition.

Other Raise/Lower Methods

See *Figure 3.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*.

Besides the traditional tapchanging via:

- Out-of-band voltage conditions (operative in automatic mode [**AUTO** LED illuminated])
- Front-panel **MOTOR CONTROL RAISE** and **LOWER** pushbuttons or toggle switch (operative in manual mode [**MANUAL** LED illuminated])

tapchanging can also occur via the following:

- Serial port command **RAI** (raise) or **LOW** (lower) (operative in remote mode [**REMOTE** LED illuminated])
- SELOGIC Group setting RAISESV (raise) or LOWERSV (lower) (operative if a **REMOTE** or **AUTO** LED is illuminated)

The factory-default Group settings for RAISESV and LOWERSV are:

- RAISESV := TOOLOW AND AUTO (tap is at too low of value and in the automatic mode)
- LOWERSV := TOOHIGH AND AUTO (tap is at too high of value and in the automatic mode)

These factory-default Group settings realize the automatic tapping described in *TAPMAX/TAPMIN Values Constrain Regulator Operation* on page 5.7 (for the present tap value found outside the TAPMAX/TAPMIN bounds).

Other Tap-Changer Outputs

Analog Output

The following analog quantities are updated after each successful tap operation (see *Table F.1*).

TAP_POS

TAP_POS is the actual tap position, as the SEL-2431 sees it (see the bottoms of *Figure 5.2–Figure 5.6*). Tap position is stored in nonvolatile memory, in case the SEL-2431 loses and then regains power. *Digital Outputs* on page 5.12 discusses tap position more, especially abnormalities concerning tap position.

If the SEL-2431 gets off tap, the tap position can be set again. See *TAP Command* on page 9.31 for information on viewing and setting the tap position. Tap position can also be viewed or set via the front panel (see *Section 10: Front-Panel Operations*).

Tap Delta Analog Quantities

Tap delta analog Quantities are identified as the analog quantities starting with "DLT_". They are signed values, and are calculated after each successful tap operation using the fundamental metered values discussed in *Fundamental (Instantaneous) Metering* on page 7.3. They are stored in volatile memory and are reset to 0 when the device restarts.

Digital Outputs

Refer to *Figure B.5–Figure B.8* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*, depending on the voltage regulator model, for the following logic output descriptions (e.g., see the representation of an Operations Counter switch in one of the referenced figures).

The following Device Word bits are normal tap-changer operation outputs:

- OPSWHCN—Operations Counter switch closed and corresponding SEL-2431 input energized (see *Figure C.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*). The Operations Counter switch closes momentarily for each tap operation of a GE, Toshiba CR-3, ITB RAV-2, and Romagnole SVR voltage regulator. The Operations Counter switch is closed on each odd tap (open on the even taps) for a Siemens voltage regulator. The Howard regulator's operations counter switch is closed on even taps and open on odd taps. Cooper voltage regulators do not have an Operations Counter switch.
- TAPNEUT—Neutral Position switch closed and corresponding SEL-2431 LED illuminated (see *Figure C.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*).
- TAPDONE—Momentarily asserts for the completion of a single tap operation.
- MRAISE—Raise motor current flowing (see Raise current sense in *Figure C.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*). MRAISE assertion continues for a Cooper voltage regulator when hold current takes over from raise current path (see *Figure B.6* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*).
- MLOWER—Lower motor current flowing (see Lower current sense in *Figure C.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*). MLOWER assertion continues for a Cooper voltage regulator when hold current takes over from lower current path (see *Figure B.6* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*).
- MHOLD—Hold motor current flowing (see Hold current sense in *Figure C.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*; Cooper voltage regulator only).

The following Device Word bits are abnormal tap-changer operation outputs:

- OPNOCUR—Momentarily asserts (in place of TAPDONE) if the Operations Counter switch closed momentarily (GE, Toshiba CR-3, ITB RAV-2, and Romagnole SVR voltage regulators) or changed state (Siemens or Howard voltage regulators), but no raise or lower motor current was flowing. Cooper voltage regulators do not have an Operations Counter switch, so OPNOCUR asserts momentarily if the hold motor current drops out, but no raise or lower motor current was previously flowing (see *Figure B.6* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*).
- TAP_OFF—This only applies to a Siemens or Howard voltage regulator (see *Figure B.5* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*). For a Siemens voltage regulator (Global setting TAPCHNGR := SIEMENS), TAP_OFF asserts if the Operations Counter switch is closed, but the tap is an even number (e.g., Tap = –2) or the Operations Counter switch is open, but the tap is an odd number (e.g., Tap = 7). For a Howard voltage regulator (Global setting TAPCHNGR := HOWARD), TAP_OFF asserts if the Operations Counter switch is open, but the tap is an even number (e.g., Tap = 6) or the Operations Counter switch is closed, but the tap is an odd number (e.g., Tap = –11).
- NO_NEUT—Asserts if Tap = 0, but the Neutral Position switch is not closed.
- TAP_DIF—Momentarily asserts if the Neutral Position switch newly closes, but the tap did not go directly from Tap = 1 to Tap = 0 (Neutral) for a lower operation [nor directly from Tap = –1 to Tap = 0 (Neutral) for a raise operation]. Expected behavior for the Neutral Position switch newly closing is that the tap should go to Tap = 0 (Neutral) from the appropriate, adjacent tap (adjacent Tap = –1 for a raise or adjacent Tap = 1 for a lower).
- RSEFAIL—When tap mechanism feedback is enabled (Global setting TPFDBK = Y), RSEFAIL momentarily asserts if no tap change occurs after waiting for Global setting TAPDUR seconds after calling for a raise operation (motor raise current detected at the TAPDUR time out, as normally expected). When tap mechanism feedback is not enabled (Global setting TPFDBK = N), RSEFAIL momentarily asserts after waiting for Global setting TAPDUR seconds after calling for a raise operation.
- RSELIM—Momentarily asserts if no tap change occurs after waiting Global setting TAPDUR seconds after calling for a raise operation (motor current not detected at the TAPDUR time out). This alarm condition could very well be the voltage regulator at its raise limit switch tab (motor raise current path open circuited by the raise limit switch).
- LWRFAIL—When tap mechanism feedback is enabled (Global setting TPFDBK = Y), LWRFAIL momentarily asserts if no tap change occurs after waiting for Global setting TAPDUR seconds after calling for a lower operation (motor lower current detected at the TAPDUR time out, as normally expected). When tap mechanism feedback is not enabled (Global setting TPFDBK = N), LWRFAIL momentarily asserts after waiting for Global setting TAPDUR seconds after calling for a lower operation.

➤ LWRLIM—Momentarily asserts if no tap change occurs after waiting Global setting TAPDUR seconds after calling for a lower operation (motor current not detected at the TAPDUR time out). This alarm condition could very well be the voltage regulator at its lower limit switch tab (motor lower current path open circuited by the lower limit switch).

Device Word bits TAP_OFF, NO_NEUT, and TAP_DIF indicate that the tap position is off. Though, anytime the Neutral Position switch newly closes, the tap position is immediately reset to Tap position = 0 (Neutral).

Routing of Abnormal Tap-Changer Outputs in Factory-Default Settings

NOTE: If you disable tap mechanism feedback (Global setting TPFDBK = N) for generating the TAPDONE signal, you should remove the RSEFAIL and LWRFAIL Device Word Bits from default logic setting SV01 so that these Device Word bits do not generate nuisance alarms for every tap change.

Device Word bits OPNOCUR, TAP_DIF, RSFAIL, LWRFAIL, and XTAP16L and XTAP16R (*Figure 5.3* and *Figure 5.4*) are routed (via SELOGIC setting SV01) to:

➤ Front-panel **ALARM** LED (Front Panel setting ALARM) and the alarm output contact OUT101 (Logic setting OUT101)

➤ Event report trigger (Report setting ER)

The front-panel **ALARM** LED and the alarm output contact OUT101 also have Device Word bits TAP_OFF and NO_NEUT routed to them.

The Sequential Events Recorder (SER) settings (Report settings SER*xx*) contain all the Digital Output Device Word bits, plus many more (see *Factory-Default Settings* on page 8.17).

SECTION 6

Logic Functions

Overview

Functions use operands (inputs) and operators to generate outputs. Complex functions are created by using the outputs of several functions as operands in the new function.

Embedded voltage regulator control functions such as voltage control elements, raising and lowering logic, and event report triggering use logic built into the SEL-2431 voltage regulator control. In some cases, these embedded functions can be customized because they include SELOGIC control equations as inputs. The outputs of these functions and equations are generally made available as Device Word bits. Each function and equation is discussed in the appropriate control and monitoring section.

Custom functions may be constructed with SELOGIC control equations using operands such as SELOGIC variables and embedded voltage regulator control functions.

NOTE: All SELOGIC control equations must be set to NA, 0, 1, a single Device Word bit, or a combination of Device Word bits.

This section describes the use of SELOGIC control equation programming to customize voltage regulator control operation and automate substations. This section covers the following topics:

- SELOGIC control equation operands
- SELOGIC control equation operators
- SELOGIC control equation functions

SELOGIC Control Equation Capacity

SELOGIC control equation available capacity is a measure of remaining execution capacity and settings storage capacity. For maximum efficiency, use parentheses only when necessary and set unused equations to NA rather than 0 or 1.

Each SELOGIC control equation has a 15-operand maximum. Use a SELOGIC control equation variable (SV01–SV08) as an intermediate setting step if more operands are required.

Because the SEL-2431 executes the logic at a deterministic interval, there is a limit to the amount of SELOGIC control equation programming that the voltage regulator control can execute. Rather than limit parameters to guarantee that an application does not exceed the maximum processing requirements, the voltage regulator control measures and calculates the available capacity when SELOGIC control equations are entered. The voltage regulator control will not allow entry of programming that will cause it to be unable to complete all SELOGIC control equations each processing interval. The voltage regulator control calculates capacities based on the total amount of SELOGIC control equation programming executed in Global, Group, Logic, and several other settings areas.

Use the **STATUS S** command to view available execution capacity and settings storage.

SELOGIC Control Equation Operands

Outputs from embedded voltage regulator control functions are generally available for use as operands in SELOGIC control equations. Some analog values are available as operands as well. Use these operands to customize the operation of your SEL-2431 and use the SEL-2431 to automate substation operation. The operands available for use in SELOGIC control equations are summarized in *Table 6.1*.

Table 6.1 Summary of SELOGIC Control Equation Operands

Operand Type	Device Word Bit Operands
Constants	0, 1
Inputs	Status Inputs, Optoisolated Inputs
Inputs	Local Bits (see *Section 10: Front-Panel Operations*)
Inputs	Remote Bits (see *Section 9: Communications*)
Elements	Voltage and Control Elements (see *Section 3: Control Algorithms*)
Functions	Variables/Timers, Latch Bits, Counters
Outputs	Raise and Lower Outputs, Output Contacts
Analog	Received, Measured, or Calculated Analog Values

Device Word Bits

Data within the voltage regulator control are available for use in SELOGIC control equations. Device Word bits include received digital values including optoisolated inputs, control bits, and remote bits. They also include calculated digital values such as SELOGIC control equation variables, SELOGIC control equation functions, and protection and control elements. *Appendix E: Device Word Bits* contains a list of Device Word bits available within the SEL-2431.

Analog Quantities

The SELOGIC column in *Table F.1* indicates the analog quantities available for SELOGIC expressions within the SEL-2431.

SELOGIC Control Equation Operators

Use the analog comparators to create a Boolean result from an analog value, and Boolean operators to combine values with a resulting Boolean value. Edge-trigger operators provide a pulse output. Combine the operators and operands to form statements that evaluate complex logic. *Table 6.2* contains a summary of operators available in the SEL-2431.

Operator Precedence

When you combine several operators and operands within a single expression, the SEL-2431 evaluates the operators from left to right starting with the highest precedence operators working down to the lowest precedence. This means that if you write an equation with three AND operators, for example SV01 AND SV02 AND SV03, each AND will be evaluated from the left to the right. If you substitute NOT SV04 for SV03 to make SV01 AND SV02 AND NOT SV04, the voltage regulator control evaluates the NOT operation of SV04 first and uses the result in subsequent evaluation of the expression. Operator precedence is shown in *Table 6.2*.

Table 6.2 Operator Precedence

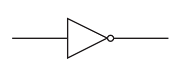
Operator	Description
( )	Parenthesis
NOT	Boolean Complement
R_TRIG	Rising-Edge Trigger
F_TRIG	Falling-Edge Trigger
<, >, <=, =>	Analog Comparison
=	Analog Equality Check
<>	Analog Inequality Check
AND	Boolean AND
OR	Boolean OR

Parentheses Operator

Use paired parentheses to control the execution order of operations in a SELOGIC control equation. Use as many as 14 nested sets of parentheses in each SELOGIC control equation. The voltage regulator control calculates the result of the operation on the innermost pair of parentheses first and then uses this result with the remaining operations.

NOT Operator

Use the NOT operator to invert a Boolean value. Create a NOT function using the NOT operator. This function would be described mathematically by the equation f(A) = NOT A and graphically by the following IEEE symbol:



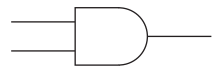
AND Operator

Use AND to combine two Boolean values according to the truth table shown in *Table 6.3*.

Table 6.3 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

Create an AND function using the AND operator. This function would be described mathematically by the equation f(A,B) = A AND B and graphically by the following IEEE symbol:



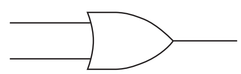
OR Operator

Use OR to combine two Boolean values according to the truth table shown in *Table 6.4*.

Table 6.4 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

Create an OR function using the OR operator. This function would be described mathematically by the equation f(A,B) = A OR B and graphically by the following IEEE symbol:



R_TRIG Operator

R_TRIG is a time-based function that creates a pulse when a rising edge is detected, as shown in *Figure 6.1*. Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only after the value changes state.

R_TRIG applies to individual Device Word bits only, not to groups of elements within parentheses. For example, the SELogic control equation event report generation setting uses several rising-edge operators:

ER := **R_TRIG RAISE OR R_TRIG OUT102**

When a logical 0 to logical 1 transition of ER is detected, the SEL-2431 generates an event report (if the voltage regulator control is not already generating a report that encompasses the new transition). The rising-edge operators in the ER equation enable detection of each individual transition.

Suppose RAISE CONTROL and OUT102 assert. *Figure 6.1* demonstrates the action of the rising-edge operator R_TRIG on the individual elements in setting ER.

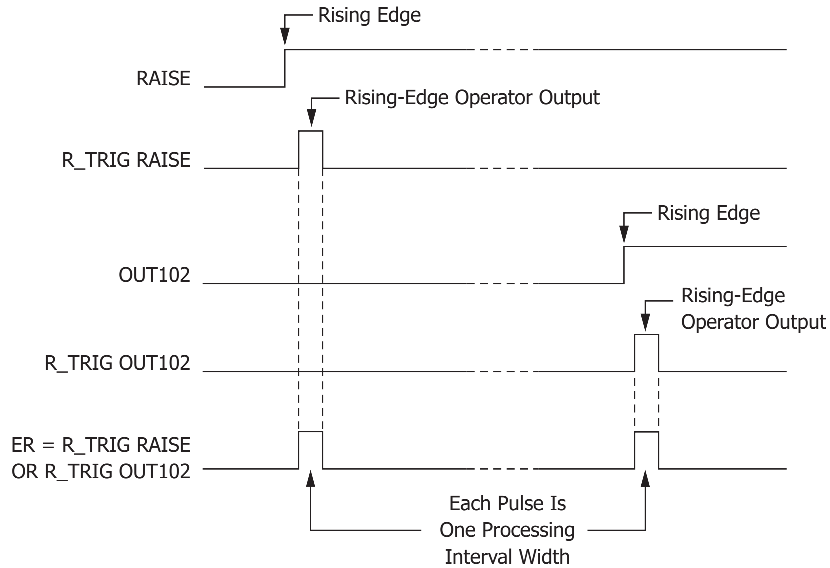


Figure 6.1 Rising-Edge Operator Example

Note in *Figure 6.1* that setting ER detects two separate rising edges, because of the application of rising-edge operators R_TRIG. The rising edge operator R_TRIG in front of a Device Word bit detects this logical 0 to logical 1 transition as a rising edge and as a result asserts to logical 1 for one processing interval. The assertion of OUT102 is some appreciable time later and will generate another event report, if the first event capture has ended when OUT102 asserts.

If the rising-edge operators R_TRIG were not applied and setting ER was:

ER := **RAISE OR OUT102**

the ER setting would not detect the assertion of OUT102, because RAISE would continue to be asserted at logical 1.

F_TRIG Operator

F_TRIG is a time-based function that creates a pulse when a falling edge is detected, as shown in *Figure 6.2*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state.

The argument of an F_TRIG statement must be a single Device Word bit within the SEL-2431. An example of the voltage regulator control detecting a falling edge of a calculated quantity is shown in *Figure 6.2*.

For example, suppose the SELOGIC control equation event report generation setting is set with the detection of the falling edge of output contact OUT101:

ER := **. . . OR F_TRIG OUT101**

Figure 6.2 demonstrates the action of the falling-edge operator F_TRIG on the underfrequency element in setting ER.

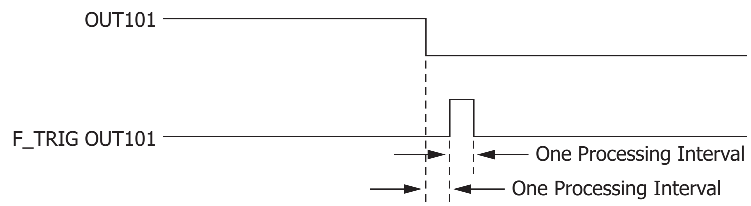


Figure 6.2 Falling-Edge Operator Example

Analog Comparisons

The <, >, <=, => comparator operators are generally used to determine states to drive a sequence of actions. Use the = check operator to check whether an integer value is equal to another integer value. Do not use the = check operator for noninteger values, because it is unlikely that they will ever be equal.

Use the analog comparators to create your own schemes. For example, monitor the frequency on your system to initiate an alarm if there is a large frequency excursion. The following equation is an example of how to implement this alarm:

SV03 : = **FREQ > 65#Assert SV03 if the system frequency is more than 65 Hz**

Comments

The pound symbol (#) is used as a comment operator. All characters entered after the # will be treated as text instead of logic.

NOTE: Comments may be entered in upper- or lowercase letters.

SELOGIC control equation comments are very powerful tools for documenting and clarifying programming. Even programming that is well understood during installation and commissioning should have comments to help with any modifications needed later. These comments are stored in the SEL-2431.

SELOGIC Control Equation Functions

Variables/Timers

The SEL-2431 has eight (8) SELOGIC control equation variables/timers. Each SELOGIC control equation variable/timer has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 6.3*.

These timers have pickup and dropout time settings (SV*n*PU and SV*n*DO, *n* = 01–08).

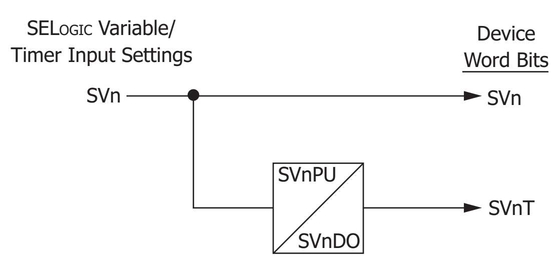


Figure 6.3 SELOGIC Control Equation Variables/Timers

If power to the SEL-2431 is lost, settings are changed for the active setting group, or the active setting group is changed, the SELOGIC control equation variables/timers are reset. Device Word bits SV*n* and SV*n*T (*n* = 01–08) are reset to logical 0 and corresponding timer settings SV*n*PU and SV*n*DO are reloaded after power restoration, settings change, or active setting group switch.

Example 1

In the SELOGIC control equation settings, a SELOGIC control equation timer can be used to check if forward demand line current is greater than 200 A for 10 minutes:

SV02 := **ILFDEM > 200**

When forward demand line current exceeds 200 A, Device Word bit SV02 asserts, initiating pickup timer SV02PU. Timer pickup setting SV02PU is set to 10 minutes (SV02PU := 600 seconds). Timer dropout setting SV02DO is set for an instantaneous dropout (SV02DO := 0 seconds). The output of the timer (Device Word bit SV02T) operates output contact OUT103:

OUT103 := **SV02T**

Timer Reset Conditions

If power to the voltage regulator control is lost, settings are changed for the active setting group, or the active setting group is changed, the SELOGIC control equation variables/timers are reset. Device Word bits SV*n* and SV*n*T (*n* = 01–08) are reset to logical 0 and corresponding timer settings SV*n*PU and SV*n*DO load up again.

Latch Bits

The SEL-2431 latch control switches retain their state even when power to the voltage regulator control is lost. If the latch control switch is set to a programmable output contact and power to the SEL-2431 is lost, the state of the latch control switch is stored in nonvolatile memory, but the output contact will go to its de-energized state. When power to the SEL-2431 is restored, the programmable output contact will go back to the state of the latch control switch after voltage regulator control initialization.

Traditional latching relay output contact states are changed by pulsing the latching relay inputs (see *Figure 6.4*). Pulse the set input to close (set) the latching relay output contact. Pulse the reset input to open (reset) the latching relay output contact. Often the external contacts wired to the latching relay inputs are from remote control equipment (e.g., SCADA, RTU).

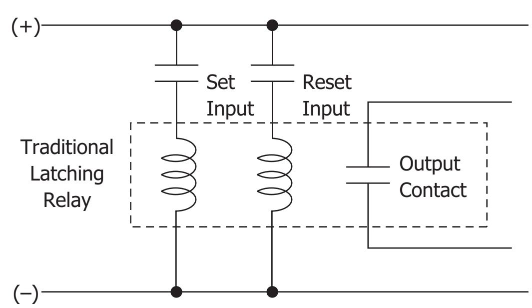


Figure 6.4 Traditional Latching Relay

Eight latch control switches in the SEL-2431 provide latching relay functionality (see *Latch Bits Set/Reset SELOGIC Equations* on page SET.9).

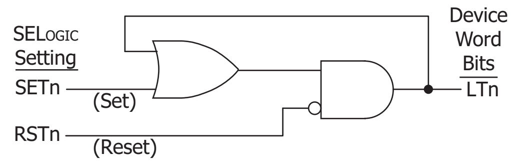


Figure 6.5 Latch Control Switches Drive Latch Bits LT01–LT08

The output of the latch control switch in *Figure 6.5* is a Device Word bit LT*n* (*n* = 01–08), called a latch bit. The latch control switch logic in *Figure 6.5* repeats for each latch bit LT01–LT08. Use these latch bits in SELOGIC control equations.

These latch control switches each have the following SELOGIC control equation settings:

- SET*n* (set latch bit LT*n* to logical 1)
- RST*n* (reset latch bit LT*n* to logical 0)

If setting SET*n* asserts to logical 1, latch bit LT*n* asserts to logical 1. If setting RST*n* asserts to logical 1, latch bit LT*n* deasserts to logical 0. If both settings SET*n* and RST*n* assert to logical 1, setting RST*n* has priority and latch bit LT*n* deasserts to logical 0.

Latch Bits: Application Ideas

Latch control switches can be used for applications such as setting group selection for irrigation season or maintenance.

Latch control switches can be applied to almost any control scheme. The following is an example of using a latch control switch to change the setting group in the SEL-2431.

Example: Setting Group Switch

During the irrigation season, the operator may want to adjust the traditional R and X settings for the Line-Drop Compensation (LDC) (settings VLDCFWR and VLDCFWX in *Line-Drop Compensation (LDC)* on page 3.1). Therefore, a different setting group may be utilized through a remote command from the control center.

This group switch logic is implemented in the following SELOGIC control equation settings. The timing is shown in *Figure 6.6*.

SS1 := **NOT LT01**

SS2 := **LT01**

SET01 := **R_TRIG RB01**

RST01 := **R_TRIG RB02**

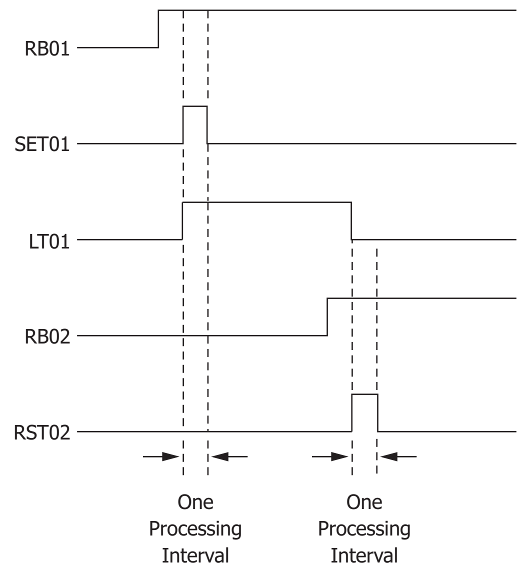


Figure 6.6 Latch Control Switch Operation Time Line

Latch Bits: Nonvolatile State

Power Loss

The states of the latch bits (LT01–LT08) are retained if power to the SEL-2431 is lost and then restored. If a latch bit is asserted (e.g., LT02 = logical 1) when power is lost, it is asserted (LT02 = logical 1) when power is restored. If a latch bit is deasserted (e.g., LT03 = logical 0) when power is lost, it is deasserted (LT03 = logical 0) when power is restored. This feature makes the latch bit feature behave the same as traditional latching relays. In a traditional installation, if power is lost to the panel, the latching relay output contact position remains unchanged.

If a latch bit is set to a programmable output contact, such as OUT103 := LT02, and power to the SEL-2431 is lost, the state of the latch bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When power to the SEL-2431 is restored, the programmable output contact will go back to the state of the latch bit after voltage regulator control initialization.

Settings Change or Active Setting Group Change

If individual settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed, the states of the latch bits (Device Word bits LT01–LT08) are retained, much like in the preceding *Power Loss* explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the latch bits (the SEL-2431 is not momentarily disabled).

If the individual settings change or active setting group change causes a change in SELOGIC control equation settings SET*n* or RST*n* (*n* = 01–08), the retained states of the latch bits can be changed, subject to the newly enabled settings SET*n* or RST*n*.

Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss, settings change, or active setting group change. The nonvolatile memory is rated for a finite number of writes for all cumulative latch bit state changes. Exceeding the limit can result in a Flash self-test failure. *An average of 70 cumulative latch bit state changes per day can be made for a 25-year voltage regulator control service life.*

This requires that SELOGIC control equation settings SET*n* and RST*n* for any given latch bit LT*n* (*n* = 01–08) be set with care. Settings SET*n* and RST*n* must not result in continuous cyclical operation of latch bit LT*n*. Use timers to qualify conditions set in settings SET*n* and RST*n*.

Counters

SELOGIC control equation counters are up- or down-counting elements. These counters conform to the standard counter function block in *IEC 61131-3 First Edition 1993-03 International Standard for Programmable Controllers - Part 3: Programming Languages*, as shown by the symbol in *Figure 6.7*.

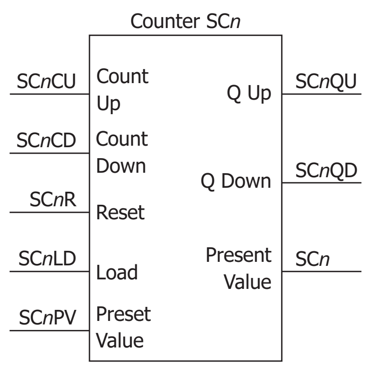


Figure 6.7 Up/Down Counters

Table 6.5 describes the Boolean input settings, counter value setting, and Boolean outputs of the counters. Eight counters are available: *n* = 01–08 (see *SELOGIC Counter Settings* on page SET.11).

Table 6.5 Counter Inputs and Outputs

Name	Type	Description
SC*n*LD	Active High Input	Load counter with the preset value (follows SELOGIC setting)
SC*n*PV	Input Value	This Preset Value is loaded when SC*n*LD pulsed. This Preset Value is used as a maximum count in the SC*n*QU comparison (follows SELOGIC setting)
SC*n*CU	Rising-Edge Input	Count Up increments the counter (follows SELOGIC setting)
SC*n*CD	Rising-Edge Input	Count Down decrements the counter (follows SELOGIC setting). If set to NA, the counter is disabled.
SC*n*R	Active High Input	Reset counter to zero (follows SELOGIC setting).
SC*n*QU	Active High Output	This Q Up output asserts when the Preset Value (maximum count) is reached (SC*n* = SC*n*PV, *n* = 01–08).
SC*n*QD	Active High Output	This Q Down output asserts when the counter is equal to zero (SC*n* = 0, *n* = 01–08).
SC*n*	Output Value	This counter output is an analog value that may be used with analog comparison operators in a SELOGIC control equation, or viewed with the **COUNTER** command.

Viewing Counters

The serial port command **COUNTER** displays the present value of SC01–SC08. See *COUNTER Command (View SELOGIC Counters)* on page 9.19.

Counters: Application Ideas

Counters can be used for such applications as keeping track of tap operations executed every day.

Examples

Example 6.1 illustrates how to use the SELOGIC control equation counters to count the number of tap operations every day and alarm when more than 30 Taps are reached per day.

Example 6.1

SC01PV := **30**	(Maximum tap operation per day)
SC01LD := **0**	(Do not load the max tap position into the counter)
SC01CU := **TAPDONE**	(Increment counter when a tap operation completes)
SC01CD := **0**	(Do not count down)
SC01R := **OP1 OR OP2**	(Reset counter at noon every day)
OP1DOW := **WEEKDAY**	
OP1TOD := **12:00**	
OP2DOW := **WEEKEND**	
OP2TOD := **12:00**	

When there is a tap operation completed, TAPDONE asserts, causing counter SC01 to count up one. If the counter value (SC01) reaches the max number of tap operations (SC01PV), the Device Word bit SC01QU asserts. An alarm can be sent to the operator to inspect the regulator.

OP1 asserting every weekday at 12:00 PM and OP2 asserting every weekend at 12:00 PM causes the tap counter SC01 to reset.

Counters: Volatile State and Disabled Behavior

Power Loss

SELOGIC counters SC01–SC08 are reset to a count value of zero after power to the SEL-2431 voltage regulator control module is lost and then restored. The counter output Device Word bits behave as explained below for enabled and disabled counters.

Settings Change or Active Group Change

SELOGIC counters SC01–SC08 are retained through settings changes and active group changes.

Enabled and Disabled Counters

If a settings change or group change results in a different number of enabled counters (logic enable setting ESC changes), the counters behave as follows:

➤ Newly enabled counters (or enabled counters after power is restored) start at a count value of zero, with output SC*nn*QD = logical 1, and SC*nn*QU = logical 0

➤ Disabled counters are set to zero, with both outputs SC*mm*QD and SC*mm*QU forced to logical 0

Optoisolated Inputs

See *Optoisolated Inputs IN201 through IN204* in *Appendix C: Internal SEL-2431 Wiring and Extra I/O Connections* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for connection information.

Figure 6.9 shows examples of energized and de-energized inputs and corresponding Device Word bit states.

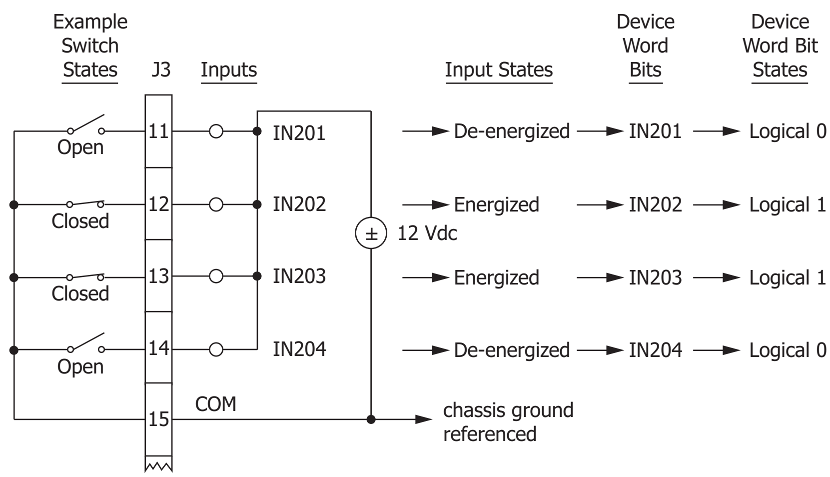


Figure 6.8 Example Operation of Optoisolated Inputs

Example Application

Device Word bits IN201–IN204 can be used as inputs into a latch (see *Figure 6.5*) and the latch output can be input into the active setting group switching logic (see *Table 6.7*). Then scheme operation can change according to the signals applied to optoisolated inputs. Many other applications are possible.

120 Vac Whetted Inputs

See *120 VAC WHETTING Output and Input IN101 and IN102* in *Appendix C: Internal SEL-2431 Wiring and Extra I/O Connections* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for connection information.

Device Word bits IN101 and IN102 behave much like Device Word bits IN201–IN204 in *Figure 6.8*, except inputs IN101 and IN102 respond to nominal 120 Vac voltage.

Remote Bits

Up to 16 remote control switches are operated via the serial communications Port 1 or by Telnet over Ethernet Port E. They may be operated using any of the following:

- ➤ SEL ASCII command **CONTROL** as described in *Section 9: Communications*.
- ➤ Fast Operate commands as described in *Appendix C: SEL Communications Processors*.
- ➤ DNP3 Objects 10 and 12 as described in *Appendix D: DNP3 Communications*.

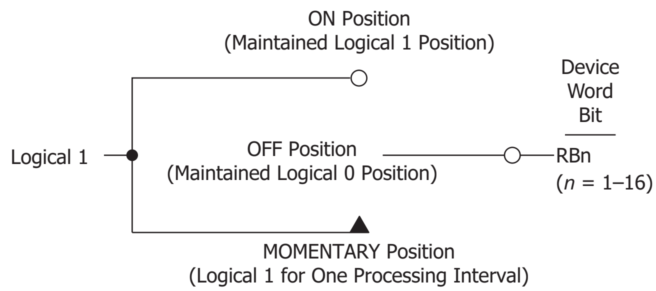


Figure 6.9 ON/OFF/MOMENTARY Remote Control Switch

The output of the switch in *Figure 6.9* is a Device Word bit (RB01–RB16) called a Remote Bit and repeats for each Remote Bit. Use these Device Bits in SELOGIC control equations.

Remote Bit RB*n* may be in the ON (RB*n* = logical 1) position, in the OFF (RB*n* = logical 0) position, or maintained in the OFF (RB*n* = logical 0) position and pulsed to the MOMENTARY (RB*n* = logical 1) position for one processing interval (1 cycle).

The state of each remote bit (Device Word bits RB01–RB16) is retained if voltage regulator control settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed.

Application Ideas

With SELOGIC control equations, the remote bits can be used in applications similar to those that use local bits.

Also, remote bits can be used much as optoisolated inputs are used in operating latch control switches. Pulse (momentarily operate) the remote bits for this application.

Momentary Position

This subsection describes how the momentary position of the remote control switch operates using the SEL ASCII command **CONTROL**. It operates in the same manner when used with a Fast Operate or DNP3 pulse command.

Use the **CON RB*n* P** command to put the remote control switch in the momentary ON position for one processing interval, regardless of its initial state. The remote control switch is then placed in the OFF position.

If RB*n* is initially at logical 0, pulsing it with the **CON RB*n* P** command will change RB*n* to a logical 1 for one processing interval, and then return it to a logical 0. If RB*n* is initially at logical 1 instead, pulsing it with the **CON RB*n* P** command will change RB*n* to a logical 0.

Volatile State

The states of the remote bits (Device Word bits RB01–RB16) are not retained if power to the SEL-2431 is lost and then restored. The remote control switches always come back in the OFF position (corresponding remote bit is deasserted to logical 0) when power is restored to the SEL-2431.

Multiple Setting Groups

The SEL-2431 has four (4) independent setting groups. Each setting group has complete voltage regulator control (voltage, voltage control algorithm, etc.) and SELOGIC control equation settings. The active setting group can be:

- Shown or selected with the SEL ASCII serial port **GROUP** command as described in *Section 9: Communications*.
- Shown or selected with the `MAIN` menu `Set/Show` menu item and the `Active Group` submenu item as described in *Section 10: Front-Panel Operations*.
- Selected with SELOGIC control equation settings SS1–SS4. Settings SS1–SS4 have priority over all other selection methods. Use remote bits in these equations to select setting groups with Fast Operate commands as described in *Appendix C: SEL Communications Processors* or with DNP3 Objects 10 and 12 as described in *Appendix D: DNP3 Communications*.
- Shown with DNP3 Objects 30 and 32 as described in *Appendix D: DNP3 Communications*.

Setting Groups: Application Ideas

Setting groups can be used for such applications as:

- Environmental conditions such as winter storms, periods of high summer heat, etc.
- Abnormal reverse-power conditions
- Commissioning and operation

Active Setting Group Indication

Only one setting group can be active at a time. Device Word bits SG1–SG4 indicate the active setting group, as shown in *Table 6.6*.

Table 6.6 Definitions for Active Setting Group Indication Device Word Bits SG1–SG4

Device Word Bit	Definition
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group

For example, if setting Group 4 is the active setting group, Device Word bit SG4 asserts to logical 1, and the other Device Word bits SG1, SG2, and SG3 are all deasserted to logical 0.

Active Setting Group Selection

The Global settings class contains the SELOGIC control equation settings SS1–SS4, as shown in *Table 6.7*.

Table 6.7 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1–SS4

Setting	Definition
SS1	Go to (or remain in) setting Group 1
SS2	Go to (or remain in) setting Group 2
SS3	Go to (or remain in) setting Group 3
SS4	Go to (or remain in) setting Group 4

The operation of these settings is explained with the following example:

Example 6.2

Assume the active setting group starts out as setting Group 3. Corresponding Device Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group.

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, and SS4. With settings SS1–SS4 all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS4) asserts to logical 1, the voltage regulator control switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 4) as the active setting group, after qualifying time setting TGR:

TGR	Group Change Delay Setting	(settable from 0 to 900 seconds)

In this example, TGR qualifies the assertion of setting SS4 before it can change the active setting group.

Active Setting Group Changes

The voltage regulator control is disabled for less than one second while in the process of changing active setting groups. Voltage regulator control elements, timers, and logic are reset, unless indicated otherwise in the specific logic description. For example, local bit (LB01–LB08), remote bit (RB01–RB16), and latch bit (LT01–LT16) states are retained during an active setting group change. The output contacts do not change state until the voltage regulator control enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group. For instance, if setting OUT104 := 1 (logical 1) in Group 2, and setting OUT104 := 1 (logical 1) in Group 3, and the voltage regulator control is switched from Group 2 to Group 3, OUT104 stays energized before, during, and after the group change. However, if the Group 3 setting was OUT104 := 0 (logical 0) instead, then OUT104 remains energized until the voltage regulator control enables in Group 3, solves the SELOGIC equations, and causes OUT104 to de-energize. See *Figure 6.13* for examples of output contacts in the de-energized state (i.e., corresponding output contact coils de-energized).

Example: Active Setting Group Switching

Use a single optoisolated input to switch between two setting groups in the SEL-2431. In this example, optoisolated input IN201 on the voltage regulator control is connected to a SCADA contact in *Figure 6.10*. Each pulse of the SCADA contact changes the active setting group from one setting group, such as setting Group 1, to another, such as setting Group 4. The SCADA contact is not maintained, just pulsed to switch from one active setting group to another.

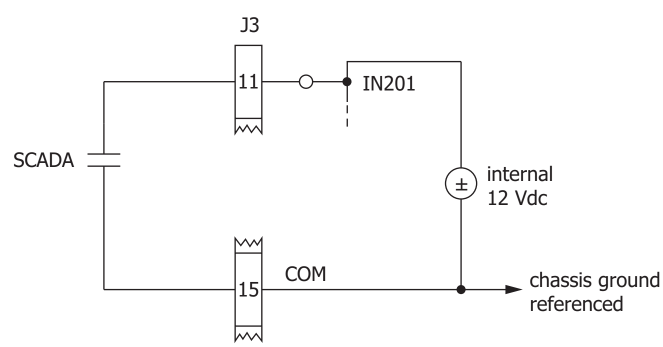


Figure 6.10 SCADA Contact Pulses Input IN201 to Switch Active Setting Group Between Setting Groups 1 and 4

If setting Group 1 is the active setting group and the SCADA contact is pulsed, setting Group 4 becomes the active setting group. If the SCADA contact is pulsed again, setting Group 1 becomes the active setting group again. The setting group control operates in a cyclical manner.

This logic is implemented in the SELOGIC control equation settings in *Table 6.8*.

Table 6.8 SELOGIC Control Equation Settings for Switching Active Setting Group Between Setting Groups 1 and 4 (Sheet 1 of 2)

Setting Group 1	Setting Group 4
SV08PU := 60.00	SV08PU := 60.00
SV08DO := 0.00	SV08DO := 0.00
SV08 := SG1	SV08 := SG4

Table 6.8 SELOGIC Control Equation Settings for Switching Active Setting Group Between Setting Groups 1 and 4 (Sheet 2 of 2)

Setting Group 1	Setting Group 4
Global Settings	
SS1 := IN201 AND SV08T AND NOT SG1	
SS2 := 0	
SS3 := 0	
SS4 := IN201 AND SV08T AND NOT SG4	
SS5 := 0	
SS6 := 0	

SELOGIC control equation timer input setting SV08 in *Table 6.8* has logic output SV08T, shown in operation in *Figure 6.11* for both setting Groups 1 and 4. The settings for SS1 and SS4 include expressions that steer the IN201 assertion to the appropriate setting. SS1 is only allowed to operate when the voltage regulator control is not in Group 1, and SS4 is only allowed to operate when the voltage regulator control is not in Group 4. These details are explained below.

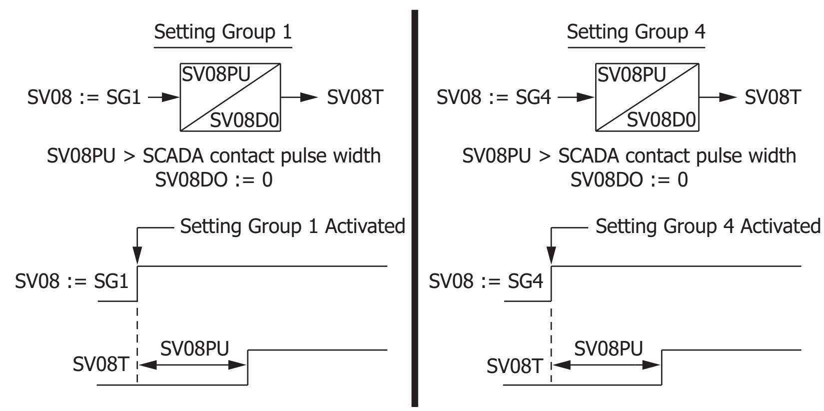


Figure 6.11 SELOGIC Control Equation Variable Timer SV08T Used in Setting Group Switch

In this example, timer SV08T is used in both setting groups: different timers could have been used with the same operational result. The timers reset during the setting group change, allowing the same timer to be used in both setting groups.

Timer pickup setting SV08PU is set greater than the pulse width of the SCADA contact (*Figure 6.10*). This allows only one active setting group change, such as from setting Group 1 to 4, for each pulse of the SCADA contact, and subsequent assertion of input IN201. The function of the SELOGIC control equations in *Table 6.8* becomes more apparent in the following example scenario.

Example 6.3

Start Out in Setting Group 1. The SEL-2431 has been in setting Group 1 for some time, with timer logic output SV08T asserted to logical 1, thus enabling SELOGIC control equation setting SS4 for the assertion of input IN201. The inclusion of AND NOT SG1 in the setting for SS1 prevents SS1 from detecting the next IN201 assertion, see *Figure 6.12*.

Example 6.3

Note that *Figure 6.12* shows both setting Group 1 and setting Group 4 settings. The setting Group 1 settings (near the top of *Figure 6.12*) are enabled only when setting Group 1 is the active setting group and likewise for the setting Group 4 settings near the bottom of the figure. The group selection settings, SS1 and SS4, are Global settings, and are enabled in every setting group.

Switch to Setting Group 4. The SCADA contact pulses input IN201, and the active setting group changes to setting Group 4 after qualifying time setting TGR (perhaps set at a cycle or so to qualify the assertion of setting SS4).

Setting Group 4 is now the active setting group, and Device Word bit SG4 asserts to logical 1. After the voltage regulator control has been in setting Group 4 for a time period equal to SV08PU, the timer logic output SV08T asserts to logical 1, thus enabling SELOGIC control equation setting SS1 for a new assertion of input IN201. The inclusion of AND NOT SG4 in the setting for SS4 prevents SS4 from detecting the next IN201 assertion.

Note that input IN201 is still asserted because setting Group 4 is activated. Pickup time SV08PU keeps the continued assertion of input IN201 from causing the active setting group to revert back again to setting Group 1 for a single assertion of input IN201. This keeps the active setting group from being changed at a time interval less than time SV08PU.

Switch Back to Setting Group 1. The SCADA contact pulses input IN201 a second time, and the active setting group changes back to setting Group 1 after qualifying time setting TGR, perhaps set at a cycle or so to qualify the assertion of setting SS1. The timing is shown in *Figure 6.12*.

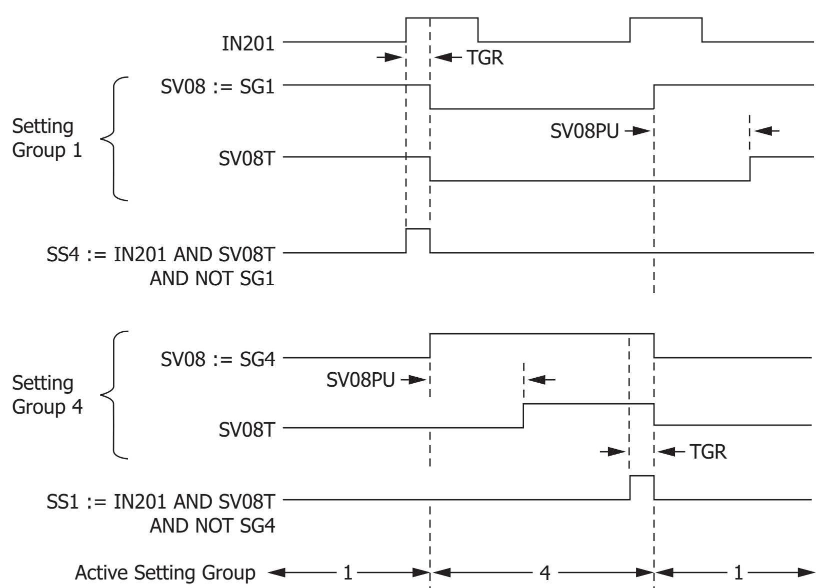


Figure 6.12 Active Setting Group Switching (With Single Input) Timing

Active Setting: Nonvolatile State

Power Loss

The active setting group is retained if power to the voltage regulator control is lost and then restored. If a particular setting group is active (e.g., setting Group 4) when power is lost, the same setting group is active when power is restored.

Settings Change

If individual settings are changed for the active setting group or one of the other setting groups, the active setting group is retained, much like *Example 6.4*.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group, so the voltage regulator control is not momentarily disabled.

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1–SS4, the active setting group can be changed, subject to the newly enabled SS1–SS4 settings.

Make Active Setting Group Switching Settings With Care

The active setting group is stored in nonvolatile memory so it can be retained during power loss or settings change. The nonvolatile memory is rated for a finite number of writes for all setting group changes. Exceeding the limit can result in a Flash self-test failure. *An average of four (4) setting group changes per day can be made for a 25-year voltage regulator control service life.*

This requires that SELOGIC control equation settings SS1–SS4 (see *Table 6.7*) be set with care. Settings SS1–SS4 must not result in continuous cyclical changing of the active setting group. Time setting TGR qualifies settings SS1–SS4 before changing the active setting group.

Output Contacts

See *Output Contacts OUT101 through OUT104* in *Appendix C: Internal SEL-2431 Wiring and Extra I/O Connections* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for output contact type and connection information.

SEL-2431 output contacts are normally operated using SELOGIC control equation OUT*n* (*n* = 101–104) or via other methods.

These two methods are ordinarily only used in testing:

- SEL ASCII command **PULSE** as described in *Section 9: Communications*.
- Front-panel HMI Control menu and Output Contacts submenu as described in *Section 10: Front-Panel Operations*.

Figure 6.13 shows the example operation of Device Word bits that in turn control corresponding output contacts. Output contacts OUT103 and OUT104 are not shown in *Figure 6.13*, but operate similarly to output contact OUT102.

SELOGIC control equation settings OUT*n* and serial port ASCII command **PULSE OUT*n*** are shown as inputs into the logic in *Figure 6.13*. Front-panel HMI, not shown in *Figure 6.13*, has the same logical effect as the serial port ASCII command **PULSE OUT*n*** in *Figure 6.13*—it is just a different means to the same result (assertion of Device Word bit OUT*n*).

SCADA Operation

To operate output contacts via SCADA, use one of the following methods of operation.

- ➤ Fast Operate commands as described in *Appendix C: SEL Communications Processors*.
- ➤ DNP3 Objects 10 and 12 as described in *Appendix D: DNP3 Communications*.

Both methods must first be programmed using SELOGIC control equation OUT*n* (*n* = 101–104). For example, remote bit RB01 may be used to control output OUT102 with the setting OUT102 := RB01 (see *Remote Bits* on page 6.13).

Output Contact Operation

The assertion of a Device Word bit causes the energization of the corresponding output contact coil. Depending on the contact type (Form A or Form B), the output contact closes or opens. A Form A output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A Form B output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

The default settings are

OUT101 := **NOT ALARM**

OUT102 through OUT104 := **0**

The output SELOGIC equations are located in the logic settings class, see *Output SELOGIC Equations* on page SET.13.

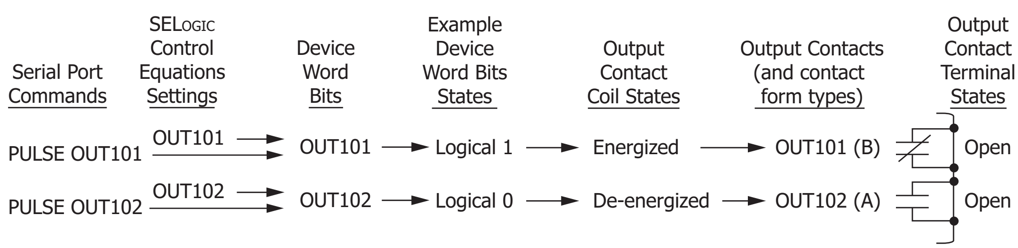


Figure 6.13 Logic Flow for Example Output Contact Operation

Overcurrent Elements

Seven levels of load overcurrent elements are available. The different levels are enabled with the E50L enable setting, as shown in *Figure 6.14–Figure 6.16*. In addition, there are two directional threshold elements (50FWDP and 50REVP) which are used in *Section 4: Control Operating Modes* to determine the operational mode of the voltage regulator control. One fast-operating fault overcurrent element is provided to trigger an alarm when an overcurrent fault occurs on the power system.

The ranges of all overcurrent settings depend on advanced Global setting 50TYPE. If 50TYPE is “A sec”, the ranges will be in amperes secondary. If 50TYPE is “% rated”, the ranges will be in percent of nominal rating (100 percent corresponds to 0.20 A secondary).

Settings Ranges

Setting range for pickup settings 50L1P–50L7P:

0.002 to 0.700 A secondary, or 1 to 350%

Setting range for pickup settings 50FWDP and 50REVP:

0.002 to 0.020 A secondary, or 1 to 10%

Setting range for pickup setting 50FLTP:

0.4 to 2.0 A secondary, or 200 to 1000%

Accuracy

Voltage Control Accuracy—Steady State (V secondary)

Measured Channels:

± 0.3% (–40° to + 85°C, 108–132 Vac) (IEEE C57.15-1999)

Calculated Values:

± 1.0% (–40° to + 85°C, 108–132 Vac)

Overcurrent Accuracy—Steady State (A secondary)

General Overcurrent Elements:

± 0.3% ± 500 µA (0.002–0.700 A)

Fault Overcurrent Element:

± 0.3% ± 500 µA (0.4–2.0 A)

Overcurrent Element Response (Applied Current > 2x Pickup Setting)

General Overcurrent Elements:

< 10 cycles

Fault Overcurrent Element:

<3 cycles

Metering Accuracy

Load Current:

±0.3% ±500 µA (0.001–2.000 A) and ±0.5° (0.020–2.000 A)

Harmonics (2nd–15th):

Current: ±5% of fundamental (0.02–0.64 A)

Voltages:

±0.3% and ±0.5° (80–145 Vac)

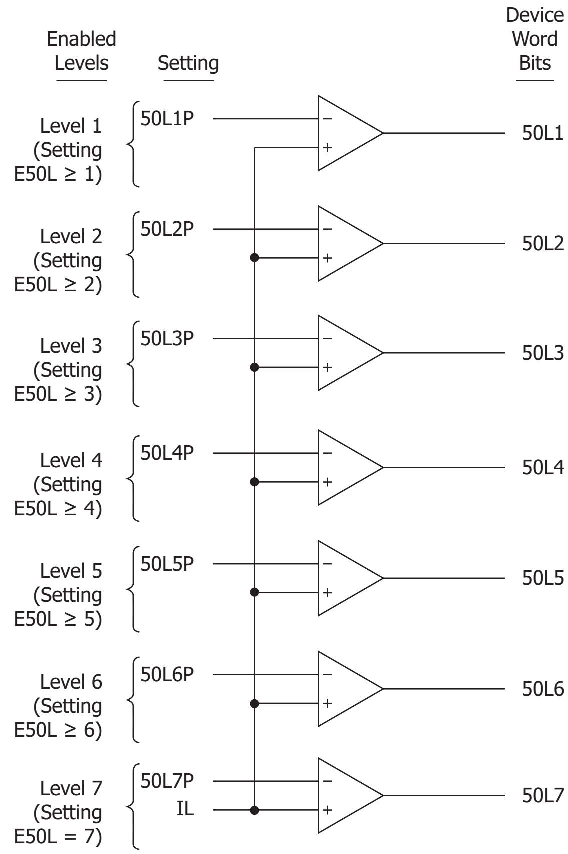


Figure 6.14 Levels 1–7 Load Overcurrent Elements

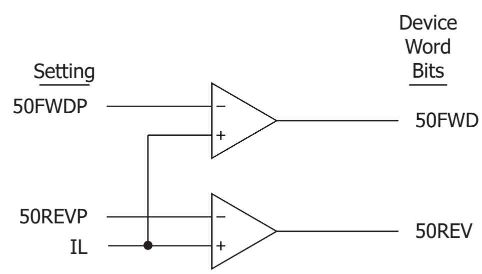


Figure 6.15 Directional Threshold Elements

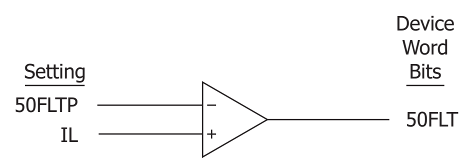


Figure 6.16 Fault Overcurrent Element

Pickup Operation

The load instantaneous overcurrent element logic begins with *Figure 6.14*. The pickup settings for each level (50L1P–50L7P) are compared to the magnitudes of the load current IL. The logic outputs in *Figure 6.13* are Device Word bits and operate as follows (Level 1 example shown):

50L1 =	1 (logical 1)	if IL > pickup setting 50L1P
	0 (logical 0)	if IL ≤ pickup setting 50L1P
50FWD =	1 (logical 1)	if IL > pickup setting 50FWDP
	0 (logical 0)	if IL ≤ pickup setting 50FWDP
50REV =	1 (logical 1)	if IL > pickup setting 50REVP
	0 (logical 0)	if IL ≤ pickup setting 50REVP
50FLT =	1 (logical 1)	if IL > pickup setting 50FLTP
	0 (logical 0)	if IL ≤ pickup setting 50FLTP

NOTE: The 50FLT element uses a fast-responding current measurement input for rapid detection of system faults.

SELOGIC Reset Equation

The SEL-2431 can be programmed to automatically reset data for demand, peak demand, energy, max/min metering, and tap counters.

In the Global settings, program the SELOGIC reset equation RST_DEM to reset demand metering, RST_PDM to reset the peak demand metering, RST_ENE to reset Energy metering, RST_MML to reset max/min metering, and RST_TAP to reset tap position counters. These five SELOGIC reset equations are hidden if Global setting EGADVS := N (Enable Global Advanced Settings is set to N). EGADVS must be set to Y to be able to set the SELOGIC reset equations.

NOTE: Do not press and hold the **DRAG HAND RESET** pushbutton. Doing so causes the DHR bit to assert for the duration of the pressing action. Pressing and releasing the pushbutton pulses the bit as required by the device logic.

Example 6.4 illustrates how to use the SELOGIC reset equation to reset the max/min metering data whenever the front-panel **DRAG HAND RESET** pushbutton is pressed.

Example 6.4

EGADVS := **Y**

RST_MML := **DHR**

When the **DRAG HAND RESET** pushbutton is pressed, the Device Word bit DHR asserts, causing RST_MML to assert to logical 1. Therefore, max/min metering data are also reset.

Day of Week/Time of Day Logic

The full setting range for Global settings OP*n*DOW and OP*n*TOD (*n* = 1–4) in *Figure 6.17* is found in *Global Settings* on page SET.1. These four settings are hidden if Global setting EGADVS := N (Enable Global/Advanced Settings).

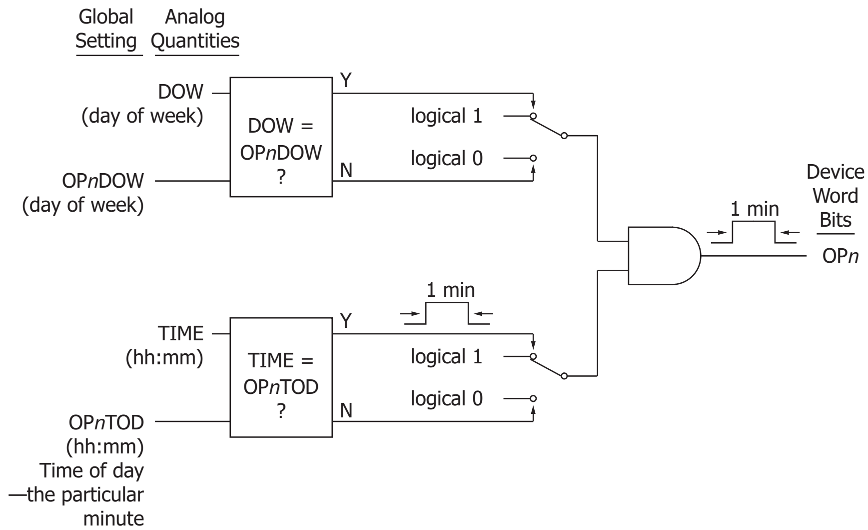


Figure 6.17 Day of Week/Time of Day Logic

Example Settings

As described by the logic in *Figure 6.17*, Device Word bit OP1 asserts for one minute at 8:45 pm on Tuesday.

OP1DOW := **TUE**

OP1TOD := **20:45**

As described by the logic in *Figure 6.17*, Device Word bit OP2 asserts for one minute at 5:15 am on Saturday and Sunday (a separate 1-minute assertion each day).

OP2DOW := **WEEKEND**

OP2TOD := **5:15**

As described by the logic in *Figure 6.17*, Device Word bit OP3 asserts daily for one minute at 12:37 pm (a separate 1-minute assertion each day).

OP3DOW := **DAILY**

OP3TOD := **12:37**

Example Application

Device Word bits OP*n* (*n* = 1–4) can be used as inputs into a latch (see *Figure 6.5*) and the latch output can be input into the active setting group switching logic (see *Table 6.7*). Then scheme operation can change on different days, at specific times. Many other applications are possible.

SECTION 7

Metering and Monitoring

Overview

The SEL-2431 Voltage Regulator Control includes extensive metering features and monitoring functions. The metering functions facilitate power system planning and operation, while the monitoring functions aid in maintenance planning and electrical load forecasting.

The metering functions include:

➤ Fundamental (instantaneous) metering
➤ Demand metering
➤ Energy metering
➤ Maximum/minimum metering
➤ Harmonic metering

The monitoring functions include:

➤ Tap operations counter
➤ Signal profile recorder

This section explains each of these features.

Metering Signal Names and Definitions

The SEL-2431 can be connected to a variety of voltage regulators, and used in several operating modes. There are many important definitions that relate to the SEL-2431 metering functions. *Table 7.1* lists the metering terms and definitions.

NOTE: Change the polarities of IL, VS, or VL or adjust the phase angle of IL with Global settings discussed in *Section 8: Settings*.

NOTE: For voltage connection details, see Voltage Selection and Correspondence to Metering on page 4.1.

Table 7.1 SEL-2431 Metering Terminology (Sheet 1 of 2)

Metering Term	Definition
IL	Measured line current, always from the voltage regulator L-bushing. The phase angle, included for primary current, is referenced to the VL phase angle. The SEL-2431 adjusts the current phase angle for closed-delta applications using Global setting D_LAG or D_LEAD.
VS	Terminal voltage, either measured or calculated, from the voltage regulator S-bushing to SL-bushing, regardless of power direction or regulation mode. The phase angle, included for primary voltage, is referenced to the VL phase angle.
VL	Terminal voltage, either measured or calculated, from the voltage regulator L-bushing to SL-bushing, regardless of power direction or regulation mode. The phase angle, included for primary voltage, is always 0.00, and is the reference for the IL and VS quantities.

NOTE: The SEL-2431 secondary VCMP quantity is the same value that is used for the voltage regulating function. If voltage reduction is enabled, the Group setting SETLDCO := Y will temporarily disable line-drop compensation when a voltage reduction is in progress. This will be seen when the metering VCMP value matches the VL or VS quantity, depending on the regulated direction.

NOTE: The SEL-2431 power quantities PL, QL, and SL are scaled by $1/\sqrt{3}$ when Global settings CONFIG := DLAG or DLEAD, and DELTA := CLOSED (see *Operating in Delta Configuration* on page 7.19).

NOTE: The SEL-2431 fundamental metering system rejects harmonics, while some hand-held meters include the effect of harmonics in their voltage readings (sometimes called a True RMS reading). See *Section 12: Testing and Troubleshooting* for information on testing the SEL-2431.

NOTE: The voltage regulator functions for reverse power and line-drop compensation are unaffected by the DELTA setting (OPEN or CLOSED), but may not operate correctly if Global setting CONFIG, D_LAG, and D_LEAD are not properly configured for the system connections.

Table 7.1 SEL-2431 Metering Terminology (Sheet 2 of 2)

Metering Term	Definition
VCMP	Voltage at the regulation point includes the effect of line-drop compensation (LDC), and the power direction (see *Figure 3.1* and *Figure 3.2*). ➤ When the control is in a forward regulating mode (Device Word bit ENFWD is asserted), VCMP is on the L-bushing side of the voltage regulator. The VCMP value may be higher or lower than the displayed VL quantity, depending on the LDC settings and line current. ➤ When the control is in a reverse regulating mode (Device Word bit ENREV is asserted), VCMP is on the S-bushing side of the voltage regulator. The VCMP value may be higher or lower than the displayed VS quantity, depending on the LDC settings and line current. ➤ When the control is in an inhibited mode (INHIBIT is asserted), the VCMP quantity is forced to 0.00. The front-panel band indicators are also extinguished in this situation.
Tap position	SEL-2431 internal tap position, TAP_POS. ➤ Positive numbers (+01, +12, etc.) indicate a nominal raise-direction tap position. A typical tap position indicator rests in a clockwise position from N. ➤ N represents neutral tap position. A tap position indicator rests on N. ➤ Negative numbers (–06, –15, etc.) indicate a nominal lower-direction tap position. A typical tap position indicator rests in a counter-clockwise position from N.
Primary	Power system currents, voltages, and power readings expressed in primary measurement units of A, kV, kW, kVAr, or kVA.
Secondary	Voltage regulator secondary metering quantities for currents and voltages. Voltages are expressed in secondary voltage base units (see *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for more information on base voltage conversion).
Volt Meter connections	The front-panel **VOLT METER** terminals, which are internally connected to the V_{S1} or V_{S2} voltage source. A digital multimeter connected to these terminals may show a different reading than the expected secondary voltage because of voltage base corrections (see *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*). If voltage harmonics are present, the connected volt meter reading may differ from the SEL-2431 secondary reading.
Forward	Power flow away from the voltage regulator L-bushing.
Reverse	Power flow away from the voltage regulator S-bushing.
Power	Power calculated using the VL and IL primary quantities, regardless of power direction or regulation mode. Real power (PL) and power factor (PF) are positive values for the forward direction, and negative values for the reverse direction.
In	Energy or power received by the voltage regulator L-bushing.
Out	Energy or power delivered by the voltage regulator L-bushing.
Delta	When Global settings CONFIG := DLAG or DLEAD and DELTA := CLOSED, the SEL-2431 shifts the angle of measured line current IL by the amount of the D_LAG or D_LEAD setting. When CONFIG := WYE or CONFIG := DLAG or DLEAD and DELTA := OPEN, the measured line current IL is not shifted. The SEL-2431 uses VL and IL to calculate the power quantities. If the Global settings CONFIG and DELTA are not configured properly, the metering of real and reactive power, and power factor, may be incorrect. See *Operating in Delta Configuration* on page 7.19 for more information on metering in the delta-connected (line-to-line) configurations.

The SEL-2431 metering values update approximately twice per second, and most are available as Analog Quantities for use in Display Points, SELOGIC analog comparisons, and DNP. See *Table F.1* for a complete listing.

The Global settings Regulator Nameplate Settings category contains the settings that affect primary and secondary scaling. See *Regulator Nameplate Data* on page 8.6 for more information.

Fundamental (Instantaneous) Metering

Description

The SEL-2431 performs current, voltage, and power metering using the fundamental (filtered) signals obtained from the same source as the voltage control algorithms. These values respond to the fundamental signal at the measured system frequency, which is usually near 50 Hz or 60 Hz. Frequency tracking ensures that frequency variations do not adversely affect metering accuracy. The Device Word bit FREQ_EN will be asserted whenever the control is tracking frequency.

The fundamental metering function updates the metering values approximately twice per second.

The SEL-2431 performs voltage base conversion using the Global settings PT1PRIM, PT1SEC, BASE_PRI, BASE_SEC, and if applicable, PT2PRIM and PT2SEC. This creates secondary voltage values that are all on the customer-base. See *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for more details.

Global settings TAPCHNGR, TYPE, and 2ND_PT are used to determine the proper mapping into the metering quantities VL and VS.

The primary values are then created from the secondary values using CTPRIM and internally derived potential transformer ratios for the V_{S1} and V_{S2} inputs.

The metered values are available in several forms:

- Serial port ASCII communications (see *METER Command Example* on page 7.4)
- Front-panel LCD (see *Display and Front-Panel Pushbuttons* on page 10.6)

Appendix F: Analog Quantities lists certain meter values that are available for:

- SELOGIC Analog Comparisons (see *Analog Comparisons* on page 6.6)
- Display points; (see *Display Points* on page 10.6)
- Signal Profile Recorder (also called Load Profile Recorder) (see *Signal Profile Recorder* on page 7.28)
- Serial port DNP (see *Default Data Map* on page D.29)
- Serial port Fast Meter communications (see *Appendix C: SEL Communications Processors)*

See *Specifications* on page 1.7 for a listing of the fundamental metering accuracy in the SEL-2431.

These fundamental quantities are used in the Instantaneous Metering report, as well as the Demand, Energy, and Maximum/Minimum Metering functions, described later in this section.

Because the fundamental quantities are filtered to the power system frequency, they are immune to signal energy at dc and harmonic frequencies.

Harmonics Metering on page 7.14 uses the full-signal spectrum (except dc) in the calculations.

Table 7.2 lists the Fundamental Metering Quantities and Analog Quantity Names. Some quantities are available with primary scaling, some are available with both primary and secondary scaling, and some values are unitless. See *Table F.1* for a complete list of Analog Quantities in the SEL-2431.

Table 7.2 SEL-2431 Fundamental Metering Quantities

Fundamental Metering Name	Primary Fundamental Metering Analog Quantity Name (Units)	Secondary Fundamental Metering Analog Quantity Name (Units)	Fundamental Metering Analog Quantity Name (Unitless Values)
Line Current	IL (A)	ILSEC (A)	
S-to-SL Bushing Voltage	VS (kV)	VSSEC (V)	
L-to-SL Bushing Voltage	VL (kV)	VLSEC (V)	
Compensated Voltage	VCMP (kV)	VCMPSEC (V)	
Real Power	PL (kW)		
Reactive Power	QL (kVAr)		
Apparent Power	SL (kVA)		
Power Factor			PF (–1.000 to 1.000)
Power Factor Lag/Lead			PFLD (0 = lagging, 1 = leading)
Power Quadrant			PFQ (1, 2, 3, or 4)
Tap Position			TAP_POS (–16 to 16)
Frequency			FREQ

Frequency Measurement

NOTE: During testing, it is possible to power the SEL-2431 with voltage input V_{S1} de-energized. In this situation, the frequency measurement system will not be active, and the SEL-2431 will report NFREQ setting as the frequency (50 or 60 Hz).

The SEL-2431 measures the power system frequency from the V_{S1} voltage input. The measured frequency is included in the fundamental metering report, and Max/Min metering report. If the V_{S1} signal is interrupted, the frequency measurement remains at the last measured value.

METER Command Example

Figure 7.1 shows a sample **MET** command response. See *METER Command (Metering Data)* on page 9.23 for details on the **MET** command.

```
=>MET <Enter>

SEL-2431                                  Date: 04/26/2007   Time: 10:29:38
Voltage Reg

Operating Mode      Locked Forward
Regulation Status   Forward

Primary
                 IL
Magnitude (A)   134.8
Angle (deg)     -18.72

                   VS        VL       VCMP
Magnitude (kV)     7.245     7.245     7.245
Angle (deg)        0.00      0.00


Tap Position     =  N

Secondary
        IL
(A)    0.108

        VS      VL     VCMP
(V)   120.75  120.75  120.75

Primary Power
    P        Q        S        PF          QUADRANT
   (kW)    (kVAr)    (kVA)
      925      313      977   0.947  LAG   Q1

Frequency (Hz) = 59.98
```

Figure 7.1 Sample METER Command Response

The **MET** command reports the operating mode and the regulation status, as described in *Table 7.3*. See *Section 4: Control Operating Modes* for more information on these messages.

Table 7.3 Operating Mode and Regulation Status Messages in METER Command

Group Setting OPMODE :=	Operating Mode Messages	Possible Regulation Status Messages
LOCKFWD	LOCKED FORWARD	FORWARD, INHIBIT
LOCKREV	LOCKED REVERSE	REVERSE, INHIBIT
IDLEREV	IDLE REVERSE	FORWARD, INHIBIT
BIDIR	BIDIRECTIONAL	FORWARD, INHIBIT, REVERSE
COGEN	COGENERATION	FORWARD, INHIBIT, FWD with REV LDC[a]
FLEXDG	FLEXDG COGENERATION or FLEXDG BIDIRECTIONAL	FORWARD, INHIBIT, FWD with REV LDC[a], FWD with FWD LDC[b], FWD with 0 LDC[c] INHIBIT, REVERSE, REV with 0 LDC[d]

[a] This message is an abbreviation of "Forward with Reverse Line-Drop Compensation."
[b] This message is an abbreviation of "Forward with Forward Line-Drop Compensation."
[c] This message is an abbreviation of "Forward with Zero (no) Line-Drop Compensation."
[d] This message is an abbreviation of "Reverse with Zero (no) Line-Drop Compensation."

See *Table 4.5* for clarification of Possible Regulation Status Messages in *Table 7.3* for OPMODE := FLEXDG.

Demand Metering

The SEL-2431 provides thermal demand metering with a settable demand interval. The Group setting DMTC (Demand Meter Time Constant) can be set at 5, 10, 15, 30, or 60 minutes. The factory-default setting is 15.

The demand metering setting is available via the **SET** command (see *Table 8.1*) and also *Demand Meter Settings* on page SET.9. Also refer to *METER Command Example* on page 7.4.

The SEL-2431 provides separate forward and reverse direction demand metering for the quantities shown in *Table 7.4*.

Table 7.4 Demand Metering Quantities

Fundamental Metering Analog Quantity Name	Demand Metering Description	Forward Demand Metering Analog Quantity Name	Reverse Demand Metering Analog Quantity Name
IL	Line Current	ILFDEM	ILRDEM
PL	Real Power	PFDEM	PRDEM
QL (> 0)	Reactive Power OUT	QFODEM (Quadrant 1)	QRODEM (Quadrant 2)
QL (< 0)	Reactive Power IN	QFIDEM (Quadrant 4)	QRIDEM (Quadrant 3)
SL	Apparent Power	SFDEM	SRDEM

The forward and reverse determination is made by *Meter Power Direction* on page 7.15. The demand metering algorithm records the data as follows:

- When Device Word bit MET_FWD is asserted, the forward demand metering algorithms are updated with the values from fundamental metering, and the reverse demand metering algorithms are updated with numeric inputs of 0.00.
- When Device Word bit MET_FWD is deasserted, the forward demand metering algorithms are updated with numeric inputs of 0.00, and the reverse demand metering algorithms are updated with the values from fundamental metering.

Thermal Demand Metering

The example in *Figure 7.2* shows the response of thermal demand meters to a step current input. The current input is at a magnitude of zero and then suddenly goes to an instantaneous level of 1.0 per unit (a “step”).

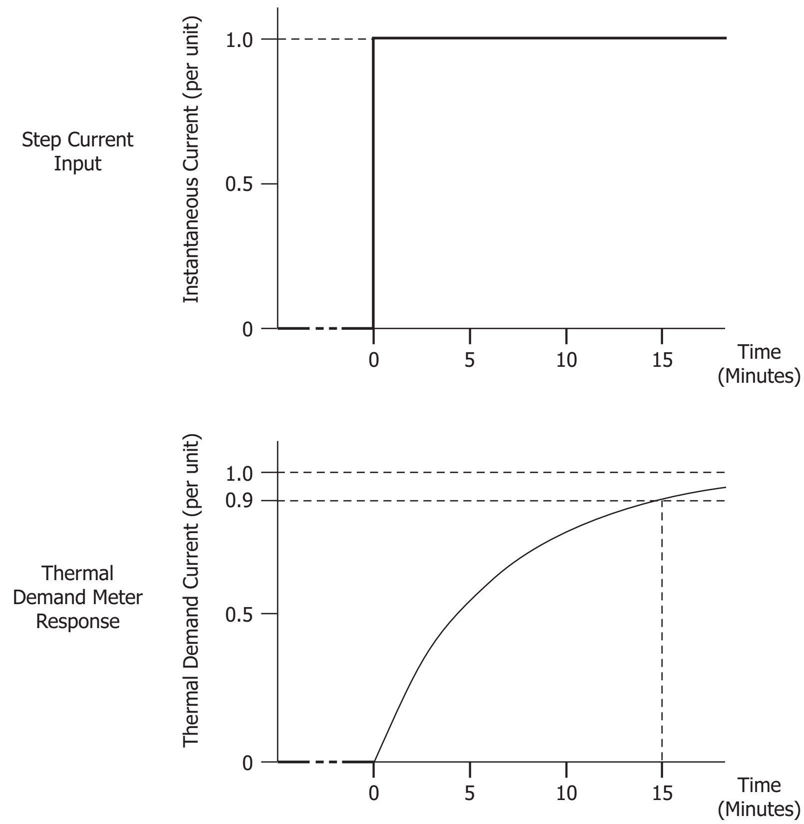


Figure 7.2 Response of Thermal Demand Meters to a Step Input (Setting DMTC = 15 Minutes)

Thermal Demand Meter Response

The response of the thermal demand meter in *Figure 7.2* (middle) to the step current input (top) is analogous to the series RC circuit in *Figure 7.3*.

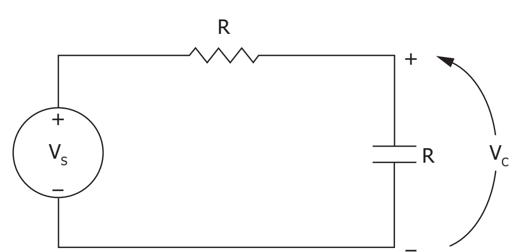


Figure 7.3 Voltage V_S Applied to Series RC Circuit

In the analogy:

- ➤ Voltage V_S in *Figure 7.3* corresponds to the step current input in *Figure 7.2* (top).
- ➤ Voltage V_C across the capacitor in *Figure 7.3* corresponds to the response of the thermal demand meter in *Figure 7.2* (bottom).

If voltage V_S in *Figure 7.3* has been at zero (V_S = 0.0 per unit) for some time, voltage V_C across the capacitor in *Figure 7.3* is also at zero (V_C = 0.0 per unit). If voltage V_S is suddenly stepped up to some constant value (V_S = 1.0 per unit), voltage V_C across the capacitor starts to rise toward the 1.0 per unit value. This voltage rise across the capacitor is analogous to the response of the thermal demand meter in *Figure 7.2* (bottom) to the step current input (top).

NOTE: The example in this section discussed demand current, but the same method applies to the power values listed in Table 7.4.

In general, because voltage V_C across the capacitor in *Figure 7.3* cannot change instantaneously, the thermal demand meter response is not immediate either for the increasing or decreasing applied instantaneous current. The thermal demand meter response time is based on the demand meter time constant setting DMTC (see *Table 7.4*). Note in *Figure 7.2*, the thermal demand meter response (middle) is at 90 percent (0.9 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC := 15 minutes, referenced to when the step current input is first applied.

The SEL-2431 updates thermal demand values approximately every 0.5 seconds.

Peak Demand Metering

The SEL-2431 records the peak demand values for the forward and reverse demand metering quantities listed in *Table 7.4* and the date and time that each peak was recorded.

Peak demand values are shown with a date and time of `(Reset)` when no data has been recorded. This will usually be seen just after the peak demands have been reset or when the control is only experiencing power flow in one direction. For example, if the power flow has always been in the forward direction, the reverse peak demand registers all show `(Reset)`.

To avoid false recording during power system disturbances, peak demand recording is suspended when the 50FLT Device Word bit asserts, and does not resume until 50FLT has been deasserted for 60 seconds.

The peak demand data are recorded to nonvolatile memory every four hours, at 03:50, 07:50, 11:50, 15:50, 19:50, and 23:50. If the control power is later interrupted, any newer demand peaks are lost. When the control comes back into service, the peak demand values are be updated from the last stored values in nonvolatile memory.

The peak demand data are displayed in the same report as the demand meter data, as shown in *Figure 7.4*.

View or Reset Demand Metering Information

Via Serial Port

Use the **MET D** command to display demand and peak demand data. A sample response is shown in *Figure 7.4*. See *METER Command (Metering Data)* on page 9.23 for more information on the serial port command.

```
=>MET D <Enter>

SEL-2431                                 Date: 04/30/2007   Time: 13:13:44
Voltage Reg

Line Current (IL)
          DEMAND    PEAK    DATE     TIME
          (A pri)  (A pri)
Forward       122      129  04/27/2007 21:18:55
Reverse         0        0  (Reset)

Real Power (P)
          DEMAND    PEAK    DATE     TIME
           (kW)     (kW)
Forward       781      838  04/27/2007 21:14:03
Reverse         0        0  (Reset)

Reactive Power (Q)
             DEMAND    PEAK    DATE     TIME
             (kVAr)   (kVAr)
Forward OUT      443      382  04/27/2007 21:18:47
Forward IN         0      106  04/30/2007 02:25:53
Reverse OUT        0        0  (Reset)
Reverse IN         0        0  (Reset)

Apparent Power (S)
          DEMAND    PEAK    DATE     TIME
           (kVA)    (kVA)
Forward       898      921  04/28/2007 18:38:53
Reverse         0        0  (Reset)

Last Demand Reset  04/28/2007 04:32:14
Last Peak Reset    04/27/2007 14:14:51

=>
```

Figure 7.4 Sample METER D Command Response

To reset the peak demand meter data, use the **MET D R P** command. This action does *not* clear the thermal demand algorithm. The peak demand values are all set to zero and the associated date and time entries are set to `(Reset)` after the peak demand reset is issued. The Last Peak Reset date and time is updated with the time of the reset.

To reset the thermal demand meter algorithm, use the **MET D R D** command. This action does *not* clear the peak demand values and is normally used after testing the SEL-2431. The thermal demand meter algorithm is automatically reset when the SEL-2431 control is powered up, or when a change is made to active settings, or the active setting group is switched. Whatever the initiating cause, the Last Demand Reset date and time is updated with the time of the reset.

For more details on the reset commands, see *METER Command (Metering Data)* on page 9.23.

Via Front Panel

The information and reset functions available via the serial port commands **MET D**, **MET D R D**, and **MET D R P** are also available via the front-panel menu (see *Front-Panel Menus and Screens* on page 10.11).

Via SELogic Equation

Demand and peak demand reset functions are also available as programmable reset functions through Global Settings. See SELogic *Reset Equation* on page 6.23 for information on programmable reset functions.

Energy Metering

The SEL-2431 voltage regulator control provides energy metering of real and reactive energy, as listed in *Table 7.5*.

Table 7.5 Energy Metering Quantities

Fundamental Metering Analog Quantity Name	Energy Metering Description	Energy Metering Analog Quantity Name	Units
PL (> 0)	Real Energy OUT	MWHOUT	MWh
PL (< 0)	Real Energy IN	MWHIN	MWh
QL (> 0)	Reactive Energy OUT	MVARHOUT	MVArh
QL (< 0)	Reactive Energy IN	MVARHIN	MVArh

Energy metering is independent of the SEL-2431 Group setting OPMODE. The control determines the OUT or IN direction based solely on the sign of the PL or QL power quantity, as indicated in *Table 7.5*.

All energy values are reported as non-negative numbers.

View or Reset Energy Metering Information

Via Serial Port

Use the **MET E** command to display energy metering data. A sample response is shown in *Figure 7.5*. See *METER Command (Metering Data)* on page 9.23 for more information on the serial port command.

```
=>MET E <Enter>

SEL-2431                                 Date: 04/30/2007   Time: 14:22:22
Voltage Reg

Energy
        REAL      REACTIVE
       (MWh)      (MVArh)
OUT       39.61       14.29
IN         0.00        0.24

Last Energy Reset  04/27/2007 14:14:51

=>
```

Figure 7.5 Sample METER E Command Response

To reset the energy meter data, use the **MET E R** command. This action also updates the Last Energy Reset date and time.

For more details on the reset commands, see *METER Command (Metering Data)* on page 9.23.

Via Front Panel

The information and reset functions available via the serial port commands **MET E** and **MET E R** are also available via the front-panel menu (see *Front-Panel Menus and Screens* on page 10.11).

Via SELOGIC Equation

Energy metering reset is also available as a programmable reset function through Global Settings. See SELOGIC *Reset Equation* on page 6.23 for information on programmable reset functions.

Energy Metering Updating and Storage

The SEL-2431 updates energy values approximately every two seconds.

The SEL-2431 stores energy values to nonvolatile storage every four hours, at 03:50, 07:50, 11:50, 15:50, 19:50, and 23:50, and overwrites the previous stored value. Should the voltage regulator control lose control power, it will restore the previously recorded energy values.

Accumulated energy metering values function like those in an electromechanical energy meter. When the energy meter reaches 99999.999 MWh or 99999.999 MVARh, the SEL-2431 restarts at zero.

Maximum/Minimum Metering

The SEL-2431 includes a maximum/minimum (Max/Min) metering function that records the excursions of certain fundamental metering quantities, and the date and time stamps at which each quantity reached its maximum and minimum value. The Max/Min metering values are listed in *Table 7.6*, and *Table F.1* give a complete list of Analog Quantities in the SEL-2431.

Table 7.6 Max/Min Metering Quantities

Fundamental Metering Analog Quantity Name	Description (Units)	Forward Max/Min Analog Quantity Names	Reverse Max/Min Analog Quantity Names
IL	Line current (A pri)	ILFMX, ILFMN	ILRMX, ILRMN
VS	S-terminal voltage (kV)	VSFMX, VSFMN	VSRMX, VSRMN
VSSEC	S-terminal voltage (V sec)	VSSFMX, VSSFMN	VSSRMX, VSSRMN
VL	L-terminal voltage (kV)	VLFMX, VLFMN	VLRMX, VLRMN
VLSEC	L-terminal voltage (V sec)	VLSFMX, VLSFMN	VLSRMX, VLSRMN
VCMP	Compensated voltage (kV)	VCFMX, VCFMN	VCRMX, VCRMN
VCMPSEC	Compensated voltage (V sec)	VCSFMX, VCSFMN	VCSRMX, VCSRMN
PL	Real power (kW)	PFMX, PFMN	PRMX, PRMN
QL	Reactive power (kVAr)	QFMX, QFMN	QRMX, QRMN
PF	Power factor at max/min apparent power (unitless)	PFFMX, PFFMN	PFRMX, PFRMN
FREQ	Frequency (Hz)	FRQFMX, FRQFMN	FRQRMX, FRQRMN
TAP_POS	Tap position (unitless)	TAPFMX, TAPFMN	TAPRMX, TAPRMN

The forward and reverse determination is made by *Meter Power Direction* on page 7.15. The demand metering algorithms records the data as follows:

- ➤ When Device Word bit MET_FWD is asserted, the forward Max/Min registers are updated with any new maximum or minimum values.
- ➤ When Device Word bit MET_FWD is deasserted, the reverse Max/Min registers are updated with any new maximum or minimum values.

NOTE: Recording of new Max/Min values is suspended in certain situations, as described in Maximum/Minimum Metering Update and Storage.

NOTE: It is possible to program the SEL-2431 to reset Max/Min metering via SELOGIC control equation, which could include the drag hand reset condition. See SELOGIC RESET EQUATION ON PAGE 6.23 for information on programmable reset functions.

The Max/Min metering function for tap position is independent of the voltage regulator Tap Position Indicator drag-hands. With factory-default settings, resetting the drag-hands has no effect on the Max/Min metering, and resetting the metering has no effect on the drag hands.

Maximum/Minimum values for real power, reactive power, power factor, and tap position may be positive or negative values. All other Max/Min values are reported as non-negative numbers. The values indicate the range of the quantity that has occurred since the last Max/Min reset procedure. These functions simulate analog meter drag-hands, with the maximum value representing the upper drag-hand and the minimum value representing the lower drag-hand.

Table 7.7 shows the values that the SEL-2431 would record for various reactive power flow conditions (for this discussion, assume forward metering mode). If the power conditions resulted in some reverse mode meter operation, the separate Max/Min values for the reverse direction are updated with the recorded values, in a similar fashion, and the forward readings are left unchanged until the forward metering direction is resumed.

Table 7.7 Operation of Max/Min Metering With Reactive Power Quantities

If Reactive Power Varies		Recorded MAX[a]	Recorded MIN
From:	To:		
97	162	162	97
–42	14	14	–42
–253	–174	–174	–253
–62	274	274	–62

[a] For simplicity, the date and time stamps are not shown here.

View or Reset Maximum/Minimum Metering Information

Via Serial Port

Use the **MET M** command to display energy metering data. A sample response is shown in *Figure 7.6*. See *METER Command (Metering Data)* on page 9.23 for more information on the serial port command.

```
=>MET M <Enter>

SEL-2431                               Date: 05/02/2007   Time: 14:49:31
Voltage Reg

Forward
                   MAX        DATE     TIME        MIN        DATE     TIME
IL (A pri)         147     04/27/2007 21:17:04      82     04/30/2007 04:55:23
VS (kV)              7.55  05/01/2007 07:15:32       7.03  04/30/2007 19:01:09
VS (V sec)         125.8   05/01/2007 07:15:32     117.2   04/30/2007 19:01:09
VL (kV)              7.33  04/29/2007 22:35:38       7.11  05/01/2007 12:18:09
VL (V sec)         122.1   04/29/2007 22:35:38     118.6   05/01/2007 12:18:09
VCMP (kV)            7.33  04/29/2007 22:35:38       7.11  05/01/2007 12:18:09
VCMP (V sec)       122.1   04/29/2007 22:35:38     118.6   05/01/2007 12:18:09
P (kW)             929     04/30/2007 21:13:19     557     04/29/2007 04:04:12
Q (kVAr)           571     04/30/2007 16:44:07    -122     05/02/2007 00:32:25
S (kVA)           1044     04/27/2007 22:12:34     606     04/29/2007 04:04:12
PF @ S Max/Min   0.875     04/27/2007 22:12:34   0.921     04/29/2007 04:04:12
Freq (Hz)           60.06  04/28/2007 06:13:40      59.89  05/01/2007 18:44:07
Tap Pos            +04     04/30/2007 18:55:04     -06     05/01/2007 07:23:59


Reverse
                   MAX     DATE     TIME     MIN     DATE     TIME
IL (A pri)      $$$$$$     (Reset)        $$$$$$     (Reset)
VS (kV)          $$$$$     (Reset)         $$$$$     (Reset)
VS (V sec)       $$$$$     (Reset)         $$$$$     (Reset)
VL (kV)          $$$$$     (Reset)         $$$$$     (Reset)
VL (V sec)       $$$$$     (Reset)         $$$$$     (Reset)
VCMP (kV)        $$$$$     (Reset)         $$$$$     (Reset)
VCMP (V sec)     $$$$$     (Reset)         $$$$$     (Reset)
P (kW)          $$$$$$     (Reset)        $$$$$$     (Reset)
Q (kVAr)        $$$$$$     (Reset)        $$$$$$     (Reset)
S (kVA)         $$$$$$     (Reset)        $$$$$$     (Reset)
PF @ S Max/Min   $$$$$     (Reset)         $$$$$     (Reset)
Freq (Hz)        $$$$$     (Reset)         $$$$$     (Reset)
Tap Pos            $$$     (Reset)           $$$     (Reset)

Last Max/Min Reset  04/27/2007 14:14:51

=>
```

Figure 7.6 Sample METER M Command Response

To reset the energy meter data, use the **MET M R** command. This action also updates the Last Max/Min date and time.

For more details on the reset command, see *METER Command (Metering Data)* on page 9.23.

Via Front Panel

The metering and reset functions available via serial port commands **MET M** and **MET M R** are also available via the front-panel menu. See *Front-Panel Menus and Screens* on page 10.11.

Via SELOGIC Equation

Max/Min metering reset is also available as a programmable reset function through Global settings. See SELOGIC *Reset Equation* on page 6.23 for more information on programmable reset functions.

Maximum/Minimum Metering Update and Storage

The SEL-2431 records the maximum and minimum values separately for the forward and reverse direction meter operation, for the quantities listed in *Table 7.6*, and the date and time that each maximum or minimum excursion was recorded.

Max/Min values are shown with a date and time of `(Reset)` when no data has been recorded. This will usually be seen just after the Max/Min metering values have been reset, or when the control is only experiencing power flow in one direction. For example, if the power flow has always been in the forward direction, the reverse Max/Min registers all show `(Reset)`, as shown in *Figure 7.6*.

The SEL-2431 qualifies a new maximum or minimum value by requiring the quantity to be above the previous maximum, or below the previous minimum, for approximately two seconds. The control avoids recording zeros during no-load conditions, such as for a load-side breaker operation.

To avoid false recording during power system disturbances, changes in configuration, or changes in power flow, the SEL-2431 suspends recording of new Max/Min values under the following conditions:

- For approximately three minutes after the SEL-2431 is turned on.
- For approximately three minutes after a change in metered direction (which is indicated by a change in state of Device Word bit MET_FWD).
- For approximately three minutes after changing any active setting or switching between setting groups.
- During a tap change operation and for approximately three seconds afterwards.
- When the voltage on input V_{S1} is too low and for approximately three seconds after the voltage recovers.
- During fault overcurrent element (50FLT) assertion.

NOTE: The voltage measured on input V_{S1} must be above 80 percent of the Global setting BASE_SEC for the Max/Min metering system to function.

The Max/Min data are recorded to nonvolatile memory every four hours at 03:50, 07:50, 11:50, 15:50, 19:50, and 23:50. If the control power is later interrupted, any newer Max/Min data are lost. When the control comes back into service, the Max/Min values are updated from the last stored values in nonvolatile memory.

Harmonics Metering

The SEL-2431 is capable of measuring signal distortions as high as the 15th harmonic on the line current (IL) and L-bushing voltage (VL) inputs.

NOTE: When TAPCHNGR = Siemens, 2ND_PT = N, and TYPE = A, harmonics are calculated from the S-bushing voltage (VS) input.

Approximately twice per second, the SEL-2431 calculates the following data for the IL and VL signals:

- Fundamental Root Mean Squared (rms) magnitude (1st harmonic, in primary units)
- Harmonic content n, where $n = 2$ –15 (in percent of fundamental)
- Total Harmonic Distortion (THD)

View Harmonic Metering

The harmonic calculations are visible in the serial port **MET H** command and through the front-panel `METER` menu. See *METER Command (Metering Data)* on page 9.23 for more information on the serial port command and *Front-Panel Menus and Screens* on page 10.11 for more information on the front-panel menu.

A sample METER H response is shown in *Figure 7.7*.

```
=>>MET H <Enter>

SEL-2431                                 Date: 05/04/2007   Time: 08:15:22
Voltage Reg

Current
                   IL
Fundamental (A)   118.7
THD (%)             9

Voltage
                    VL
Fundamental (kV)    7.27
THD (%)             3

Harmonics
           IL   VL
    2 (%)    0    0
    3 (%)    8    3
    4 (%)    0    0
    5 (%)    3    2
    6 (%)    0    0
    7 (%)    2    1
    8 (%)    0    0
    9 (%)    1    0
   10 (%)    0    0
   11 (%)    1    0
   12 (%)    0    0
   13 (%)    0    0
   14 (%)    0    0
   15 (%)    0    0

=>
```

Figure 7.7 Sample METER H Command Response

The fundamental rms magnitude value is expressed in A primary for the current channel (IL) and kV primary for the voltage channel VL.

The individual harmonics (2nd–15th) are expressed as a percentage of the fundamental, with an upper limit of 100 percent.

There is no dc component calculated.

To avoid calculating meaningless harmonics during outages, if the fundamental magnitude of IL is less than 0.02 A secondary, the harmonics IL and the THD calculations are set to zero.

The THD quantities are available for control functions by using them in SELOGIC control equations as part of an analog comparison. See *Analog Comparisons* on page 6.6 for details.

Meter Power Direction

Power metering is an important function that is often misunderstood. The SEL-2431 uses standard methods to calculate power and specific design features to report forward and reverse power conditions.

Phase Relationships

The SEL-2431 measures the phase angle of current IL relative to voltage VL, and uses this information to determine the metering power quantities. *Figure 7.8* shows how the various IL phase angles affect the sign of real power (P) and reactive power (Q).

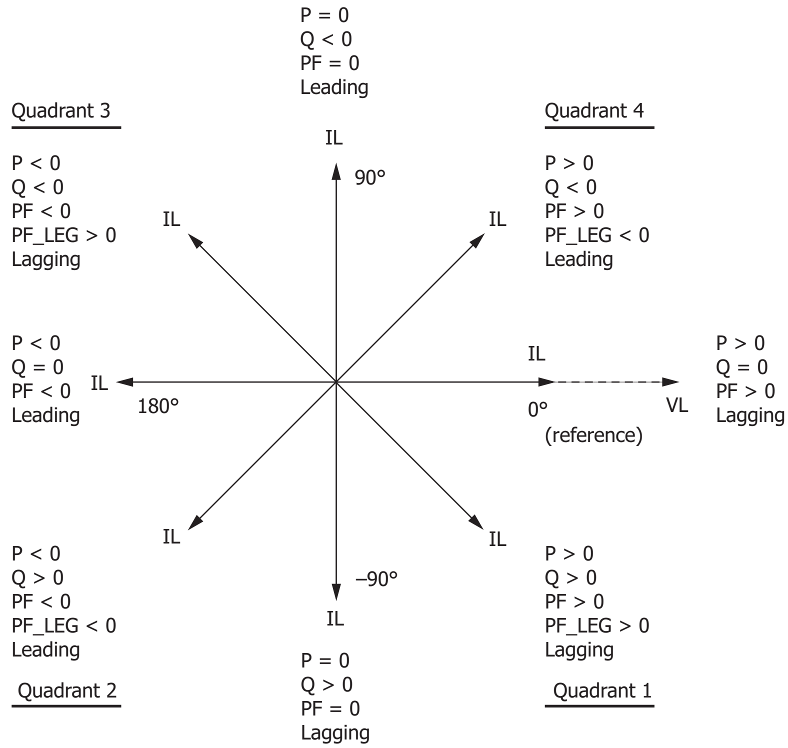


Figure 7.8 SEL-2431 Power Metering Quadrants

When configured for closed-delta operation, the SEL-2431 adjusts the phase angle of IL by the D_LAG or D_LEAD setting (typically 30 degrees). This adjustment allows the reported power factor to closely match the actual line loading. In closed-delta configuration, the power readings PL, QL, and SL, are also scaled by $1/\sqrt{3}$, to allow the power readings from a three-phase voltage regulator bank to be determined through simple addition.

NOTE: The power scaling by $1/\sqrt{3}$ is performed for closed-delta applications because the measured voltage is really a line-to-line voltage, but the control is calculating single-phase quantities on a line-to-neutral basis.

When configured for open-delta operation, the SEL-2431 does not adjust the phase of IL, nor does it scale the power quantities PL, QL, and SL.

See *Operating in Delta Configuration* on page 7.19 for further details on reading the power metering for delta-connected applications.

When expressed on a power basis (real power and reactive power) the SEL-2431 power metering uses the terminology shown in *Figure 7.9*. The quadrant numbering matches *Figure 1* of standard IEEE 1459-2000. Notice that the quadrants are flipped with respect to *Figure 7.8*. This is caused by the convention that a lagging current causes positive reactive power (Vars).

The SEL-2431 calculates power factor in two ways. PF is calculated per the IEEE 1459-2000 standard as:

$$PF = \frac{PL}{SL}$$

Equation 7.1

where:

PF = power factor
PL = real power
SL = apparent power

Note that the sign of PF follows the sign of the real power PL. SL is apparent power and is always positive.

The SEL-2431 also calculates a legacy power factor that is compatible with other voltage regulator controls.

$$\mathrm{PF\_LEG} = \mathrm{sign}\frac{|\mathrm{PL}|}{\mathrm{SL}}$$

Equation 7.2

where:

sign follows leading or lagging power factor.
is positive for lagging power factor.
is negative for leading power factor.

$|\mathrm{PL}|$ = magnitude of real power

SL = apparent power

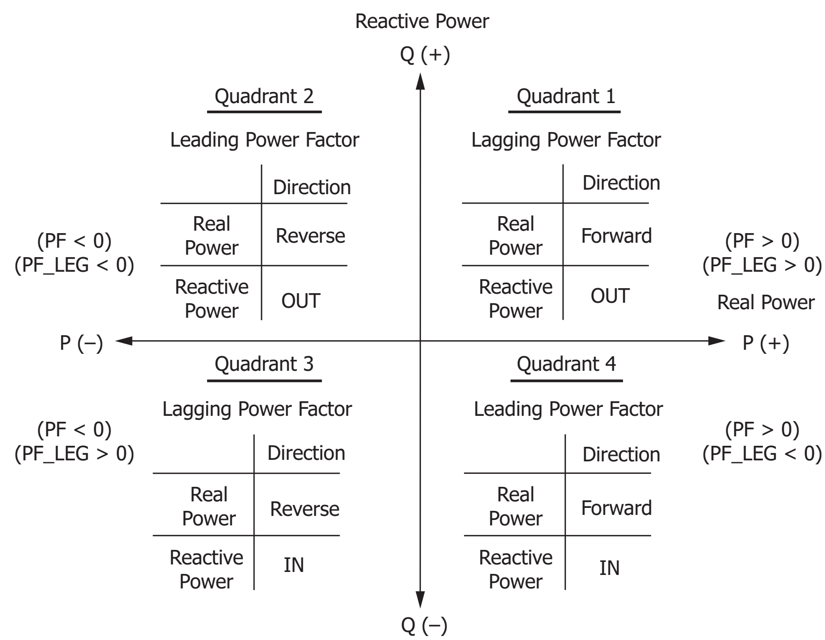


Figure 7.9 SEL-2431 Power Metering Definitions

Forward and Reverse Direction

The SEL-2431 forward direction is when the voltage regulator is providing real power out through the L-bushing. This corresponds to the traditional installation with “L” meaning “load”, and the voltage regulator can raise the voltage on the L-bushing by increasing the tap position (for example, from neutral to +01, or “Raise 1” on tap position indicators).

The reverse direction is when the voltage regulator is providing real power out through the S-bushing. This is the inverse of the traditional installation with “S” representing “load”, and the voltage regulator can raise the voltage on the S-bushing by decreasing the tap position (for example, from neutral to –01, or “Lower 1” on tap position indicators).

To avoid possible confusion, the SEL-2431 voltage regulator control documentation avoids the use of “Source” and “Load” as much as possible. Instead, the bushing names are used (VS, VL) and these quantities always refer to the voltages on those bushings (whether measured or calculated), regardless of the power direction.

The SEL-2431 always calculates the power quantities using the voltage VL, and current IL, and the analog quantity names are PL, QL, and SL.

Forward and Reverse Demand, Peak Demand, and Maximum/Minimum Meter Operation

The SEL-2431 uses the Group setting OPMODE and the Directional Element output Device Word bits FORWARD and REVERSE to determine which registers to update. *Figure 7.10* contains the logic diagram for the MET_FWD Device Word bit. See *Section 4: Control Operating Modes* for more information.

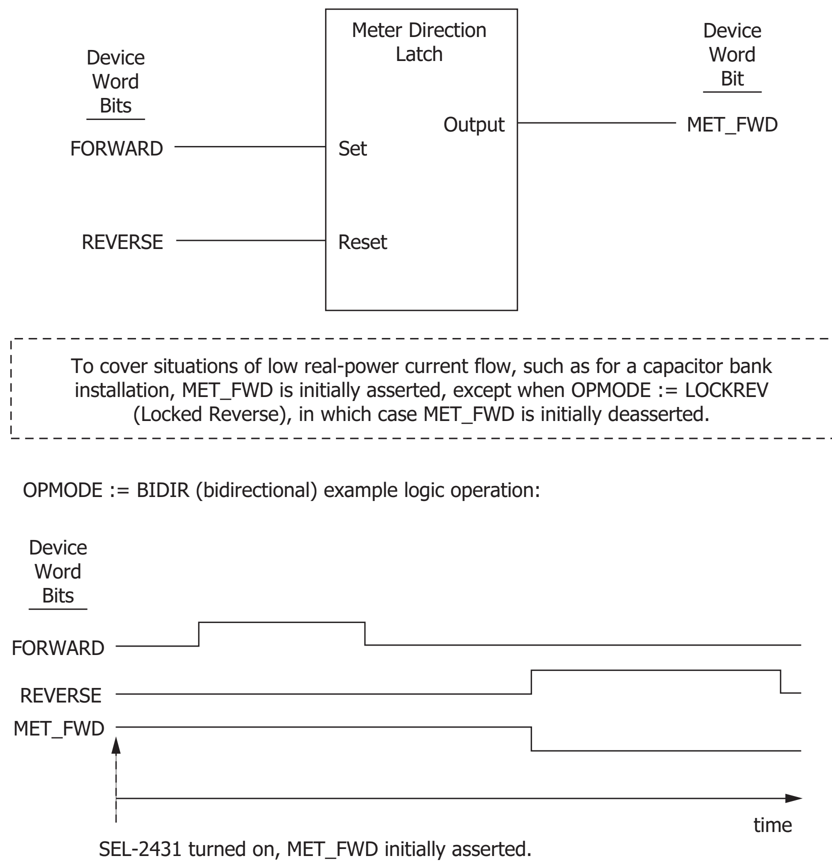


Figure 7.10 MET_FWD Logic

When MET_FWD is asserted, the following actions occur:

- The forward-direction demand metering algorithms are executed using the fundamental metering current and power data.
- The reverse direction demand metering algorithms are updated using numeric zero as inputs.
- The forward maximum/minimum metering registers are updated.
- The reverse maximum/minimum metering registers are not updated.

NOTE: For a voltage regulator operated in locked forward mode (OPMODE := LOCKFWD), it is still possible for reverse demand, peak demand, and max/min metering values to be recorded if the REVERSE Device Word bit asserts. If reverse power flow is unexpected, this will be an easy way to detect it. The converse is true for locked reverse mode.

When MET_FWD is deasserted, the following actions occur:

- ➤ The forward direction demand metering algorithms are updated using numeric zero as inputs.
- ➤ The reverse-direction demand metering algorithms are executed using the fundamental metering current and power data.
- ➤ The forward reverse maximum/minimum metering registers are not updated.
- ➤ The reverse maximum/minimum metering registers are updated.

This MET_FWD logic is designed to prevent oscillations between forward and reverse during steady-state conditions near the forward or reverse operating boundary.

Real Power and Energy

Figure 7.9 shows the terminology used for real power in the SEL-2431. Positive PL readings are considered forward in demand and max/min metering, and negative PL readings are considered reverse. The MET_FWD Device Word bit defines which direction is active.

It is possible for small positive real power values to be present when MET_FWD is not asserted, and conversely, for small, negative real power values to be present when MET_FWD is asserted. These are caused by the hysteresis of the MET_FWD Device Word bit, as shown in *Figure 7.10*.

The energy metering differs by calling real energy (MWh) in the forward direction “OUT”, and energy in the reverse direction “IN”, which is not shown in *Figure 7.9*.

Reactive Power and Energy

Figure 7.9 shows the terminology used for reactive power in the SEL-2431. Positive QL readings are called “OUT”, and negative QL readings are called “IN”.

The SEL-2431 demand metering function calculates separate demand and peak demand values for each quadrant of power operation (1, 2, 3, or 4). When MET_FWD is asserted, the values for quadrants 1 or 4 are updated (depending in the sign of QL), and when MET_FWD is deasserted, the values for quadrants 2 or 3 are updated (depending in the sign of QL).

The energy metering calls positive reactive energy (MVArh) “OUT” and negative reactive energy “IN”.

Operating in Delta Configuration

When the Global settings in categories Regulator Nameplate Data and Connection Data are properly entered, the SEL-2431 automatically scales the power and energy values for open-delta and closed-delta applications so that the total power of the regulated line can be determined by simply adding up the power readings from each regulator in the bank.

NOTE: Figure 7.11 also holds true for properly configured wye-connected regulator installations.

Figure 7.11 shows an example three-phase calculation using front-panel metering screens for a closed-delta installation, and *Figure 7.12* shows the same calculation for an open-delta bank for similar load conditions.

For closed-delta applications, to determine the effective voltage regulator loading instead of the line loading, multiply the closed-delta apparent power readings by $\sqrt{3} = 1.73$. With the example data in *Figure 7.11*, this gives apparent power readings of 1485, 1194, 1349 kVA for the three voltage regulators.

For open-delta and wye-connected voltage regulators, the reported apparent power value for each voltage regulator is the effective loading.

SEL-2431, AB unit		BC unit		CA unit	3-phase line
Real Power (P) 786 kW	+	612 kW	+	731 kW	= 2129 kW
Reactive Power (Q) 343 kVAr	+	318 kVAr	+	269 kVAr	= 930 kVAr
Apparent Power (S) 857 kVA	+	689 kVA	+	779 kVA	= 2325 kVA (①)
Power Factor (PF) 0.916 LAG		0.887 LAG		0.938 LAG	(Cannot add the power factor readings)

① See Three-Phase Power Readings.

Figure 7.11 Example Summation of Power Readings for Closed-Delta Installations

SEL-2431, AB unit		CB unit	3-phase line
Real Power (P) 881 kW	+	1245 kW	= 2126 kW
Reactive Power (Q) 1196 kVAr	+	–257 kVAr	= 939 kVAr
Apparent Power (S) 1485 kVA	+	1271 kVA	= 2756 kVA (①)
Power Factor (PF) 0.593 LAG		0.979 LEAD	(Cannot add the power factor readings)

① See Three-Phase Power Readings.

Figure 7.12 Example Summation of Power Readings for Open-Delta Installations

NOTE: In open-delta configuration, the power readings from a single SEL-2431 are not too meaningful. However, when added to the readings from the companion SEL-2431, the summation represents the line load. This is caused by the definition of one voltage regulator as leading and the other as lagging.

To calculate the three-phase power factor, divide the three-phase results P/S, and use *Figure 7.9* to determine whether the power factor is lagging or leading by inspecting the sign of the three-phase values of P and Q.

Three-Phase Power Readings

The three-phase apparent power (kVA) results shown in *Figure 7.11* and *Figure 7.12* are called arithmetic apparent power, and may differ from the vector apparent power, calculated by using *Equation 7.3*.

$$S_{vector} = \sqrt{(P_{3-phase})^2 + (Q_{3-phase})^2}$$

Equation 7.3

Using *Equation 7.3* with the closed-delta results from *Figure 7.11* gives a vector apparent power of:

$$S_{vector} = \sqrt{2129^2 + 930^2} = 2323 \text{ kVA (closed delta)}$$

For the closed-delta case, the vector and arithmetic apparent power results are practically the same if all power system loads are connected line-to-line.

The same equations work for a wye-connected regulator bank, however, there may be significant differences in the arithmetic and vector apparent power results if the power flow is highly unbalanced between phases.

Using *Equation 7.3* with the open-delta results from *Figure 7.12* gives a vector apparent power of

$$S_{vector} = \sqrt{2126^2 + 939^2} = 2324 \text{ kVA (open delta)}$$

For the open-delta case, the vector and arithmetic apparent power results are not the same, with the vector result being about 0.84 times the arithmetic result (2324 / 2756 = 0.84 in this example).

For a balanced system, the apparent power difference is $\sqrt{3}$ / 2 = 0.866 as explained below:

Balanced System—Open-Delta Apparent Power Proof

We have shown that the vector apparent power represents the true line load. *Equation 7.4* shows three ways of expressing the total line load.

$$S_{vector} = 3 \cdot |I| \cdot |V_{LN}| = 3 \cdot |I| \cdot \left(\frac{1}{\sqrt{3}}|V_{LL}|\right) = \sqrt{3} \cdot |I| \cdot |V_{LL}|$$

Equation 7.4

The apparent power reading from each control is:

$$S = |I| \cdot |V_{LL}| = |I| \cdot \sqrt{3} \cdot |V_{LN}|$$

The sum from two controls is:

$$S_{arithmetic} = S + S = 2S$$

Expanding this equation, and arranging terms, we get *Equation 7.5*:

$$\begin{aligned} S_{arithmetic} &= S + S = 2S = 2(|I| \cdot |V_{LL}|) \\ &= 2(|I| \cdot \sqrt{3} \cdot |V_{LN}|) = 2\sqrt{3} \cdot (|I| \cdot |V_{LN}|) \\ S_{arithmetic} &= (2\sqrt{3} \cdot (|I| \cdot |V_{LN}|)) \end{aligned}$$

Equation 7.5

When we divide the first version of *Equation 7.4* by *Equation 7.5*, we get:

$$\frac{S_{vector}}{S_{arithmetic}} = \frac{3 \cdot |I| \cdot |V_{IN}|}{2\sqrt{3} \cdot (|I| \cdot |V_{LN}|)} = \frac{\sqrt{3}}{2}$$

Thus, for a balanced open-delta system, the actual line loading (vector apparent power) is $\sqrt{3}$ / 2 times the arithmetic apparent power (sum of control S readings).

Three-Phase Power Factor Calculations

Three-phase power factor can be calculated using either the arithmetic or vector apparent power, as shown in *Equation 7.6* and *Equation 7.7*.

$$PF_{arithmetic} = \frac{P_{3-phase}}{S_{arithmetic}}$$

Equation 7.6

$$PF_{vector} = \frac{P_{3-phase}}{S_{vector}}$$

Equation 7.7

Using *Equation 7.6* and *Equation 7.7* with the closed-delta results from *Figure 7.11* gives power factor readings of:

$$PF_{arithmetic} = \frac{2129}{2325} = 0.916, \ PF_{vector} = \frac{2129}{2323} = 0.917 \text{ (closed delta)}$$

Using *Equation 7.6* and *Equation 7.7* with the open-delta results from *Figure 7.12* gives power factor readings of:

$$PF_{arithmetic} = \frac{2126}{2756} = 0.771, \ PF_{vector} = \frac{2126}{2324} = 0.914 \text{ (open delta)}$$

These example results show that the vector power factor is more representative of the load conditions than the arithmetic power factor (for three-wire systems).

For either three-phase power factor calculation method, use *Figure 7.9* to compare the sign of the three-phase P and Q values, and then determine the quadrant and the lag or lead information. All of the example values in *Figure 7.11* and *Figure 7.12* are in power quadrant 1 with a lagging power factor.

Tap Operations Counter

The SEL-2431 records the voltage regulator tap-change operations to assist with maintenance decisions, to assist in system improvement analysis, and to help detect voltage regulator misapplication on the power system.

Overall operations and per-tap operations are stored in nonvolatile memory. The nonvolatile memory for the Total Operations counter is updated with each tap change operation, and the remaining counter values are stored once per hour.

The SEL-2431 maintains two versions of the counters:

➤ Total (since the control was placed into service).

➤ Since Reset (since last reset using the **TAP R** command). The reset date and time is also recorded.

Overall counter values are provided, as shown in *Table 7.8*, and per-tap counters as shown in *Table 7.9*.

Table 7.8 Overall Operations Counters (Sheet 1 of 2)

Overall Counters	Description	Comments
Total Operations	Total number of operations	Unaffected by **TAP R**. Can be preloaded by **TAP W**.
Year to Date	Number of operations since January 1st	Unaffected by **TAP R** and **TAP W**.

Table 7.8 Overall Operations Counters (Sheet 2 of 2)

Overall Counters	Description	Comments
Month to Date	Number of operations since the beginning of the month	Updates approximately once per hour. Unaffected by **TAP R** and **TAP W**.
Sliding 24 hour	Number of operations in the previous 24 hours	Updates approximately once per hour. Unaffected by **TAP R** and **TAP W**.
Since Reset	Total number of operations	Reset by **TAP R**.

Table 7.9 Per-Tap Operations Counters

Per Tap Counters	Description[a]
–16	Number of times regulator tapped to –16
–15	Number of times regulator tapped to –15
. . .	Similar for taps –14 through –02
–01	Number of times regulator tapped to –01
N	Number of times regulator tapped to N (neutral)
+01	Number of times regulator tapped to +01
. . .	Similar for taps +02 through +14
+15	Number of times regulator tapped to +15
+16	Number of times regulator tapped to +16

[a] All counters have two versions: Total and Since Reset. The Total counters are unaffected by the **TAP R** command.

View Tap Counter Information

Via Serial Port

Use the **TAP** command to display energy-metering data. A sample response is shown in *Figure 7.13* and *Figure 7.18*. See *TAP Command* on page 9.31 for more information on the serial port command.

```
=>TAP <Enter>

SEL-2431                                 Date: 05/07/2007   Time: 18:43:54
Voltage Reg

Present Tap Position  +06

Operations Counters
Total     296

Year to Date      296
Month to Date      36
Sliding 24 hr       7
Since Reset        11


Tap Counters
     TOTAL   SINCE RESET
-16       0       0
-15       0       0
-14       0       0
-13       0       0
-12       1       0
-11       3       0
-10       4       0
-09       6       0
```

Figure 7.13 Sample TAP Command Response

```
-08       6       0
-07       4       0
-06       3       0
-05       4       0
-04       5       0
-03       3       0
-02       4       0
-01       7       0
 N       11       0

+01      14       0
+02      15       0
+03      13       0
+04      13       1
+05      22       2
+06      25       3
+07      19       2
+08      15       2

+09      18       1
+10      18       0
+11      13       0
+12      10       0
+13      11       0
+14      13       0
+15      11       0
+16       5       0

Last Tap Counter Reset  05/05/2007 13:12:40

=>
```

Figure 7.13 Sample TAP Command Response (Continued)

Via Front Panel

The serial port **TAP** command information is also available via the front-panel menu (see *Front-Panel Menus and Screens* on page 10.11).

Preload Tap Counters

To simplify record-keeping when replacing an existing regulator, the SEL-2431 allows the Total values to be preloaded using the **TAP W** command, or through the front-panel menu (see *Front-Panel Menus and Screens* on page 10.11). This feature lets the previous control operations counter information transfer into the new control.

If the previous voltage regulator control does not display per-tap counter values, enter zeros in these fields. See *Figure 7.15* for an example of the **TAP W** command, where only the total operations count (2483) is known from before, and all of the previous per-tap count data in the SEL-2431 (possibly from bench testing) is overwritten with 0. After entry, the SEL-2431 displays the entire TAP report and asks for a confirmation before updating the values.

NOTE: The Level 2 password is required to use the **TAP W** command.

The **TAP W** command does not affect the `SINCE RESET` values.

```
=>>TAP W <Enter>

SEL-2431                                  Date: 05/08/2007   Time: 06:47:42
Voltage Reg

Tap Counter Monitor Preload

Total Operations Count  (0-500000)          OPCNTT =    296 ? 2483


Tap Counters
-16  (0-32767)                              T16M   =      0 ?
-15  (0-32767)                              T15M   =      0 ?
-14  (0-32767)                              T14M   =      0 ?
-13  (0-32767)                              T13M   =      0 ?
-12  (0-32767)                              T12M   =      1 ? 0
```

Figure 7.14 Sample TAP W Command Response

```
-11  (0-32767)                        T11M   =      3 ? 0
-10  (0-32767)                        T10M   =      4 ? 0
-09  (0-32767)                        T09M   =      6 ? 0
-08  (0-32767)                        T08M   =      6 ? 0
-07  (0-32767)                        T07M   =      4 ? 0
-06  (0-32767)                        T06M   =      3 ? 0
-05  (0-32767)                        T05M   =      4 ? 0
-04  (0-32767)                        T04M   =      5 ? 0
-03  (0-32767)                        T03M   =      3 ? 0
-02  (0-32767)                        T02M   =      4 ? 0

-01  (0-32767)                        T01M   =      7 ? 0
 N   (0-32767)                        TN     =     11 ? 0
+01  (0-32767)                        T01P   =     14 ? 0
+02  (0-32767)                        T02P   =     15 ? 0
+03  (0-32767)                        T03P   =     13 ? 0
+04  (0-32767)                        T04P   =     13 ? 0
+05  (0-32767)                        T05P   =     22 ? 0
+06  (0-32767)                        T06P   =     25 ? 0
+07  (0-32767)                        T07P   =     19 ? 0

+08  (0-32767)                        T08P   =     15 ? 0
+09  (0-32767)                        T09P   =     18 ? 0
+10  (0-32767)                        T10P   =     18 ? 0
+11  (0-32767)                        T11P   =     13 ? 0
+12  (0-32767)                        T12P   =     10 ? 0
+13  (0-32767)                        T13P   =     11 ? 0
+14  (0-32767)                        T14P   =     13 ? 0
+15  (0-32767)                        T15P   =     11 ? 0
+16  (0-32767)                        T16P   =      5 ? 0

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

SEL-2431                            Date: 05/08/2007   Time: 06:48:11
Voltage Reg

Present Tap Position  +06

Operations Counters
Total    2483

Year to Date      296
Month to Date      36
Sliding 24 hr       7
Since Reset        11


Tap Counters
     TOTAL   SINCE RESET
-16       0       0
-15       0       0
-14       0       0
-13       0       0
-12       0       0
-11       0       0
-10       0       0
-09       0       0
-08       0       0
-07       0       0
-06       0       0
-05       0       0
-04       0       0
-03       0       0
-02       0       0
-01       0       0
 N        0       0
```

Figure 7.14 Sample TAP W Command Response (Continued)

```
+01       0       0
+02       0       0
+03       0       0
+04       0       1
+05       0       2
+06       0       3
+07       0       2
+08       0       2
+09       0       1
+10       0       0
+11       0       0
+12       0       0
+13       0       0
+14       0       0
+15       0       0
+16       0       0

Last Tap Counter Reset  05/07/2007 19:11:06

=>>
```

Figure 7.14 Sample TAP W Command Response (Continued)

Reset Tap Counter Information

To reset the SINCE RESET tap data, use the **TAP R** command. This action also updates the Last Tap Counter Reset date and time. See *Figure 7.15* for an example.

In normal operation, the **TAP R** command could be issued on a routine basis, perhaps after a monthly inspection, while the **TAP W** command would only be used after replacing a control.

The **TAP R** command does not affect the “Total” count quantities.

TAP R is available via front-panel access. For more details on the **TAP R** command, see *TAP Command* on page 9.31.

```
=>>TAP R <Enter>
Reset Tap Counters
Are you sure (Y,N)? Y <Enter>
Clearing Complete

=>>
```

Figure 7.15 Sample TAP R Command Response

View Tap Position

The SEL-2431 internal tap position appears near the top of the TAP reports, as shown in *Figure 7.16*, where called Present Tap position. See *Table 7.1* for details on tap position terminology.

The tap position can be viewed by itself using the **TAP P** command, as shown in *Figure 7.17*.

The tap position may also be displayed using the **Front Panel Tap Counters > Display** menu, as described in *Front-Panel Menus and Screens* on page 10.11.

```
=>TAP P <Enter>

SEL-2431                                Date: 05/08/2007   Time: 07:22:40
Voltage Reg

Tap Position = +06

=>
```

Figure 7.16 Sample TAP P Command Response

Change Internal Tap Position

When installing the SEL-2431, set the internal tap-position to match the position of the voltage regulator by using the **TAP P *x*** command, replacing *n* with the desired tap position (–15, +4, +15, etc.). The user cannot set the tap position to neutral. If you attempt to set the controller to neutral, the command aborts. See *Figure 7.17* for an example of setting the tap position to –3.

The tap position may also be set via the front-panel **Front Panel Tap Counters > Set Tap Position** menu (see *Front-Panel Menus and Screens* on page 10.11).

```
=>TAP P -3 <Enter>

SEL-2431                                  Date: 05/08/2007   Time: 07:22:52
Voltage Reg

Existing Control Tap Position:  +06
Request to change the Control Tap Position to:  -03
Requested tap position should match Voltage Regulator actual tap position.

Are you sure (Y,N)? Y <Enter>

Tap Position = -03

=>
```

Figure 7.17 Sample TAP P x Command Response

```
=>TAP <Enter>

delay                                     Date: 05/08/2007   Time: 07:25:32
spring drive

Present Tap Position  -03

Operations Counters
Total    2483


Year to Date      296
Month to Date      36
Sliding 24 hr       7
Since Reset         0

Tap Counters
     TOTAL   SINCE RESET

-16       0       0
-15       0       0
-14       0       0
-13       0       0
-12       0       0
-11       0       0
-10       0       0
-09       0       0
-08       0       0

-07       0       0
-06       0       0
-05       0       0
-04       0       0
-03       0       0
-02       0       0
-01       0       0

 N        0       0
+01       0       0
+02       0       0
+03       0       0
+04       0       0
+05       0       0
+06       0       0
+07       0       0
```

Figure 7.18 Sample TAP Command Response after TAP W, TAP R, and TAP P x

```
+08      0      0
+09      0      0
+10      0      0
+11      0      0
+12      0      0
+13      0      0
+14      0      0
+15      0      0
+16      0      0

Last Tap Counter Reset  05/08/2007 06:48:40

=>
```

Figure 7.18 Sample TAP Command Response after TAP W, TAP R, and TAP P x

Signal Profile Recorder

The SEL-2431 Signal Profile Recorder is capable of recording as many as 16 selectable analog quantities at a periodic rate and storing the data in nonvolatile memory. Conditional recording is supported, which allows recording to be turned off at uninteresting times, preserving the memory for important data. Each entry contains a date and time stamp, and between 1 and 16 user-configurable data quantities.

Configuring the Signal Profile Recorder

See *Table F.1* for the Analog Quantities that are available for use in the Signal Profile Recorder.

The signal profile list settings are contained in the Report Settings class, and can be set using the **SET R** command, and viewed using the **SHO R** command. Signal Profile settings are easily configured using QuickSet, described in *Section 2: PC Software*.

NOTE: Changing any of the Signal Profile List Settings will clear all stored signal profile data.

Refer to *SET Command (Change Settings)* on page 9.28, and *Report Settings* on page SET.18 for details on entering the Signal Profile settings using the **SET R** command. Refer to *SHOW Command (Show/View Settings)* on page 9.29 for information on the **SHO** command.

NOTE: The time stamp recorded for signal profile data may differ by as long as 5 seconds from the expected recording time.

Report Setting SPAR controls the signal profile acquisition rate, selectable at 5, 10, 15, 30, or 60 minutes. The acquisition of new data is tied to the time of day, so when SPAR := 5, recording takes place at 9:35, 9:40, 9:45, etc. After changing the SPAR setting, the SEL-2431 may wait an extra period before recording commences, but does not erase existing data. For instance, if SPAR is changed to 10 at 9:46, the next data may not appear until 10:00, because the interval ending at 9:50 was not a complete SPAR interval.

SELOGIC equation SPEN controls the recording of Signal Profile data. When this equation evaluates to logical 1, recording is enabled, and when it evaluates to logical 0, recording is suspended. A possible use for this function would be shutting off recording at night for a voltage regulator installed on a commercial distribution line (see *Day of Week/Time of Day Logic* on page 6.24) or during system maintenance.

The SEL-2431 factory-default settings include 15 quantities, recorded every 15 minutes, as shown in *Factory-Default Settings* on page 8.17.

View or Reset Signal Profile Data

Use the **PRO** serial port command to display Signal Profile Data. A sample response is shown in *Figure 7.19*. See *PRO Command (Profile Report)* on page 9.26 for more information on the serial port command.

NOTE: This is a similar function to the Load Profile Recorder (LDP) used in other SEL products, and the SEL-2431 will respond to the **LDP** command the same as the **PRO** command.

The signal profile report is available in ASCII format (using the **PRO** command) and SEL Compressed ASCII format (using the **CPR** command).

```
=>PRO <Enter>

SEL-2431                                 Date: 05/09/2007   Time: 16:00:56
Voltage Reg

#     DATE         TIME         IL        VLSEC     VCMPSEC    TAP_POS
5  05/09/2007  15:40:00.259      0.000    127.660    127.660     -3.000
4  05/09/2007  15:45:00.284      0.000    127.700    127.700     -1.000
3  05/09/2007  15:50:00.309      0.000    128.315    128.315     -1.000
2  05/09/2007  15:55:00.324      0.000    128.070    128.070     -1.000
1  05/09/2007  16:00:00.338      0.000    127.985    127.985     -1.000

=>
```

Figure 7.19 Sample PRO Command Response (SPAR := 5 Minutes)

Standard ASCII terminal programs do not display reports wider than 80 columns with clarity, because the longer lines wrap around and the headings can be hard to read. Because of this, the **PRO** command is best suited for viewing reports that only contain as many as four analog values in the SPLIST setting.

For more than four data selections, the Compressed ASCII command **CPR** (Compressed Profile) may be a more convenient method, because it is in a machine-readable format, and can be imported into a spreadsheet for graphing or analysis. *Figure 7.20* shows the CPR response for the same data as *Figure 7.19*. The final value on each line of the CPR response is the checksum for that line, in hexadecimal. See *Appendix C: SEL Communications Processors* for more information on SEL Compressed ASCII commands.

```
=>CPR <Enter>
"REC_NUM","YEAR","MONTH","DAY","HOUR","MIN","SEC","MSEC","IL","VLSEC","VCMPSEC",
   "TAP_POS","157C"
5,2007,5,9,15,40,0,259,0.000,127.660,127.660,-3.000,"09EA"
4,2007,5,9,15,45,0,284,0.000,127.700,127.700,-1.000,"09E0"
3,2007,5,9,15,50,0,309,0.000,128.315,128.315,-1.000,"09DF"
2,2007,5,9,15,55,0,324,0.000,128.070,128.070,-1.000,"09DC"
1,2007,5,9,16,0,0,338,0.000,127.985,127.985,-1.000,"09C3"

=>
```

Figure 7.20 Sample CPR Command Response (SPAR := 5 Minutes)

To reset the signal profile recorder, use the **PRO C** command, as shown in *Figure 7.21*.

```
=>PRO C <Enter>
Profile Clear
Are you sure (Y,N)? Y <Enter>
Clearing Complete

=>
```

Figure 7.21 Sample PRO C Command Response

Signal Profile Recorder Capacity

The SEL-2431 Signal Profile Recorder capacity is 8640 entries of analog quantities and date/time stamps stored in nonvolatile memory. When the memory fills-up, the SEL-2431 overwrites (replaces) the oldest records with new records, so that the most recent 8640 records are always available.

The amount of time before data overwrite is a function of how many quantities are selected for recording, and at what rate the data are updated (defined by Report setting SPAR). For example, if 16 analogs are entered in the SPLIST settings and SPAR := 15 minutes, the SEL-2431 can record at least 90 days worth of data before overwrite occurs.

SECTION 8

Settings

Overview

The SEL-2431 Voltage Regulator Control stores customer-entered settings in nonvolatile memory. Settings are divided into the following settings classes:

- Global
- Group *n* (where *n* = Group 1–4)
- Logic *n* (where *n* = Group 1–4)
- Front Panel
- Report
- Port *p* (where *p* = F, 1, and 2 [Ports 1 and 2 are optional communications ports])
- Distributed Network Protocol (DNP) Maps 1 and 2 (see *Appendix D: DNP3 Communications* for details on DNP settings)

Some setting classes have multiple instances. In the above list, there are four "settings groups" for Group and Logic settings and as many as three Port setting instances, one for each serial port.

Settings may be viewed or set in several ways, as shown in *Table 8.1*.

Table 8.1 Methods of Accessing Settings

	Serial Port Commands	Front Panel HMI Set/ Show Menu	QuickSet
Display Settings	All settings (**SHO** command)	Some settings[a, b]	All settings
Change Settings	All settings (**SET** command)	Some settings[a, b]	All settings

[a] Only Global, Group, and Port setting classes can be accessed.
[b] SELOGIC control equations that include analog comparisons cannot be edited on the HMI.

See *Factory-Default Settings* for examples of the **SHO** command, including the factory-default settings.

The **SET** command is described in the next subsection. *Table 8.2* lists the settings classes with a brief description, and the page numbers for the *SEL-2431 Settings Sheets* included at the end of this section. The order of the settings sheets matches the bulleted list above.

See *Set/Show Menu* on page 10.29 for details on accessing settings via the front-panel HMI. See *Section 2: PC Software* for QuickSet information.

Table 8.2 Serial Port SET Commands

Command	Settings Type	Description	Settings Sheets[a]
SET G	Global	Voltage regulator nameplate data, system parameters, date and time processing, group switch, and meter reset functions	*SET.1–SET.3*
SET *n*	Group	Voltage regulator identification strings, operating mode, forward and reverse operation voltage set points, time delays, line-drop compensation, overcurrent elements, voltage reduction, voltage limiting, control overrides, and demand metering for settings Group *n* (*n* = 1, 2, 3, 4)	*SET.4–SET.7*
SET L *n*	Logic	Programmable SELOGIC latches, variables/timers, counters, and digital outputs for settings Group *n* (*n* = 1, 2, 3, 4)	*SET.8–SET.12*
SET F	Front Panel	Front-panel HMI time-out, contrast, and direct-action pushbutton definitions; programmable LEDs, volt meter terminals, display points, local bits, and control configuration override settings	*SET.13–SET.16*
SET R	Report	Sequential Events Recorder (SER) trigger conditions, event report settings, and Signal Profile (PRO) settings	*SET.17–SET.19*
SET P *p*	Port	Serial port settings for serial port *p* (*p* = F, 1, or 2)	*SET.20–SET.22*

[a] Located at the end of this section.

View settings with the respective serial port **SHOW** commands (**SHO G**, **SHO**, **SHO L**, **SHO F**, **SHO R**, **SHO P**, and **SHO D**). See *SHOW Command (Show/View Settings)* on page 9.29 for more information.

Make Global Settings (SET G) First

For most applications, make Global settings (*Global Settings* on page SET.1) before making the other non-communications setting entries (Group, Logic, Front Panel, etc.). Changes to Global settings may cause settings in the Front-Panel class to be hidden from view or changed to default values.

Port and DNP settings may be made in any order.

The Global settings, in general, define the overall physical connections, equipment type, and system voltage levels, and normally will not need to be changed once initially configured for a specific voltage regulator installation.

For basic new and retrofit voltage regulator applications, the Logic, Front Panel, and Report settings classes may be left at the factory-default values. Changes are only required to these classes when advanced control, indication, or reporting functions are required.

Settings Changes Via Front Panel

The Global, Group, and Port Settings classes may be viewed or changed via the front-panel HMI (see *Set/Show Menu* on page 10.29).

Settings Changes Via PC Software

QuickSet provides easy-to-use settings management (see *Settings* on page 2.6).

Settings Changes Via the Serial Port

NOTE: In this manual, commands you type appear in bold/uppercase: **SET**. Computer keys you press appear in bold/brackets: **<Enter>**.

See *Section 9: Communications* for information on serial port communications and voltage regulator control access levels. The **SET** commands in *Table 8.2* operate at Access Level 2 (screen prompt: =>>). To change a specific setting, enter the command:

SET *n m s* TE[RSE]

where:

n = L, G, R, F, P, or D (parameter *n* is not entered for the Group settings).

m = group (1–4), port (F, 1, or 2), or DNP map (1 or 2). The SEL-2431 selects the active group or port if *m* is not specified.

s = the name of the specific setting you wish to jump to and begin setting. If *s* is not entered, the voltage regulator control starts at the first setting.

TERSE (or TE) = instructs the SEL-2431 to skip the `SHOW` display after the last setting. Use this parameter to speed up the **SET** command. If you wish to review the settings before saving, do not use the TERSE option.

When you issue the **SET** command, the SEL-2431 presents a list of settings, one at a time. Enter a new setting or press **<Enter>** to accept the existing setting. Editing keystrokes are shown in *Table 8.3*.

Table 8.3 Set Command Editing Keystrokes

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

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

When all the settings are entered, the SEL-2431 displays the new settings and prompts for approval to enable them. Answer **Y <Enter>** to enable the new settings.

Settings Changes May Affect SALARM Device Word Bit

The SEL-2431 handles settings changes as shown in *Table 8.4*.

Table 8.4 Settings Changes Effects (SALARM Device Word Bit, ENABLED LED, and SER)

Settings Change	SALARM Device Word Bit Pulsed for One Second?	ENABLED LED Extinguished for Less Than One Second?	Sequential Events Recorder (SER) "Settings Changed" Entry?
Global	Yes	Yes	Yes
Active Group	Yes	Yes	Yes
Inactive Group	Yes	No	Yes
Active Logic	Yes	Yes	Yes
Inactive Logic	Yes	No	Yes
Front Panel	Yes	Yes	Yes
Report	Yes	Yes	Yes
Port (any)	No	No	No
DNP Map	No	No	No
Copy from active to inactive group[a]	Yes	No	Yes
Copy from inactive to active group[a]	Yes	Yes	Yes
Group Change[b]	Yes	Yes	Yes

[a] See COPY Command (Copy Setting Group) on page 9.18.
[b] See Multiple Setting Groups on page 6.14.

In *Table 8.4*, an inactive group is one of the four settings groups that is not the currently active group. For example, if Setting Group 2 is currently active, Settings Groups 1, 3, and 4 are inactive. A **SET L 4** command represents a change to Logic settings in inactive Settings Group 4.

The SALARM Device Word bit is in the factory-default Front Panel setting for ALARM, which is present in the factory-default Logic setting for OUT101.

If the **ENABLED** LED is extinguished, then SEL-2431 voltage regulator functions are disabled.

The SER is described in *Section 11: Analyzing Events*.

SELOGIC Control Equation Settings

SELOGIC control equations appear in the Global, Group, Logic, Front Panel, and Report settings classes of the SEL-2431.

The SEL-2431 offers enhanced SELOGIC control equation settings capabilities such as nested parentheses, analog comparisons, comments, and the NA setting. The SELOGIC control equation setting syntax is fully described in *Section 6: Logic Functions*.

Device Word Bits

Device Word bits can be used in SELOGIC control equation settings. SELOGIC control equation settings examples are given in *Section 4: Control Operating Modes* through *Section 6: Logic Functions*. With a few exceptions, SELOGIC control equation settings can also be set directly to 1 (logical 1), 0 (logical 0), and NA (not applicable).

See *Table E.1* and *Table E.2* for a listing and description of the SEL-2431 Device Word bits.

NA Setting

NOTE: Some settings do not allow a setting of NA, and these are indicated in the *SEL-2431 Settings Sheets*.

From a logic standpoint, setting a SELOGIC control equation to NA acts similarly to setting the equation to 0 (logical 0). The difference between 0 and NA is that the 0 setting consumes a small amount of microprocessor time every processing interval, while the NA setting consumes no microprocessor time. Thus, several SELOGIC control equations have factory-default values of NA, which allows more microprocessor time for other functions.

For example, setting REMOTSV := NA in Front Panel settings will result in Device Word bit REMOTSV being "permanently deasserted."

See SELOGIC *Control Equation Capacity* on page 6.1 for more information.

Analog Comparisons

Analog Quantities on page 6.2 describes the use of Analog Quantities in SELOGIC control equations.

Settings Explanations

Note that most of the settings in the setting sheets that follow include references for additional information. The following explanations are for settings that do not have reference information anywhere else in the instruction manual.

Enable Settings

Enable settings are available in Global, Group, Front Panel, and Report settings. Enable settings can cause other settings to be available or hidden, which reduces the number of settings to be made in most applications. Settings that are controlled by enable settings are indicated on the setting sheets. Some of these enable settings directly affect the SEL-2431 built-in logic. *Table 8.5* lists the enable settings.

Table 8.5 Use of Enable Settings (Sheet 1 of 2)

Enable Setting	Controls	Settings Sheet
EGADVS	Global settings for Data Reset, Group Selection, Time-of-Day Operation, and Time and Date Management	*SET.1*
ELDC	Group settings VLDCFWR, VLDCFWX, VLDCRVR, VLDCRVX	*SET.5*
E50L	Group settings 50L1P through 50L7P	*SET.5*
ENREDUC	Group settings VREDMOD through SETLDC0	*SET.5*

Table 8.5 Use of Enable Settings (Sheet 2 of 2)

Enable Setting	Controls	Settings Sheet
ENLIMIT	Group settings VMAX and VMIN	*SET.6*
ENRUNBK	Group settings RBKBLSV, RUNBKPU, DBNDH, DBNDL	*SET.6*
ELAT	Logic settings SET01 through RST08	*SET.8*
ESV	Logic settings SV01 through SV08DO	*SET.8*
ESC	Logic settings SC01PV through SC08CD	*SET.8*
EDP	Front Panel settings DP01 through DP32	*SET.13*
ELB	Front Panel settings NLB01 through PLB08	*SET.13*
ESERDEL	Report settings SRDLCNT through SRDLTIM	*SET.17*

General Global Settings

Refer to *General Settings* on page SET.1.

The Global setting NFREQ allows you to configure the SEL-2431 to your specific system.

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

Set DATE_F to format the date displayed in voltage regulator control reports and the front-panel display. Set DATE_F to MDY to display dates in Month/Day/Year format; set DATE_F to YMD to display dates in Year/Month/Day format; set DATE_F to DMY to display dates in Day/Month/Year format.

The factory-default setting EGADVS := N hides several Global settings categories that are not used in every application. Set EGADVS := Y (Enable Global Advanced Settings) to enable the settings categories for Data Reset, Group Selection, Time-of-Day Operation, and Time and Date Management.

Regulator Nameplate Data

See *Regulator Nameplate Data* on page SET.1. Most of the information needed for this category can be found on the voltage regulator nameplate or in the accompanying manual.

Regulator Rated Voltage (KV)

NOTE: The actual system voltage is often lower than the KV setting value and is entered in setting BASE_PRI, which is in the Connection Data category.

E/E_1Y designates a winding that may be delta-connected for operation on an E volt system or may be wye-connected for operation on an E_1 volt system[1]. In either case, make setting KV in accordance with the voltage regulator nameplate value E (in kV), typically shown as:

```
RATED VOLTAGE 7620/13200Y
```

In this example, make setting KV := 7.62.

Use the rated voltage (above) even when the voltage regulator has nameplate voltage selections indicated by a pin or embossed mark.

[1] IEEE Std C57.12.00-2021, IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers, clause 5.12.3 Schematic representation, Table 7, Identification (1)(b).

Current Transformer Polarity (CTPOL)

NOTE: If polarity settings need to be changed from normal polarity (:= NORM), then only one polarity setting really needs to be changed (e.g., CTPOL := REV, PT1POL := NORM, and PT2POL := NORM is effectively the same as CTPOL := NORM, PT1POL := REV, and PT2POL := REV). Also, changing all three polarity settings (CTPOL, PT1POL, and PT2POL) to reverse (:= REV) is effectively the same as leaving them all normal (:= NORM).

The CTPOL setting selects normal (NORM) or reverse (REV) polarity of the current transformer connection. The CTPOL setting affects the SEL-2431 reverse power determination and metering system IL current and power readings. If power flow direction appears opposite of what is expected (see *Fundamental (Instantaneous) Metering* on page 7.3 and *Meter Power Direction* on page 7.15), CTPOL (or the appropriate voltage polarity setting, PT1POL or PT2POL, corresponding to metering system VL voltage) should be changed to correct the error.

CT Primary Current (CTPRIM)

NOTE: The SEL-2431 fixes the secondary rating of the voltage regulator current transformer at 0.20 A sec.

Set CTPRIM to the voltage regulator primary current transformer nominal rating, in primary amperes. On some voltage regulators, this CT Primary rating may differ from the voltage regulator nameplate current capacity at a given voltage.

Tap Changer Type (TAPCHNGR)

Set TAPCHNGR to the voltage regulator tap changer manufacturer. Choose from GE, COOPER, SIEMENS, or HOWARD. When connected to a Toshiba CR-3, ITB RAV-2, and Romagnole SVR voltage regulator, set TAPCHNGR to GE.

Regulator Type (TYPE)

Set TYPE to match the voltage regulator as shown in *Table 8.6*.

Table 8.6 Voltage Regulator Types (Sheet 1 of 2)

Manufacturer (TAPCHNGR Setting)	Sample Regulator Models	Type	Available Number of Internal Voltages	PT1 Source	Reference Drawing
General Electric (GE)	VR-1, ML32	A (Straight)	1	PT (L-bushing to SL)	*Figure B.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
General Electric (GE)	VR-1, ML32	B (Inverted)	1	Shunt (Utility) winding (L-bushing to SL)	*Figure B.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Cooper (COOPER)	VR-32	A (Straight)	1	PT (L-bushing to SL)	*Figure B.2* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Cooper (COOPER)	VR-32	B (Inverted)	1	Shunt (Utility) winding (L-bushing to SL)	*Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Siemens (SIEMENS)	JFR	A (Straight)	2[a]	Shunt (Utility) winding (S-bushing to SL)	*Figure B.1* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Siemens (SIEMENS)	JFR	B (Inverted)	1	Shunt (Utility) winding (L-bushing to SL)	*Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Howard Industries (HOWARD)	SVR-1	A (Straight)	2	Shunt (Utility) winding (S-bushing to SL)	*Figure B.1* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Howard Industries (HOWARD)	SVR-1	B (Inverted)	1	Shunt (Utility) winding (L-bushing to SL)	*Figure B.1* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Toshiba (GE)	CR-3	B (Inverted)	1	Shunt (Utility) winding (L-bushing to SL)	*Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*

Table 8.6 Voltage Regulator Types (Sheet 2 of 2)

Manufacturer (TAPCHNGR Setting)	Sample Regulator Models	Type	Available Number of Internal Voltages	PT1 Source	Reference Drawing
ITB (GE)	RAV-2	B (Inverted)	1	Shunt (Utility) winding (L-bushing to SL)	*Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*
Romagnole (GE)	SVR	B (Inverted)	1	Shunt (Utility) winding (L-bushing to SL)	*Figure B.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*

[a] Also available with a single source-side PT.

See the *SEL-2431 Voltage Regulator Control Field Reference Guide* for more information on compatible voltage regulators.

PT1 Winding Polarity (PT1POL)

NOTE: If polarity settings need to be changed from normal polarity (:= NORM), then only one polarity setting really needs to be changed (e.g., CTPOL := REV, PT1POL := NORM, and PT2POL := NORM is effectively the same as CTPOL := NORM, PT1POL := REV, and PT2POL := REV). Also, changing all three polarity settings (CTPOL, PT1POL, and PT2POL) to reverse (:= REV) is effectively the same as leaving them all normal (:= NORM).

NOTE: If left uncorrected (for Siemens or Howard tap changers), the reverse V_{S1} polarity will cause Line Drop Compensation errors during reverse direction operation, when Group Setting OPMODE = LOCKREV (locked reverse) or BIDIR (bidirectional).

The PT1POL setting selects normal (NORM) or reverse (REV) polarity of the PT1 voltage connection.

If the voltage regulator is Type B (with any TAPCHNGR setting), or if it is a Type A (with TAPCHNGR = COOPER or GE), the PT1POL setting affects the SEL-2431 Reverse Power determination and metering system VL voltage and power readings. If the power flow direction appears opposite of what is expected (see *Fundamental (Instantaneous) Metering* on page 7.3 and *Meter Power Direction* on page 7.15), PT1POL (or CTPOL) should be changed to correct the error.

If the voltage regulator is a Type A with TAPCHGR = SIEMENS or HOWARD, the PT1POL setting affects the SEL-2431 metering of VS (see *Section 7: Metering and Monitoring*). If the phase of VS appears 180 degrees out of phase with VL, PT1POL (or PT2POL corresponding to VL) should be changed to correct the mismatch.

PT1 Primary Voltage (PT1PRIM) and Secondary Voltage (PT1SEC)

NOTE: See Appendix E: Voltage Base and Ratio Correction Transformer in the SEL-2431 Voltage Regulator Control Field Reference Guide for example settings.

Enter the primary (PT1PRIM, in kV) and secondary (PT1SEC, in V) winding information for the PT1 source. *Table 8.6* lists the source of the PT1 input for the various regulator manufacturers. If there is a ratio correction transformer present in the PT1 circuit, use the output voltage rating for the chosen tap in the PT1SEC setting, as shown in *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*.

Second PT Connected (2ND_PT), PT2 Polarity (PT2POL), PT2 Primary Voltage (PT2PRIM), and Secondary Voltage (PT2SEC)

NOTE: The second voltage input is a necessity for Howard Type A regulators, so the SEL-2431 does not prompt for the 2ND_PT setting in that case.

Set 2ND_PT := Y when a second PT is connected on the source or load side of the voltage regulator, and connected to the VS2 input of the SEL-2431.

The settings PT2POL, PT2PRIM and PT2SEC are only displayed when a second PT is connected.

NOTE: If polarity settings need to be changed from normal polarity (:= NORM), then only one polarity setting really needs to be changed (e.g., CTPOL := REV, PT1POL := NORM, and PT2POL := NORM is effectively the same as CTPOL := NORM, PT1POL := REV, and PT2POL := REV). Also, changing all three polarity settings (CTPOL, PT1POL, and PT2POL) to reverse (:= REV) is effectively the same as leaving them all normal (:= NORM).

The PT2POL setting selects normal (NORM) or reverse (REV) polarity of the PT2 voltage connection.

If the voltage regulator is Type B (with any TAPCHNGR setting), or if it is a Type A (with TAPCHNGR = COOPER or GE), the PT2POL setting affects the SEL-2431 metering of VS (see *Section 7: Metering and Monitoring*). If the phase of VS appears 180 degrees out of phase with VL, PT2POL (or PT1POL corresponding to VL) should be changed to correct the mismatch.

If the voltage regulator is a Type A with TAPCHGR = SIEMENS or HOWARD, the PT2POL setting affects the SEL-2431 Reverse Power determination and metering system VL voltage and power readings. If power flow direction appears opposite of what is expected (see *Fundamental (Instantaneous) Metering* on page 7.3 and *Meter Power Direction* on page 7.15), PT2POL (or CTPOL) should be changed to correct the error.

Enter the primary (PT2PRIM, in kV) and secondary (PT2SEC, in V) winding information for the second PT. If there is a ratio correction transformer present in the second PT circuit, use the output voltage rating for the chosen tap in the PT2SEC setting, as shown in *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*.

Advanced Regulator Settings

Neutral Over Run (NEUTOVR) (for Siemens Regulators Only)

NOTE: If NEUTOVER is set longer than the voltage regulator takes to change taps, the control will overshoot the neutral position while in automatic mode.

With Siemens voltage regulators, an additional time delay setting called NEUTOVR (Neutral Over Run) is displayed. This causes the tap changer motor to be kept energized for an additional time when neutral position is newly entered, ensuring the voltage regulator internal reversing switch is left in one of its closed states. This should be set according to the voltage regulator documentation.

To prevent spurious NO_NEUT alarms, the NEUTOVR setting may be decreased as the regulator ages.

Tap Position Based on Feedback (TPFDBK)

Tap position is normally determined by feedback from the voltage regulator. The SEL-2431 determines when a tap operation is complete by monitoring the operations switch input (Siemens, Howard, and GE regulators) or the holding switch input (Cooper regulators). The SEL-2431 then increments (raise) or decrements (lower) the internal tap position counter based on this feedback. If you choose not to use this feedback mechanism to keep track of tap position because the primary device does not have the proper indicating switch, set TPFDBK = N. In this case, the SEL-2431 keeps track of the tap position by incrementing (raise) or decrementing (lower) the internal tap position counter TAPDUR seconds after the start of the raise or lower tap pulse starts.

The TPFDBK setting is not displayed and is forced to its default value of Y when EGADVS = N. Only in rare, extenuating circumstances will you need to set TPFDBK. For those rare cases where there is no feedback mechanism for tap position (operations counter switch or holding switch), set TPFDBK = N.

Tap Pulse Duration (TAPDUR)

NOTE: For GE, Siemens, Howard Industries, and Cooper (spring drive or direct drive) voltage regulators, if TAPDUR is set less than the time it takes the tap mechanism to complete a tap change, the regulator may not change taps completely.

The TAPDUR setting defines how long the device should wait after initiating a tap change, before it should observe feedback. For GE, Siemens, and Howard Industries voltage regulators, the feedback it sees is related to the operations counter. For Cooper voltage regulators, the feedback it sees is related to the holding switch. If the device initiates a tap change, and does not observe the expected feedback within TAPDUR seconds, it will stop attempting to make that tap, and alarm.

For GE, Siemens, and Howard Industries voltage regulators, set the maximum tap duration to a value greater than the maximum amount of time it takes the tap mechanism in the regulator mechanism to complete one tap position movement, but less than twice the time it takes the mechanism to complete one tap position movement. For example, if your regulator takes 5.0 seconds to complete a tap operation, set TAPDUR = 8.0 seconds, which is greater than 5.0 seconds but less than 10.0 seconds (2 • 5 = 10).

For Cooper spring drive and direct voltage regulators, set TAPDUR according to the guidelines outlined for GE, Siemens, and Howard Industries voltage regulators as outlined above. For Cooper Quik-Drive voltage regulators, set TAPDUR just shorter than the tap operation time. For example, if the Cooper Quik-Drive voltage regulator takes 250 ms to complete a tap operation, set TAPDUR to 0.1 seconds. Analyze an event report to determine how long the regulator takes to complete a tap operation.

The TAPDUR setting is not displayed and is forced to its default value of 8.0 seconds when EGADVS = N. Only when TPFDBK = N will you need to set TAPDUR.

SEAL_PB

Set SEAL_PB to allow the membrane pushbutton-style raise and lower buttons to seal in once pressed. With this configuration, the raise or lower command will be held until the tap feedback is received. This setting does not impact the behavior of raise or lower when the mode of operation is automatic.

GE_WIND

With GE voltage regulators, an additional time delay setting called GE_WIND (GE Window) is displayed if EGADVS = Y. This setting is not displayed and is forced to its default value of 2.0 seconds when EGADVS = N. For most cases, you will not need to set GE_WIND. This setting controls the amount of time where changes in the operations counter switch are ignored after the initial change of state of the operations counter.

The operations counter switch inside a GE voltage regulator may come out of alignment over time. This misalignment may cause the SEL-2431 to lose track of tap position as the regulator fails to pulse the operations counter switch after each tap operation. Enable and set this setting appropriately if the SEL-2431 has lost track of the proper tap position on a GE voltage regulator.

TAP_DHR

With Cooper voltage regulators, an additional setting called TAP_DHR is displayed if EGADVS = Y. This setting is not displayed and is forced to its default value of N when EGADVS = N. For most cases, you will not need to set TAP_DHR. The SEL-2431 resets its internal tap position to neutral every time it senses that the neutral position switch is closed. Normally, the neutral position switch only closes when the voltage regulator is in the neutral tap position. In some older McGraw-Edison voltage regulators, the neutral position switch asserts along with DHR. With tap position synchronization suppressed (TAP_DHR = Y), operation of DHR will not impact the tap position.

50TYPE

The 50TYPE setting is not displayed and is forced to its default value of "A sec" when EGADVS = N. Set 50TYPE to "% rated" to change the range of the overcurrent settings (50L1P, 50FLTP, 50FWDP, etc.) from A sec to % rated.

This setting is useful for users accustomed to setting the threshold values based on percent of rated line current, rather than on secondary amperes.

Per Unit Regulator Impedance Magnitude (ZREGMAG) and Regulator Impedance Angle (ZREGANG)

PERCENT IMPEDANCE VALUE OF THE VOLTAGE REGULATOR:
The impedance of a voltage regulator is not a standard nameplate value. If a manufacturer can provide the percent impedance (and impedance angle) for their voltage regulator, the percent impedance value is provided on the circuit kVA base (also referred to as the through kVA base). The percent impedance value is used to derive setting ZREGMAG. The adjoining ZREGMAG discussion provides background on related voltage regulator nameplate parameters, followed by equations for deriving setting ZREGMAG.
If such impedance values are not available, then just **use the factory default values** for ZREGMAG and ZREGANG.

Settings ZREGMAG and ZREGANG are used to calculate source (or load) voltage when only load (or source) voltage, respectively, is connected (global setting 2ND_PT = N). If 2ND_PT = Y, these two settings are hidden. The factory default values are:

ZREGMAG = 0.0040 per unit

ZREGANG = 80 degrees

Base Impedance Background

ZREGMAG is applied to the internally calculated base impedance of the voltage regulator to derive an impedance magnitude. This impedance magnitude (along with the impedance angle) then provides the series winding voltage drop (per the current flowing through the voltage regulator and the voltage tap) used in calculating source (or load) voltage. The base impedance of a voltage regulator is derived from nameplate data in one of the following ways:

base impedance = (rated voltage)/(rated load amperes)

or

base impedance = $(\text{rated voltage})^2$/[(rated kVA) • 10 • (1000 V/kV)]

FACTORY DEFAULT ORIGIN

The ZREGMAG factory default value of 0.0040 per unit impedance (equivalent to 0.4 percent impedance) is taken from the classic reference: Electrical Transmission and Distribution Reference Book, Central Station Engineers of the Westinghouse Electric Corporation, 1964 [Chapter 11: Relay and Circuit-Breaker Applications, Table 13 - Impedance of Feeder Regulators - Percent on Circuit kVA Base - Plus or Minus 10 Percent Regulation].

where the nameplate data:

- rated voltage is in units of V primary
- rated load amperes is in units of A primary
- rated kVA is based on the 10 percent (0.10 per unit) maximum voltage regulation.

rated kVA = (rated voltage • 0.10) • (kV/1000 V) • (rated load amperes)
= (rated voltage) • (kV/1000 V) • (rated load amperes)/10

Per the sidebar note, if a manufacturer provides a percent impedance value for their voltage regulator, it is referenced to the circuit kVA base. The circuit kVA base is used in autotransformer base impedance calculations and voltage regulators are essentially autotransformers. The following relationship is used for voltage regulators:

$$\begin{aligned}\text{circuit kVA} &= (\text{rated kVA}) \bullet 10\\ &= (\text{rated voltage}) \bullet (\text{kV/1000 V}) \bullet (\text{rated load amperes})\end{aligned}$$

Substituting circuit kVA into the preceding base impedance derivation that uses rated kVA:

$$\begin{aligned}\text{base impedance} &= (\text{rated voltage})^2/[(\text{rated kVA}) \bullet 10 \bullet (1000\ \text{V/kV})]\\ &= (\text{rated voltage})^2/[(\text{circuit kVA}) \bullet (1000\ \text{V/kV})]\\ &= (\text{rated voltage})/(\text{rated load amperes})\end{aligned}$$

For the internally calculated base impedance, rated voltage is derived from global setting KV:

$$\text{rated voltage} = (\text{global setting KV}) \times (1000\ \text{V/kV})$$

Rated load amperes and global setting CTPRIM are in units of A primary. CTPRIM corresponds to rated load amperes as:

CTPRIM ≥ rated load amperes

The base impedance of the voltage regulator is internally calculated as:

base impedance = (global setting KV) • (1000 V/kV)/(global setting CTPRIM)

Calculating Setting ZREGMAG

ZREGMAG is applied to this internally calculated base impedance of the voltage regulator to internally derive an impedance magnitude. Thus, if global setting **CTPRIM > rated load amperes**, then calculate ZREGMAG as follows (using the discussed percent impedance value provided by the manufacturer):

ZREGMAG (in per unit) = percent impedance value • (per unit/100 percent) • (global setting CTPRIM)/(rated load amperes)

Otherwise, if global setting **CTPRIM = rated load amperes**, then calculate ZREGMAG as follows:

ZREGMAG (in per unit) = percent impedance value • (per unit/100 percent)

Per Unit Voltage Adjustment (VADJUST)

Setting VADJUST is a per unit value used in calculating source (or load) voltage when only load (or source) voltage, respectively, is connected (global setting 2ND_PT = N). It is also used in calculating tap delta voltage thresholds in conjunction with group settings TAPDELTL and TAPDELTH for use in the Flexible Distributed Generation scheme (see *Tap Delta Voltage Settings and Analysis (OPMODE = FLEXDG)* on page 4.10). If neither of these conditions apply, then setting VADJUST is of no effect (just leave at factory default).

NOTE: Setting VADJUST is not forced by global setting TAPCHNGR. The manufacturer association with series winding percentage type given in *Table 8.7* for Type B voltage regulators may change with newer models (inquire of the manufacturer as to the series winding percentage type).

Table 8.7 Setting VADJUST Values for Different Voltage Regulator Types

Voltage Regulator	Series Winding Percentage Type	Voltage Boost at Full Raise	VADJUST (per unit)
Type A (Straight)	10%	10%	0.100 (factory default)
Type B (Inverted) Siemens, GE	10%	11.1%	0.111
Type B (Inverted) Eaton/Cooper	9.1%	10%	0.100 (factory default)

For Type B (Inverted) voltage regulators (other than those in *Table 8.7*), inquire of the manufacturer as to the series winding percentage type. The following discussion derives the values in *Table 8.7*.

Type A With 10% Series Winding

STATIONARY CONTACTS AND TAP POSITION

See *Figure 5.1* and *Figure 5.2* and accompanying text for the correlation between stationary contacts and tap position.

Figure B.1 and *Figure B.2* in the *SEL-2431 Field Reference Guide* show Type A (Straight) voltage regulators. If the reversing switch is in the Raise position and the tapping fingers (shown on Neutral (N) position in the figures) are on stationary contact 8, then the voltage regulator is in the full raise position. Notice the respective polarity marks at the top of the shunt and series windings.

For these Type A (Straight) voltage regulators, lets refer to the voltage across:

- ➤ the shunt winding (terminal S to terminal SL) as Vshunt
- ➤ the series winding (terminal L to terminal S) as Vseries (across the entire winding at full raise)

The shunt winding and the series winding are magnetically coupled on a shared core. The resulting voltage relationship for a Type A voltage regulator is:

$$
\begin{aligned}
\text{Vseries} &= 0.1\ \text{Vshunt} \quad \text{(10\% series winding)} \\
\text{Vsource} &= \text{voltage across terminal S to terminal SL} = \text{Vshunt} \\
\text{Vload} &= \text{voltage across terminal L to SL} = \text{Vshunt} + \text{Vseries} \\
&= \text{Vshunt} + 0.1\ \text{Vshunt} = 1.1\ \text{Vshunt} \\
\text{Vload/Vsource} &= 1.1\ \text{Vshunt/Vshunt} = 1.1 = 1 + 0.1 = 1 + \text{VADJUST} \\
\text{VADJUST} &= 0.100
\end{aligned}
$$

Thus, a 10% series winding is used on a Type A (Straight) voltage regulator to realize a 10% voltage boost at full raise (VADJUST = 0.100).

Type B With 10% Series Winding

Figure B.3 and *Figure B.4* in the *SEL-2431 Field Reference Guide* show Type B (Inverted) voltage regulators. If the reversing switch is in the Raise position and the tapping fingers (shown on Neutral (N) position in the figures) are on stationary contact 8, then the voltage regulator is in the full raise position. Notice the polarity marks at the top of the shunt and series windings.

If this same shunt and series winding pairing used in the preceding Type A voltage regulator analysis (Vseries = 0.1 Vshunt; 10% series winding) is used in a Type B voltage regulator at full raise, the following results:

$$
\begin{aligned}
\text{Vsource} &= \text{voltage across terminal S to terminal SL} \\
&= \text{Vshunt} - \text{Vseries} = \text{Vshunt} - 0.1\ \text{Vshunt} = 0.9\ \text{Vshunt} \\
\text{Vload} &= \text{voltage across terminal L to SL} = \text{Vshunt}
\end{aligned}
$$

$$\text{Vload/Vsource} = \text{Vshunt}/0.9\ \text{Vshunt} = 1.111 = 1 + 0.111 = 1 + \text{VADJUST}$$
$$\text{VADJUST} = 0.111$$

Thus at full raise, a Type B (Inverted) voltage regulator has a 11.1% voltage boost when using the same 10% series winding (connected differently) that is used in Type A (Straight) voltage regulators.

Type B With 9.1% Series Winding

To have just a 10% (instead of 11.1%) voltage boost (VADJUST = 0.100) at full raise for a Type B (Inverted) voltage regulator, a different Vseries/Vshunt voltage relationship is needed.

$$\text{Let } R = \text{Vseries/Vshunt}$$
$$1 + \text{VADJUST} = \text{Vload/Vsource} = \text{Vshunt}/(\text{Vshunt} - \text{Vseries})$$

$$(\text{Vshunt} - \text{Vseries})/\text{Vshunt} = 1 - (\text{Vseries/Vshunt})$$
$$= 1 - R = 1/(1 + \text{VADJUST})$$

$$R = 1 - (1/(1 + \text{VADJUST})) = \text{VADJUST}/(1 + \text{VADJUST})$$
$$= 0.100/(1 + 0.100) = 0.091$$

The shunt winding and the series winding are magnetically coupled on a shared core, where the resulting voltage relationship for a Type B (Inverted) voltage regulator (to realize a 10% voltage boost at full raise; VADJUST = 0.100) is:

$$\text{Vseries} = 0.091\ \text{Vshunt} \qquad (9.1\%\ \text{series winding})$$

Connection Data

Base Primary Voltage (BASE_PRI) and Secondary Voltage (BASE_SEC)

Enter the nominal system primary voltage BASE_PRI in kV, and the nominal secondary voltage BASE_SEC in V. These values typically match the rating of the single-phase distribution transformers used on the regulated line. These settings allow the voltage control set points in the SEL-2431 to be made on the customer service voltage base (typically 120 V in North America), rather than on the actual secondary base, which may be different when regulators are configured for different voltage ranges.

For example, on a system with single-phase (L-N) distribution transformer ratios of 7200:120, a customer will receive 120 V secondary when the primary voltage is 7.2 kV. Make the settings BASE_PRI := 7.20 and BASE_SEC := 120.0. See *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for a complete example.

NOTE: The VOLT METER terminals on the SEL-2431 are connected directly to the V_{S1} or V_{S2} inputs. A connected voltmeter may not read the same voltages as the SEL-2431 metering when there are differences between the PT1_PRIM, PT2_PRIM, BASE_PRI, or PT1_SEC, PT2_SEC, BASE_SEC settings.

The SEL-2431 uses the BASE_PRI and BASE_SEC settings to automatically scale the V_{S1} (and V_{S2}, when present) voltages to the same base, and these corrected voltages are used in the voltage control algorithms and metering.

See *Appendix E: Voltage Base and Ratio Correction Transformer* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for a more thorough description.

Regulator Configuration (CONFIG), DELTA, D_LAG, D_LEAD, and ISHIFT

For single-phase Line-Neutral regulator installations, or for two- or three-phase voltage regulator banks connected Line-Neutral, set CONFIG := WYE. The remaining Regulator Configuration settings (DELTA, D_LAG, D_LEAD, and ISHIFT) are not present when CONFIG := WYE.

For line-to-line connected voltage regulator installations, set CONFIG to DLAG or DLEAD according to the regulator connection. See *Determine Lead and Lag Units in Open-Delta or Closed-Delta Voltage Regulator Installations* in *Section 4: Basic Settings* in the *SEL-2431 Field Reference Guide*. Note that for a closed-delta installation, all three voltage regulators will have the same CONFIG setting (DLAG or DLEAD), while for an open-delta installation, one voltage regulator will be the lead unit (CONFIG := DLEAD) and the other regulator will the lag unit (CONFIG := DLAG).

When CONFIG := DLAG or DLEAD, set DELTA := CLOSED for closed-delta applications or OPEN for open-delta applications. This ensures that the SEL-2431 metering system operates correctly. See *Operating in Delta Configuration* on page 7.19.

When CONFIG := DLAG, set D_LAG to the angle that the IL current lags the VL voltage. The lag angle is 30 degrees for a standard voltage regulator but can be set to any angle for special situations.

When CONFIG := DLEAD, set D_LEAD to the angle that the IL current leads the VL voltage. The lead angle is 30 degrees for a standard voltage regulator but can be set to any angle for special situations.

For either delta configuration (Open or Closed), the SEL-2431 uses the appropriate D_LAG or D_LEAD setting to shift the measured IL current phase relative to the voltage readings and this adjusted value is used in the algorithms for line-drop compensation and the forward and reverse direction determination. See *Line-Drop Compensation (LDC)* on page 3.1 and *Section 4: Control Operating Modes*.

The SEL-2431 metering functions only use the D_LAG or D_LEAD corrected IL current quantity when DELTA := CLOSED.

When CONFIG := SHIFT, set the ISHIFT Global setting to account for phase differences between the load current and load voltage. This is possible in such applications as three-phase voltage regulators or Load Tap Changers (LTCs) with only one voltage reference. ISHIFT is the angle in degrees by which the load current IL lags the load voltage VL.

Time and Date Management

To access the Time and Date Management settings, first set EGADVS := Y.

IRIG-B Configuration

The SEL-2431 supports IRIG-B time synchronization via serial Port 1. When serial Port 1 is ordered as an EIA-232 or 4-Wire EIA-485 port, Global setting IRIGC is available.

NOTE: The configuration of the IEEE C37.118 time source, such as the SEL-2401 Satellite-Synchronized Clock, determines whether daylight-saving time will be used in the SEL-2431.

If an IEEE C37.118-compliant time source is available, set IRIGC := C37.118. In this situation, the SEL-2431 is configured to use IEEE C37.118-compliant control block information, which automatically controls daylight-saving time and leap-second functions according to the incoming IRIG-B time signals and control block information. Device Word bits DSTP, LPSEC, LPSECP, TQUAL4, TQUAL3, TQUAL2, and TQUAL1 are active, and reflect the states of the control block functions of the decoded IRIG signal. See *Table E.2* for descriptions of these Device Word bits.

Device Word bit TSOK asserts when the SEL-2431 is synchronized to the high-accuracy C37.118 time source.

When no time signal is available, or a standard IRIG time source (not IEEE C37.118 compliant) is available, set IRIGC := NONE. In this situation, the SEL-2431 internal clock operates from the IRIG time signal, and the daylight-saving time settings are available.

Device Word bit TIRIG asserts when the SEL-2431 is synchronized to a standard IRIG time source.

When serial Port 1 is not present, or when serial Port 1 is ordered as one of the fiber-optic 2-Wire EIA-485 options, the IRIGC setting is unavailable.

Device Word bit IRIGOK asserts when either TIRIG or TSOK is asserted.

Automatic Daylight-Saving Time Settings

The SEL-2431 can automatically switch to and from daylight-saving time, as specified by the eight Global settings DST_BEGM through DST_ENDH. The first four settings control the month, week, day, and time that daylight-saving time shall commence, while the last four settings control the month, week, day, and time that daylight-saving time shall cease.

Once configured, the SEL-2431 will change to and from daylight-saving time every year at the specified time. Device Word bit DST asserts when daylight saving time is active.

The SEL-2431 interprets the week number settings DST_BEGW and DST_ENDW (1–3, L = Last) as follows:

- The first seven days of the month are considered to be in week 1.
- The second seven days of the month are considered to be in week 2.
- The third seven days of the month are considered to be in week 3.
- The last seven days of the month are considered to be in week “L”.

This method of counting of the weeks allows easy programming of statements like “the first Sunday”, “the second Saturday”, or “the last Tuesday” of a month.

As an example, consider the following settings:

DST_BEGM = 3

DST_BEGW = L

DST_BEGD = SUN

DST_BEGH = 2

DST_ENDM = 10

DST_ENDW = 3

DST_ENDD = WED

DST_ENDH = 3

With these example settings, the relay will enter daylight-saving time on the last Sunday in March at 0200 h, and leave daylight-saving time on the third Wednesday in October at 0300 h. The relay asserts Device Word bit DST when daylight-saving time is active.

When an IRIG-B time source is being used, the relay time follows the IRIG-B time, including daylight-saving time start and end, as commanded by the time source. If there is a discrepancy between the daylight-saving time settings and the received IRIG-B signal, the relay follows the IRIG-B signal.

When using IEEE C37.118 compliant IRIG-B signals (e.g., Global setting IRIGC = C37.118), the relay automatically populates the DST Device Word bit, regardless of the daylight-saving time settings.

When using regular IRIG-B signals (e.g., Global setting IRIGC = NONE), the relay only populates the DST Device Word bit if the daylight-saving time settings are properly configured.

Group Settings for Device and Terminal Identification

Refer to *Configuration Settings* on page SET.5.

The SEL-2431 has two identifier labels: the Device Identifier (DID) and the Terminal Identifier (TID). The Device Identifier is typically used to identify the voltage regulator control or the type of regulation scheme. Typical Terminal Identifiers include an abbreviation of the substation name, line terminal, power system phase, or physical location.

The SEL-2431 tags each report (event report, meter report, etc.) with the Device Identifier and Terminal Identifier. This allows you to distinguish the report as one generated for a specific regulator, phase, or substation.

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

Line-Drop Compensation (LDC)

Refer to *Line-Drop Compensation Settings* on page SET.6.

The SEL-2431 has four settings that are in units of volts secondary, but are really based on impedance.

Line-Drop Compensation Settings

The Line-Drop Compensation settings VLDCFWR, VLDCFWX, VLDCRVR, and VLDCRVX are set in terms of resistive or reactive voltage drop on the regulated secondary base voltage, at nominal rated current. See *Line-Drop Compensation (LDC)* on page 3.1.

Factory-Default Settings

The SEL-2431 factory-default settings are presented in *Figure 8.1–Figure 8.6*. Default DNP settings are shown in *Figure D.5*.

```
=>SHO G <Enter>

Global

General Settings
NFREQ    := 60           DATE_F   := MDY          EGADVS   := N

Regulator Nameplate Data
KV       := 7.20         CTPOL    := NORM         CTPRIM   := 250
TAPCHNGR := SIEMENS      NEUTOVR  := 2.0          TYPE     := B
PT1POL   := NORM         PT1PRIM  := 7.20         PT1SEC   := 120.0
2ND_PT   := N

Connection Data
BASE_PRI := 7.20         BASE_SEC := 120.0        CONFIG   := WYE

=>
```

Figure 8.1 Global Settings (SHO G) With Factory-Default Values

```
=>SHO <Enter>

Group 1

Group Settings

Configuration Settings
DID      := SEL-2431
TID      := Voltage Reg
OPMODE   := LOCKFWD      TAPMAX   := OFF          TAPMIN   := OFF
TD2      := 10.0

Forward Controller Settings
F_CHAR   := DISC         F_CNBND  := 120.0        F_BNDWD  := 2.0
F_TD1    := 60.0         F_DISC   := 0.60

Line Drop Compensation Settings
ELDC     := N

Overcurrent Settings
E50L     := 1            50L1P    := 0.250        50FLTP   := 0.600
50FWDP   := 0.002        50REVP   := 0.002

Voltage Reduction Settings
ENREDUC  := N

Voltage Limit Settings
ENLIMIT  := Y            VMAX     := 130.0        VMIN     := 110.0

Runback Settings
ENRUNBK  := N

Raise/Lower Settings
INHIBSV  := 50FLT
BLOCKSV  := 50L1 OR SV02T # LOAD CURRENT LIMIT OR LOW SYSTEM VOLTAGE CONDITIONS
RAISESV  := TOOLOW AND AUTO # TAP POSITION IS LOWER THAN SETTING TAPMIN
LOWERSV  := TOOHIGH AND AUTO # TAP POSITION IS HIGHER THAN SETTING TAPMAX

Demand Meter Settings
DMTC     := 15

=>
```

Figure 8.2 Group Settings (SHO) With Factory-Default Values

```
=>SHO L <Enter>

Logic 1

SELogic Enables
ELAT     := N             ESV      := 2             ESC      := N

SELogic Variable/Timer Settings
SV01     := RSEFAIL OR LWRFAIL OR XTAP16R OR XTAP16L OR OPNOCUR OR TAP_DIF #
            INTERFACE ERROR CONDITIONS
SV01PU   := 0.00          SV01DO   := 2.00
SV02     := VLSEC < 90.00 # LOW SYSTEM VOLTAGE, USED IN BLOCKSV EQUATION
SV02PU   := 0.00          SV02DO   := 2.00

Output SELogic Equations
OUT101   := NOT ALARM
OUT102   := 0
OUT103   := 0
OUT104   := 0

=>
```

Figure 8.3 Logic Settings (SHO L) With Factory-Default Values

```
=>SHO F <Enter>

Front Panel

General Settings
EDP      := 9             ELB      := N             FP_TO    := 15
FP_CONT  := 5

LED Settings
ALARM    := HALARM OR SALARM OR SV01T OR TAP_OFF OR NO_NEUT # SV01T ASSERTS FOR
    INTERFACE ERROR CONDITIONS
PB01LED  := PB01
PB02LED  := PB02
PB03LED  := PB03

PB04LED  := PB04
PB05LED  := PB05
PB06LED  := PB06
PB07LED  := PB07
Display Point Settings (maximum 60 characters)
   (Boolean): Device Word Bit Name, "Alias", "Set String", "Clear String"
   (Analog): Analog Quantity Name, "User Text and Formatting"
DP01     := VLSEC,"Voltage VL"
DP02     := IL,"Current IL"
DP03     := PL,"Real Power"
DP04     := QL,"Reactive Power"
DP05     := TAP_POS,"Tap Position"
DP06     := VMETER,"Test Jack Voltage"
DP07     := HALARM,,"Hardware Error - Status Failure"
DP08     := NO_NEUT,,"Neutral signal not detected."
DP09     := TAP_OFF,,"Tap position discrepancy."

Control Configuration
REMOTSV  := NA
LOCALSV  := MANUAL # FORCE TO LOCAL WHEN MANUAL SELECTED
AUTOSV   := NA
MANULSV  := NA

Selectable Operator Pushbuttons
PB01HMI  := GRP           PB02HMI  := MET           PB03HMI  := OP_CNT
PB04HMI  := V_LIM         PB05HMI  := LDC           PB06HMI  := HARM
PB07HMI  := DEMAND

=>
```

Figure 8.4 Front-Panel Settings (SHO F) With Factory-Default Values

```
=>SHO R <Enter>

Report

SER Chatter Criteria
ESERDEL  := Y             SRDLCNT  := 5             SRDLTIM  := 1.0

SER Trigger List
(Enter up to 96 Device Word bits, one per line.)
1: REMOTE
2: LOCAL
3: AUTO
4: MANUAL
5: ALARM
6: VRIPROG
7: INHIBSV
8: BLOCKSV
9: RBKBLSV
10: SPEN
11: TOOHIGH
12: TOOLOW
13: REVERSE
14: VMAXLMT
15: VMINLMT
16: RBKFWDH
17: RBKFWDL
18: RBKREVH
19: RBKREVL
20: RC
21: LC
22: RAISESV
23: LOWERSV
24: DHR
25: RSEFAIL
26: LWRFAIL
27: XTAP16R
28: XTAP16L
29: OPNOCUR
30: TAP_DIF
31: NO_NEUT
32: TAP_OFF
33: INHIBIT

Event Report Settings
ER       := SV01T # INTERFACE ERROR
PRE      := 20

Signal Profile Settings
(Enter up to 16 Analog Quantities, one per line.)

Signal Profile List
1: IL
2: VSSEC
3: VLSEC
4: VCMPSEC
5: TAP_POS
6: ILFDEM
7: PFDEM
8: QFODEM
9: QFIDEM
10: SFDEM
11: ILRDEM
12: PRDEM
13: QRODEM
14: QRIDEM
15: SRDEM
SPAR     := 15
SPEN     := 1 # ALWAYS ENABLED

=>
```

Figure 8.5 Report Settings (SHO R) With Factory-Default Values

```
=>SHO P <Enter>
Port F Settings

Communications Settings
SPEED    := 9600         BITS     := 8            PARITY   := N
STOP     := 1            RTSCTS   := N            T_OUT    := 15

SEL Protocol Settings
AUTO     := N            FASTOP   := N

=>
```

Figure 8.6 Port Settings (SHO P) With Factory-Default Values

Settings Sheets

NOTE: If the QuickSet settings editor is being used in conjunction with these settings sheets, some differences in setting order will be seen between the two formats, especially in the location of the enable settings. The Print option in QuickSet will list the settings in a similar order as these settings sheets.

The settings sheets that follow include the definitions and input range for each setting in the SEL-2431. Many of the settings categories in the settings sheets include a reference to a page, table, or figure (in parentheses) that further explains the settings.

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SEL-2431 Settings Sheets

Global Settings

(Serial Port Command SET G and Front Panel SET/SHOW Global Menu[1])

General Settings

(see *General Global Settings* on page 8.6)

Nominal frequency (50 Hz, 60 Hz)	**NFREQ :=** ______
Date format (MDY, YMD)	**DATE_F :=** ______

NOTE: See *Settings Explanations* on page 8.5.

Enable Global Advanced Settings (Y, N)	**EGADVS :=** ______

Regulator Nameplate Data

(see *Regulator Nameplate Data* on page 8.6)

Regulator Rated Voltage (0.10–40.00 kV)	**KV :=** ______
CT Winding Polarity (NORM, REV)	**CTPOL :=** ______
CT Primary Current (25–3600 A)	**CTPRIM :=** ______
Tap Changer Type (GE, COOPER, SIEMENS, HOWARD)	**TAPCHNGR :=** ______
Regulator Type (A, B)	**TYPE :=** ______
PT1 Winding Polarity (NORM, REV)[a]	**PT1POL :=** ______
PT1 Primary Voltage (0.10–40.00 kV)[a]	**PT1PRIM :=** ______
PT1 Secondary Voltage (80.0–145.0 V)[a]	**PT1SEC :=** ______

Make the following setting except when TAPCHNGR := HOWARD and TYPE := A.

Second PT Connected (Y, N)	**2ND_PT :=** ______

Make the following settings when a second PT is connected.

PT2 Winding Polarity (NORM, REV)	**PT2POL :=** ______
PT2 Primary Voltage (0.10–40.00 kV)[b]	**PT2PRIM :=** ______
PT2 Secondary Voltage (80.0–145.0 V)[b]	**PT2SEC :=** ______

[a] This setting corresponds to the voltage on the following interface terminals (figures in the SEL-2431 Voltage Regulator Control Field Reference Guide): U2-E (Siemens, Figure B.9 and Figure B.10), MS-G (Howard, Figure B.9 and Figure B.10), VM-G (Cooper, Figure B.6), NN20, NN21, or NN21-NN10 (GE Traditional, Figure B.7), 22-20 (GE Power Disconnect, Figure B.8).

[b] This setting corresponds to the voltage on the following interface terminals (figures in the SEL-2431 Voltage Regulator Control Field Reference Guide): P2-E (Siemens, Figure B.9 and Figure B.10), PS-G (Howard, Figure B.9 and Figure B.10), V7-G (Cooper, Figure B.6).

[1] SELogic control equations containing analog quantities can be viewed, but not changed, via the front-panel `Set/Show > Global` menu. For most applications, make Global settings (page SET.1–SET.4) before making the Group 1–4 settings.

Advanced Regulator Settings

(see *Advanced Regulator Settings* on page 8.9)

Make setting NEUTOVR when TAPCHNGR := SIEMENS.

Neutral Overrun (0.0–3.0 seconds) **NEUTOVR :=** ____________

Make settings TPFDBK, TAPDUR, and SEAL_PB when EGADVS := Y.

Tap Position Based on Feedback (Y, N) **TPFDBK :=** ____________

Tap Pulse Duration (0.1–15.0 seconds) **TAPDUR :=** ____________

Raise / Lower Push Button Seal-in (Y, N) **SEAL_PB :=** ____________

Make setting GE_WIND when EGADVS := Y AND TAPCHNGR := GE.

GE Operations Counter Window (0.5–10.0 seconds) **GE_WIND :=** ____________

Make setting TAP_DHR when EGADVS := Y and TAPCHNGR := COOPER.

Tap Position Synchronization Suppression (Y, N) **TAP_DHR :=** ____________

Make setting 50TYPE when EGADVS := Y.

Overcurrent Range Type (A sec, % rated) **50TYPE :=** ____________

Make ZREGMAG and ZREGANG settings when 2ND_PT := N and EGADVS := Y (see *Per Unit Regulator Impedance Magnitude (ZREGMAG) and Regulator Impedance Angle (ZREGANG)* on page 8.11)

Per Unit Regulator Impedance Magnitude (0.0010–0.0100 per unit) **ZREGMAG :=** ____________

Regulator Impedance Angle (45.0–90.0 degrees) **ZREGANG :=** ____________

Make VADJUST setting when EGADVS := Y (see *Table 8.7*)

Per Unit Voltage Adjustment (0.100–0.150) **VADJUST :=** ____________

Connection Data

(see *Connection Data* on page 8.14)

Base Primary Voltage (0.10–40.00 kV) **BASE_PRI :=** ____________

Base Secondary Voltage (80.0–145.0 V) **BASE_SEC :=** ____________

Regulator Configuration (WYE, DLAG, DLEAD, SHIFT) **CONFIG :=** ____________

Make the following setting when CONFIG := DLAG or DLEAD.

Delta Power Type (CLOSED, OPEN) **DELTA :=** ____________

Make the following setting when CONFIG := DLAG.

Angle by Which I Lags V (0–360 degrees) **D_LAG :=** ____________

Make the following setting when CONFIG := DLEAD.

Angle by Which I Leads V (0–360 degrees) **D_LEAD :=** ____________

Make the following setting when CONFIG := SHIFT.

Angle by Which I Lags V (0–360 degrees) **ISHIFT :=** ____________

Distributed Network Protocol Settings

Make the following setting when EGADVS := Y.

DNP Binary Output Operation (DEFAULT, LEGACY) **DNPBOOP :=** ____________

Data Reset SELogic Equations

(see SELogic *Reset Equation* on page 6.23)

Make the following settings when EGADVS := Y.

Reset Demand Metering	**RST_DEM :=** ______________
Reset Peak Demand Metering	**RST_PDM :=** ______________
Reset Energy Metering	**RST_ENE :=** ______________
Reset Max/Min Metering	**RST_MML :=** ______________
Reset Tap Counters	**RST_TAP :=** ______________

Setting Group Selection SELogic Equations

(see *Multiple Setting Groups* on page 6.14)

Make the following settings when EGADVS := Y.

Select Setting Group 1

SS1 := ____

Select Setting Group 2

SS2 := ____

Select Setting Group 3

SS3 := ____

Select Setting Group 4

SS4 := ____

Settings Group Change Delay

(see *Multiple Setting Groups* on page 6.14)

Make the following setting when EGADVS := Y.

Group Change Delay (0–900 seconds)	**TGR :=** ______________

Time-of-Day Operation Settings

(see *Day of Week/Time of Day Logic* on page 6.24)

Make the following setting when EGADVS := Y.

Day of the Week (Operation 1) (NA, MON–SUN, WEEKEND, WEEKDAY)	**OP1DOW :=** ______________
Time of the Day (Operation 1) (00:00–23:59)	**OP1TOD :=** ______________
Day of the Week (Operation 2) (NA, MON–SUN, WEEKEND, WEEKDAY)	**OP2DOW :=** ______________
Time of the Day (Operation 2) (00:00–23:59)	**OP2TOD :=** ______________
Day of the Week (Operation 3) (NA, MON–SUN, WEEKEND, WEEKDAY)	**OP3DOW :=** ______________
Time of The Day (Operation 3) (00:00–23:59)	**OP3TOD :=** ______________

Day of the Week (Operation 4) (NA, MON–SUN, WEEKEND, WEEKDAY) **OP4DOW :=** ____________

Time of the Day (Operation 4) (00:00–23:59) **OP4TOD :=** ____________

Note: Make each Time of the Day (OPnTOD) setting when the Day of the Week (OPnDOW) setting is not set to NA.

Phasor Measurement (PMU)

EN SYNCHRO PHASOR (Y, N) **EPMU :=** ____________

NOTE: All subsequent PMU settings are hidden if EPMU :=N.

MESSAGES PER SEC (1, 2, 5, 10, 12, 15, 20, 30, 60 for FNOM := 60 Hz; 1, 2, 5, 10, 25, 50 for FNOM := 50 Hz) **MRATE :=** ____________

PMU APPLICATION (FAST, NARROW) **PMAPP :=** ____________

FREQ BASED COMP (Y, N) **PHCOMP :=** ____________

STATION NAME (16 characters) **PMSTN :=** ____________

PMU HARDWARE ID (1–65534) **PMID :=** ____________

VOLTAGE DATA SET (V1, ALL, NA) **PHDATAV :=** ____________

VOLT COMP ANGLE (–179.99 to 180.00 deg) **VCOMP :=** ____________
Hidden if PHDATAV := NA

VS COMP ANGLE (–179.99 to 180.00 deg) **VSCOMP :=** ____________
Hidden if there is no VS voltage or PHDATAV := NA

CURRENT DATA SET (I1, ALL, NA) **PHDATAI :=** ____________

CURRENT COMP ANGLE (–179.99 to 180.00 deg) **ICOMP :=** ____________
Hidden if PHDATAI := NA

Number of 16-Bit Digital Status Words (0, 1) **NUMDSW :=** ____________

TRIG REASON BIT 1 (SELOGIC) **TREA1 :=** ____________

TRIG REASON BIT 2 (SELOGIC) **TREA2 :=** ____________

TRIG REASON BIT 3 (SELOGIC) **TREA3 :=** ____________

TRIG REASON BIT 4 (SELOGIC) **TREA4 :=** ____________

TRIGGER (SELOGIC) **PMTRIG :=** ____________

Time and Date Management

(see *Time and Date Management* on page 8.15)

Make the following setting when the SEL-2431 is ordered with communications Port 1 and EGADVS := Y.

IRIG-B Control Bit Definition (NONE, C37.118) **IRIGC :=** ____________

Make the following setting when IRIGC := NONE.

Month to Begin DST (NA, 1–12) **DST_BEGM :=** ____________

Make the following settings when DST_BEGM ≠ NA.

Week of the Month to Begin DST (1–3, L = Last) **DST_BEGW :=** ____________

Day of the Week to Begin DST (SUN–SAT) **DST_BEGD :=** ____________

Local Hour to Begin DST (0–23) **DST_BEGH :=** ____________

Month to End DST (1–12) **DST_ENDM :=** ____________

Week of the Month To End DST (1–3, L = Last) **DST_ENDW :=** ____________

Day of the Week To End DST (SUN–SAT) **DST_ENDD :=** ____________

Local Hour to End DST (0–23) **DST_ENDH :=** ____________

Group Settings

(Serial Port Command SET n[2] and Front-Panel Set/Show Group Menu[3])

Configuration Settings

(see *Group Settings for Device and Terminal Identification* on page 8.17)

Device Identification (16 characters) (0–9, A–Z, -, /, ., space)

DID := ____

Terminal Identification (16 characters) (0–9, A–Z, -, /, ., space)

TID := ____

Operating Mode (LOCKFWD, LOCKREV, IDLEREV, BIDIR, COGEN, FLEXDG) (see *Section 4: Control Operating Modes*) **OPMODE :=** ____________

Make BIASMODE setting when OPMODE := BDIR, COGEN, or FLEXDG (see *Figure 4.2* and *Figure 4.8*).

Voltage Regulation Bias Mode (OFF, FWD, REV) **BIASMODE :=** ____________

Make FLEX_50 setting when OPMODE := FLEXDG (see *Figure 4.10*, *Figure 4.11*, and *Figure 4.12*).

FLEXDG Operating Mode Current Override (OFF, FWD, REV, BOTH) **FLEX_50 :=** ____________

Make TAPDELTL and TAPDELTH settings when OPMODE := FLEXDG (see *Tap Delta Voltage Settings and Analysis (OPMODE = FLEXDG)* on page 4.10).

Low Tap Delta Voltage Threshold Per Unit (0.25–0.90) **TAPDELTL :=** ____________

High Tap Delta Voltage Threshold Per Unit (0.25–0.90) **TAPDELTH :=** ____________

Maximum Software Tap Number (OFF, 8 to 16) **TAPMAX :=** ____________

Minimum Software Tap Number (OFF, –8 to –16) **TAPMIN :=** ____________

Time Delay 2 for Subsequent Taps (1.0 to 999.0 seconds) **TD2 :=** ____________
The lower limit for Group setting TD2 will be 1.3 + Global setting NEUTOVR seconds when Global setting TAPCHNGR is set to SIEMENS. Otherwise the lower limit of TD2 is 1.0 seconds.

Forward Controller Settings

(see *"In Band" and "Out of Band" Voltage Conditions* on page G.2)

Make the following settings when preceding setting OPMODE ≠ LOCKREV.

Forward Reset Characteristic (FAST, DISC, DELAY, DLY_FRZ) **F_CHAR :=** ____________

Forward Center Band (96.0–144.0 V sec) **F_CNBND :=** ____________

Forward Band Width (1.0–10.0 V sec) **F_BNDWD :=** ____________

[2] Where n = Group 1–4; defaults to active group.
[3] SELOGIC Equations containing analog comparisons can be viewed, but not changed, via the front-panel SET/SHOW Group Menu.

Forward Time Delay 1 for First Tap (1.0 to 999.0 seconds) **F_TD1 :=** ____________

Make F_DISC setting when F_CHAR := DISC.

Forward Disc-like Reset Factor (0.10–2.00) **F_DISC :=** ____________

Make F_DLYRS setting when F_CHAR := DELAY or DLY_FRZ.

Forward Delay on Reset (0.0 to 999.0 seconds) **F_DLYRS :=** ____________

Reverse Controller Settings

(see *"In Band" and "Out of Band" Voltage Conditions* on page G.2)

Make the following settings when OPMODE := LOCKREV, BIDIR, or FLEXDG.

Reverse Reset Characteristic (FAST, DISC, DELAY, DLY_FRZ) **R_CHAR :=** ____________

Reverse Center Band (96.0–144.0 V sec) **R_CNBND :=** ____________

Reverse Band Width (1.0–10.0 V sec) **R_BNDWD :=** ____________

Reverse Time Delay 1 for First Tap (1.0 to 999.0 seconds) **R_TD1 :=** ____________

Make R_DISC setting when R_CHAR := DISC.

Reverse Disc-like Reset Factor (0.10–2.00) **R_DISC :=** ____________

Make R_DLYRS setting when R_CHAR := DELAY or DLY_FRZ.

Reverse Delay on Reset (0.0 to 999.0 seconds) **R_DLYRS :=** ____________

Line-Drop Compensation Settings

(see *Line-Drop Compensation (LDC)* on page 3.1)

ELDC setting has a range of (Y, N) if OPMODE ≠ FLEXDG.

ELDC setting has a range of (Y1, Y2, Y3, Y4, N) if OPMODE = FLEXDG (see *Table 4.5*).

Enable Line Drop Compensation (Y, N) **ELDC :=** ____________

Make VLDCFWR and VLDCFWX settings when ELDC ≠ N and OPMODE ≠ LOCKREV.

Forward Resistive LDC Voltage (–24.0 to +24.0 V sec) **VLDCFWR :=** ____________

Forward Reactive LDC Voltage (–24.0 to +24.0 V sec) **VLDCFWX :=** ____________

Make VLDCRVR and VLDCRVX settings when ELDC ≠ N and OPMODE ≠ (LOCKFWD or IDLEREV).

Reverse Resistive LDC Voltage (–24.0 to +24.0 V sec) **VLDCRVR :=** ____________

Reverse Reactive LDC Voltage (–24.0 to +24.0 V sec) **VLDCRVX :=** ____________

Make VLDCFWMP and VLDCFWMN settings when ELDC ≠ N and OPMODE ≠ LOCKREV.

Forward LDC Voltage positive maximum (OFF, +0.1 to +24.0 V sec) **VLDCFWMP :=** ____________

Forward LDC Voltage negative maximum (OFF, –0.1 to –24.0 V sec) **VLDCFWMN :=** ____________

Make VLDCRVMP and VLDCRVMN settings when ELDC ≠ N and OPMODE ≠ (LOCKFWD or IDLEREV).

Reverse LDC Voltage positive maximum (OFF, +0.1 to +24.0 V sec) **VLDCRVMP :=** ____________

Reverse LDC Voltage negative maximum (OFF, –0.1 to –24.0 V sec) **VLDCRVMN :=** ____________

Overcurrent Settings

(see *Overcurrent Elements* on page 6.20)

Load Overcurrent Element Levels (N, 1–7) **E50L :=** ______________

Range of all overcurrent settings dependent on advance global setting 50TYPE.

Number of load overcurrent element pickup settings dependent on enable setting E50L := 1–7.

Load Current Pickup (OFF, 0.002 to 0.700 A sec, OR 1% to 350%) **50L1P :=** ______________

50L2P := ______________

50L3P := ______________

50L4P := ______________

50L5P := ______________

50L6P := ______________

50L7P := ______________

Fault Overcurrent Element Pickup (OFF, 0.400 to 2.000 A sec, OR 200% to 1000%) **50FLTP :=** ______________

Make 50FWDP setting when BIASMODE ≠ FWD or OPMODE ≠ BDIR, COGEN, or FLEXDG.

Forward I Threshold (0.002 to 0.020 A sec, OR 1% to 10%) **50FWDP :=** ______________

Make 50REVP setting when BIASMODE ≠ REV or OPMODE ≠ BDIR, COGEN, or FLEXDG.

Reverse I Threshold (0.002 to 0.020 A sec, OR 1% to 10%) **50REVP :=** ______________

Voltage Reduction Settings

(see *Voltage Reduction* on page 4.24)

Enable Voltage Reduction (Y, N) **ENREDUC :=** ______________

Make the following settings when ENREDUC := Y.

Voltage Reduction Mode (PULSE, LATCH, CONTROL) **VREDMOD :=** ______________

Forward Voltage Reduction Percentage, Stage 1 (OFF, 0.1%–10.0%) **VREDFP1 :=** ______________

Make the following setting when VREDFP1 ≠ OFF.

Forward Voltage Reduction Percentage, Stage 2 (OFF, 0.1%–10.0%) **VREDFP2 :=** ______________

Make the following settings when VREDFP1 ≠ OFF and VREDFP2 ≠ OFF.

Forward Voltage Reduction Percentage, Stage 3 (OFF, 0.1%–10.0%) **VREDFP3 :=** ______________

Reverse Voltage Reduction Percentage, Stage 1 (OFF, 0.1%–10.0%) **VREDRP1 :=** ______________

Make the following setting when VREDRP1 ≠ OFF.

Reverse Voltage Reduction Percentage, Stage 2 (OFF, 0.1%–10.0%) **VREDRP2 :=** ______________

Make the following setting when VREDRP1 ≠ OFF and VREDRP2 ≠ OFF

Reverse Voltage Reduction Percentage, Stage 3 (OFF, 0.1%–10.0%) **VREDRP3 :=** ______________

Make the following settings when VREDMOD := LATCH or CONTROL.

VR Stage 1 Timer Pickup (0.0–9999.0 seconds) **VRSPU1 :=** ______________

VR Stage 2 Timer Pickup (0.0–9999.0 seconds) **VRSPU2 :=** ______________

VR Stage 3 Timer Pickup (0.0–9999.0 seconds) **VRSPU3 :=** ______________

Voltage Reduction Inputs (SELOGIC equations)

VRED1SV := ______________________________

Note: Make setting VRED2SV when VREDMOD := CONTROL or LATCH.

VRED2SV := ______________________________

Note: Make setting VRED3SV when VREDMOD := CONTROL.

VRED3SV := ______________________________

Voltage Reduction Reset (SELOGIC equation)

VRRSTSV := ______________________________

Note: Make setting VRRSTSV when VREDMOD := PULSE.

Voltage Reduction Override (SELOGIC equation)

OVRIDSV := ______________________________

Note: Make setting OVRIDSV when VREDMOD := CONTROL or LATCH.

Voltage Reduction Pulse Length for PULSE mode (0.00–9.00 seconds) **VRPULPU :=** ____________

Note: Make setting VRPULPU when VREDMOD := PULSE.

Set LDC to Zero For Voltage Reduction (Y, N) **SETLDC0 :=** ____________

Voltage Limit Settings

(see *Over- and Undervoltage Limits* on page 3.7)

Enable Max/Min Voltage Control (Y, N) **ENLIMIT :=** ____________

Make the following settings when ENLIMIT := Y.

Maximum Volts (OFF, 108.5–145.0 V secondary) **VMAX :=** ____________

Minimum Volts (OFF, 80.0–131.5 V secondary) **VMIN :=** ____________

Note: VMIN cannot be set within 3 volts of VMAX. **:=**

Runback Settings

(see *Runback High- and Low-Voltage Limits* on page 3.8)

Make the following settings when ENLIMIT := Y.

Enable Runback (Y, N) **ENRUNBK :=** ____________

Make the following settings when ENRUNBK := Y.

Runback Block (SELOGIC equation):

RBKBLSV := ______________________________

Runback Timer Pickup (0.0 to 9999.0 seconds) **RUNBKPU :=** ____________

Make the following setting when VMAX is not set to OFF.

Deadband (High) (OFF, 0.0–6.0 V secondary) **DBNDH :=** ____________

Make the following setting when VMIN is not set to OFF.

Deadband (Low) (OFF, 0.0–6.0 V secondary) **DBNDL :=** ____________

Raise/Lower Settings

(see *Inhibiting/Blocking Then Resuming Tap Operation* on page 5.11 and *Other Raise/Lower Methods* on page 5.11)

Inhibit Conditions (SELOGIC equation)

INHIBSV := ____________________

Block Tap Operations (SELOGIC equation)

BLOCKSV := ____________________

Raise Command (SELOGIC equation)

RAISESV := ____________________

Lower Command (SELOGIC equation)

LOWERSV := ____________________

Demand Meter Settings

(see *Demand Metering* on page 7.6)

Demand Meter Time Constant (5, 10, 15, 30, 60 minutes) **DMTC :=** __________

Logic Settings

(Serial Port Command SET L n[2])

SELOGIC Enables

(see *Enable Settings* on page 8.5)

SELOGIC Latches (N, 1–8) **ELAT :=** __________

SELOGIC Variables/Timers (N, 1–8) **ESV :=** __________

SELOGIC Counters (N, 1–8) **ESC :=** __________

Latch Bits Set/Reset SELOGIC Equations

(see *Figure 6.5*)

Number of latch bit set/reset settings dependent on preceding enable setting ELAT := 1–8.

Set Latch Bit LT01

SET01 := ____________________

Reset Latch Bit LT01

RST01 := ____________________

Set Latch Bit LT02

SET02 := ____________________

Reset Latch Bit LT02

RST02 := ____________________

Set Latch Bit LT03

SET03 := ____________________

Reset Latch Bit LT03

RST03 := ____________________

Set Latch Bit LT04
SET04 := ______________________________

Reset Latch Bit LT04
RST04 := ______________________________

Set Latch Bit LT05
SET05 := ______________________________

Reset Latch Bit LT05
RST05 := ______________________________

Set Latch Bit LT06
SET06 := ______________________________

Reset Latch Bit LT06
RST06 := ______________________________

Set Latch Bit LT07
SET07 := ______________________________

Reset Latch Bit LT07
RST07 := ______________________________

Set Latch Bit LT08
SET08 := ______________________________

Reset Latch Bit LT08
RST08 := ______________________________

SELOGIC Variable/Timer Settings

(see *Variables/Timers* on page 6.6)

Number of SELOGIC variables/timers settings dependent on enable setting ESV := 1–8.

SELOGIC Variable SV01 Input SELOGIC Equation
SV01 := ______________________________

SELOGIC Variable SV01 Timer Pickup (0.00–9600.00 seconds) **SV01PU :=** __________

SELOGIC Variable SV01 Timer Dropout (0.00–9600.00 seconds) **SV01DO :=** __________

Pickup and dropout timers SV02–SV08 have the same setting range as SV01.

SV02 := ______________________________
SV02PU := __________
SV02DO := __________

SV03 := ______________________________
SV03PU := __________
SV03DO := __________

SV04 := ______________________________
SV04PU := __________
SV04DO := __________

SV05 := ______________________________

SV05PU := ____________

SV05DO := ____________

SV06 := ______________________________

SV06PU := ____________

SV06DO := ____________

SV07 := ______________________________

SV07PU := ____________

SV07DO := ____________

SV08 := ______________________________

SV08PU := ____________

SV08DO := ____________

SELOGIC Counter Settings

(see *Counters* on page 6.10)

Number of SELOGIC counter settings dependent on enable setting ESC := 1–8.

Note: For any counter, if the last setting (e.g., SC02CD) is set to NA, the entire counter (SC02, in this example) is disabled. If the countdown function is not needed for a particular counter application, set the countdown setting to logical 0 (e.g., SC02CD := 0) to allow the rest of the counter to function.

Counter SC01 Preset Value, unitless (1–65000) **SC01PV :=** ____________

Counter SC01 Reset Input SELOGIC Equation

SC01R := ______________________________

Counter SC01 Load PV Input SELOGIC Equation

SC01LD := ______________________________

Counter SC01 Count Up Input SELOGIC Equation

SC01CU := ______________________________

Counter SC01 Count Down Input SELOGIC Equation

SC01CD := ______________________________

Counter SC02 Preset Value, unitless (1–65000) **SC02PV :=** ____________

Counter SC02 Reset Input SELOGIC Equation

SC02R := ______________________________

Counter SC02 Load PV Input SELOGIC Equation

SC02LD := ______________________________

Counter SC02 Count Up Input SELOGIC Equation

SC02CU := ______________________________

Counter SC02 Count Down Input SELOGIC Equation

SC02CD := ______________________________

Counter SC03 Preset Value, unitless (1–65000) **SC03PV :=** ____________

Counter SC03 Reset Input SELOGIC Equation
SC03R := ____

Counter SC03 Load PV Input SELOGIC Equation
SC03LD := ____

Counter SC03 Count Up Input SELOGIC Equation
SC03CU := ____

Counter SC03 Count Down Input SELOGIC Equation
SC03CD := ____

Counter SC04 Preset Value, unitless (1–65000) **SC04PV :=** ____________

Counter SC04 Reset Input SELOGIC Equation
SC04R := ____

Counter SC04 Load PV Input SELOGIC Equation
SC04LD := ____

Counter SC04 Count Up Input SELOGIC Equation
SC04CU := ____

Counter SC04 Count Down Input SELOGIC Equation
SC04CD := ____

Counter SC05 Preset Value, unitless (1–65000) **SC05PV :=** ____________

Counter SC05 Reset Input SELOGIC Equation
SC05R := ____

Counter SC05 Load PV Input SELOGIC Equation
SC05LD := ____

Counter SC05 Count Up Input SELOGIC Equation
SC05CU := ____

Counter SC05 Count Down Input SELOGIC Equation
SC05CD := ____

Counter SC06 Preset Value, unitless (1–65000) **SC06PV :=** ____________

Counter SC06 Reset Input SELOGIC Equation
SC06R := ____

Counter SC06 Load PV Input SELOGIC Equation
SC06LD := ____

Counter SC06 Count Up Input SELOGIC Equation
SC06CU := ____

Counter SC06 Count Down Input SELOGIC Equation
SC06CD := ____

Counter SC07 Preset Value, unitless (1–65000) **SC07PV :=** ____________

Counter SC07 Reset Input SELOGIC Equation

SC07R := ____________

Counter SC07 Load PV Input SELOGIC Equation

SC07LD := ____________

Counter SC07 Count Up Input SELOGIC Equation

SC07CU := ____________

Counter SC07 Count Down Input SELOGIC Equation

SC07CD := ____________

Counter SC08 Preset Value, unitless (1–65000) **SC08PV :=** ____________

Counter SC08 Reset Input SELOGIC Equation

SC08R := ____________

Counter SC08 Load PV Input SELOGIC Equation

SC08LD := ____________

Counter SC08 Count Up Input SELOGIC Equation

SC08CU := ____________

Counter SC08 Count Down Input SELOGIC Equation

SC08CD := ____________

Output SELOGIC Equations

(see *Output Contacts* on page 6.19)

Note: Output Contact Equations cannot be set to NA.

Output Contact OUT101

OUT101 := ____________

Output Contact OUT102

OUT102 := ____________

Output Contact OUT103

OUT103 := ____________

Output Contact OUT104

OUT104 := ____________

Front-Panel Settings

(Serial Port Command SET F)

General Settings

(see *Enable Settings* on page 8.5)

Enable Display Points (N, 1–32)	**EDP :=** ________
Enable Local Bits (N, 1–8)	**ELB :=** ________
Enable USB Mass Storage Device (Y, N)	**EUSB :=** ________
LCD Time Out (OFF, 1–30 minutes)	**FP_TO :=** ________
LCD Contrast (1–16)	**FP_CONT :=** ________

NOTE: See *Front-Panel Menus and Screens* on page 10.11.

Voltage Test Jack Settings

(see *Front Panel Settings VTJ_MODE and VTJ_L for VOLTMETER Test Terminals* on page 10.3)

Make the following setting when Global setting 2ND_PT := Y or when TAPCHNGR := HOWARD and TYPE := A.

Voltage Test Jack Mode (AUTO, MANUAL)	**VTJ_MODE :=** ________

Make the following setting when VTJ_MODE = MANUAL.

Voltage Test Jack, Select L-Bushing (SELOGIC equation)

VTJ_L := ____

LED Settings

(see Operation and Indication LEDs in Section 3: Front-Panel Interface in the SEL-2431 Field Reference Guide)

Note: The LED settings cannot be set to NA.

Alarm LED SELOGIC Equation

ALARM := ____

PB01 LED SELOGIC Equation

PB01_LED := ____

PB02 LED SELOGIC Equation

PB02_LED := ____

PB03 LED SELOGIC Equation

PB03_LED := ____

PB04 LED SELOGIC Equation

PB04_LED := ____

PB05 LED SELOGIC Equation

PB05_LED := ____

PB06 LED SELOGIC Equation

PB06_LED := ______________________________

PB07 LED SELOGIC Equation

PB07_LED := ______________________________

Display Point Settings

(see *Display Points* on page 10.6)

Number of display point settings dependent on preceding enable setting EDP := 1–32.

For all display point settings:

- Maximum 60 characters: 0–9, A–Z, -, /, ", ., {, }, space, comma
- Enter "" to clear a label.
- Use one of two types of settings:
  - **Boolean**: Device Word Bit Name, “Alias”, “Set String”, “Clear String”

Example Setting	Condition	Display
DP04 := IN101,,"EXTERNAL ON","EXTERNAL OFF"	IN101 = Asserted	"EXTERNAL ON"
DP04 := IN101,,"EXTERNAL ON","EXTERNAL OFF"	IN101 = Deasserted	"EXTERNAL OFF"

  - **Analog**: Analog Quantity Name, “User Text and Formatting”

Example Setting	Condition	Display
DP05 := ILFDEM,"Forward Demand Current = {5.3,0.001} kA"	Always Displayed	Forward Demand Current = 0.138 kA

DP01 := ______________________________

DP02 := ______________________________

DP03 := ______________________________

DP04 := ______________________________

DP05 := ______________________________

DP06 := ______________________________

DP07 := ______________________________

DP08 := ______________________________

DP09 := ______________________________

DP10 := ______________________________

DP11 := ______________________________

DP12 := ______________________________

DP13 := ______________________________

DP14 := ______________________________

DP15 := ______________________________

DP16 := ______________________________

DP17 := ______________________________

DP18 := ______________________________

DP19 := ____________________

DP20 := ____________________

DP21 := ____________________

DP22 := ____________________

DP23 := ____________________

DP24 := ____________________

DP25 := ____________________

DP26 := ____________________

DP27 := ____________________

DP28 := ____________________

DP29 := ____________________

DP30 := ____________________

DP31 := ____________________

DP32 := ____________________

Local Control Bit Labels

(see *Control Menu* on page 10.25)

Number of local bit settings dependent on preceding enable setting ELB := 1–8.

For all local bit settings:

- Allowable characters: 0–9, A– Z, -, /, ., space
- Enter "" to clear a label.

For each Local Bit *nn* = 01–08, make settings:

- NLB*nn* is the local bit Name (label) (20 characters maximum)
- CLB*nn* is the local bit Clear Label (20 characters maximum)
- SLB*nn* is the local bit Set Label (20 characters maximum)
- PLB*nn* is the local bit Pulse Label (20 characters maximum)

See *Table 10.6* for the three possible local bit switch configurations.

Local Bit 01

Name (20 characters maximum) **NLB01 :=** ____________

Clear Label (20 characters maximum) **CLB01 :=** ____________

Set Label (20 characters maximum) **SLB01 :=** ____________

Pulse Label (20 characters maximum) **PLB01 :=** ____________

Local Bit 02

Name (20 characters maximum) **NLB02 :=** ____________

Clear Label (20 characters maximum) **CLB02 :=** ____________

Set Label (20 characters maximum) **SLB02 :=** ____________

Pulse Label (20 characters maximum) **PLB02 :=** ____________

Local Bit 03

Name (20 characters maximum)	**NLB03 :=** ______________
Clear Label (20 characters maximum)	**CLB03 :=** ______________
Set Label (20 characters maximum)	**SLB03 :=** ______________
Pulse Label (20 characters maximum)	**PLB03 :=** ______________

Local Bit 04

Name (20 characters maximum)	**NLB04 :=** ______________
Clear Label (20 characters maximum)	**CLB04 :=** ______________
Set Label (20 characters maximum)	**SLB04 :=** ______________
Pulse Label (20 characters maximum)	**PLB04 :=** ______________

Local Bit 05

Name (20 characters maximum)	**NLB05 :=** ______________
Clear Label (20 characters maximum)	**CLB05 :=** ______________
Set Label (20 characters maximum)	**SLB05 :=** ______________
Pulse Label (20 characters maximum)	**PLB05 :=** ______________

Local Bit 06

Name (20 characters maximum)	**NLB06 :=** ______________
Clear Label (20 characters maximum)	**CLB06 :=** ______________
Set Label (20 characters maximum)	**SLB06 :=** ______________
Pulse Label (20 characters maximum)	**PLB06 :=** ______________

Local Bit 07

Name (20 characters maximum)	**NLB07 :=** ______________
Clear Label (20 characters maximum)	**CLB07 :=** ______________
Set Label (20 characters maximum)	**SLB07 :=** ______________
Pulse Label (20 characters maximum)	**PLB07 :=** ______________

Local Bit 08

Name (20 characters maximum)	**NLB08 :=** ______________
Clear Label (20 characters maximum)	**CLB08 :=** ______________
Set Label (20 characters maximum)	**SLB08 :=** ______________
Pulse Label (20 characters maximum)	**PLB08 :=** ______________

Control Configuration

(see CONTROL CONFIGURATION Pushbuttons in Section 3: Front-Panel Interface in the SEL-2431 Field Reference Guide)

Select Remote Configuration (SELOGIC equation)

REMOTSV := ____

Select Local Configuration (SELOGIC equation)

LOCALSV := ____

Select Automatic Configuration (SELOGIC equation)

AUTOSV := ______________________________

Select Manual Configuration (SELOGIC equation)

MANULSV := ______________________________

Selectable Operator Pushbuttons

(see *Front-Panel Settings for Operator Control Pushbuttons and LEDs* on page 10.31)

Pushbutton 1 HMI Screen (OFF, GRP, GLB, MET, OP_CNT, V_LIM, LDC, HARM, DEMAND)	**PB01HMI :=** __________
Pushbutton 2 HMI Screen (OFF, GRP, GLB, MET, OP_CNT, V_LIM, LDC, HARM, DEMAND)	**PB02HMI :=** __________
Pushbutton 3 HMI Screen (OFF, GRP, GLB, MET, OP_CNT, V_LIM, LDC, HARM, DEMAND)	**PB03HMI :=** __________
Pushbutton 4 HMI Screen (OFF, GRP, GLB, MET, OP_CNT, V_LIM, LDC, HARM, DEMAND)	**PB04HMI :=** __________
Pushbutton 5 HMI Screen (OFF, GRP, GLB, MET, OP_CNT, V_LIM, LDC, HARM, DEMAND)	**PB05HMI :=** __________
Pushbutton 6 HMI Screen (OFF, GRP, GLB, MET, OP_CNT, V_LIM, LDC, HARM, DEMAND)	**PB06HMI :=** __________
Pushbutton 7 HMI Screen (OFF, GRP, GLB, MET, OP_CNT, V_LIM, LDC, HARM, DEMAND)	**PB07HMI :=** __________

Report Settings

(Serial Port Command SET R)

SER Chatter Criteria

(see *SER Report* on page 11.8)

Auto-Removal Enable (Y, N) **ESERDEL :=** __________

Make the following settings when ESERDEL := Y.

Number of Counts (2–20) **SRDLCNT :=** __________

Removal Time (0.5–90.0 seconds) **SRDLTIM :=** __________

Set Trigger List

Enter as many as 96 Device Word elements. The SER Trigger List entries are Text-Edit mode settings, with line number prompts. The following Text-Edit mode actions are available (**SET** command).

Action	Control 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.

Action	Control Response
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.

1 := ______	**2 :=** ______	**3 :=** ______	**4 :=** ______
5 := ______	**6 :=** ______	**7 :=** ______	**8 :=** ______
9 := ______	**10 :=** ______	**11 :=** ______	**12 :=** ______
13 := ______	**14 :=** ______	**15 :=** ______	**16 :=** ______
17 := ______	**18 :=** ______	**19 :=** ______	**20 :=** ______
21 := ______	**22 :=** ______	**23 :=** ______	**24 :=** ______
25 := ______	**26 :=** ______	**27 :=** ______	**28 :=** ______
29 := ______	**30 :=** ______	**31 :=** ______	**32 :=** ______
33 := ______	**34 :=** ______	**35 :=** ______	**36 :=** ______
37 := ______	**38 :=** ______	**39 :=** ______	**40 :=** ______
41 := ______	**42 :=** ______	**43 :=** ______	**44 :=** ______
45 := ______	**46 :=** ______	**47 :=** ______	**48 :=** ______
49 := ______	**50 :=** ______	**51 :=** ______	**52 :=** ______
53 := ______	**54 :=** ______	**55 :=** ______	**56 :=** ______
57 := ______	**58 :=** ______	**59 :=** ______	**60 :=** ______
61 := ______	**62 :=** ______	**63 :=** ______	**64 :=** ______
65 := ______	**66 :=** ______	**67 :=** ______	**68 :=** ______
69 := ______	**70 :=** ______	**71 :=** ______	**72 :=** ______
73 := ______	**74 :=** ______	**75 :=** ______	**76 :=** ______
77 := ______	**78 :=** ______	**79 :=** ______	**80 :=** ______
81 := ______	**82 :=** ______	**83 :=** ______	**84 :=** ______
85 := ______	**86 :=** ______	**87 :=** ______	**88 :=** ______
89 := ______	**90 :=** ______	**91 :=** ______	**92 :=** ______
93 := ______	**94 :=** ______	**95 :=** ______	**96 :=** ______

Event Report Settings

(see *Event Reporting* on page 11.1)

Event Report Trigger SELOGIC equation

ER := ______________________________

Length of Pre-Trigger in Event Report (1–29 cycles in 1-cycle steps) **PRE :=** __________

Signal Profile Settings

(see *Signal Profile Recorder* on page 7.28)

The Signal Profile Analog Label List entries are text-edit mode settings, with line number prompts. See the table in SER Trigger List on page SET.18 for the available text-edit mode actions.

Signal Profile List

Enter as many as 16 Analog Quantities.

1 := ______	**2 :=** ______	**3 :=** ______	**4 :=** ______
5 := ______	**6 :=** ______	**7 :=** ______	**8 :=** ______
9 := ______	**10 :=** ______	**11 :=** ______	**12 :=** ______
13 := ______	**14 :=** ______	**15 :=** ______	**16 :=** ______

SP Acquisition Rate (5, 10, 15, 30, 60 min) **SPAR :=** ______

Signal Profile Enable (SELOGIC equation)

SPEN := ______

SET PORT p (p = F, 1, or 2) Command (Serial Ports Only[4])

Protocol Selection

Protocol (SEL[a], DNP[b]) **PROTO :=** ______
Hidden and set to SEL on Port F.

[a] SEL: Standard SEL ASCII protocol (see *Table 9.8*). Not available on ports with 2-Wire EIA-485 cards.
[b] DNP: Distributed Network Protocol (see *Appendix D: DNP3 Communications*). Only available on Port 1 and Port 2.

Communications Settings for PROTO := SEL

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600)[a]	**SPEED :=** ______
Data Bits (7, 8)	**BITS :=** ______
Parity (O, E, N)	**PARITY :=** ______
Stop Bits (1, 2)	**STOP :=** ______
Enable Hardware Handshaking (Y, N)	**RTSCTS[b] :=** ______
Minutes to Port Time-Out (0–30)	**T_OUT[c] :=** ______
Send Auto Messages to Port (Y, N)	**AUTO[d] :=** ______
Fast Operate Enable (Y, N)	**FASTOP[e] :=** ______

[a] SPEED := 57600 not available on serial Port F. SPEED := 57600 not allowed on Ports 1 or 2 if ordered as V-pin fiber-optic ports.
[b] Set RTSCTS := Y to enable hardware handshaking. With RTSCTS := Y, the SEL-2431 will not send characters until the CTS input is asserted. Also, if the voltage regulator control is unable to receive characters, it deasserts the RTS line (see *Hardware Flow Control* on page 9.9). This setting is only available on EIA-232 ports.
[c] Set T_OUT to the number of minutes of serial port inactivity for an automatic logout. Set T_OUT := 0 for no port time out (see *Serial Port Time-Out* on page 9.12).
[d] Set AUTO := Y to allow automatic messages at the serial port (see *Table 9.10*).
[e] Set FASTOP := Y to enable binary Fast Operate messages at the serial port. Set FASTOP := N to block binary Fast Operate messages. Refer to *Control Points* on page C.21 for the description of the SEL-2431 Fast Operate commands.

Communications Settings for PROTO := DNP

(see *Appendix D: DNP3 Communications*)

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400, 57600)[a]	**SPEED :=** ______
Minutes to Port Time-Out (1–30)	**T_OUT :=** ______
DNP Address (0–65519)	**DNPADR :=** ______

[4] If port slot 2 contains a serial communications card, it is referred to as Port 2. If port slot 2 contains a dual Ethernet card, it is referred to as Port E.

DNP Address to Report to (0–65519)	**REPADR :=** ______________
Make setting DNPECHO for fiber-optic ports.	
Enable the Echoing of the Received Messages (Y, LOOP1ST, LOOPLAST, N)	**DNPECHO :=** ______________
DNP Map (1, 2)	**DNPMAP :=** ______________
Analog Input Default Variation (1–6)	**DVARAI :=** ______________
Class for Binary Event Data (0–3)[b]	**ECLASSB :=** ______________
Class for Counter Event Data (0–3)[b]	**ECLASSC :=** ______________
Class for Analog Event Data (0–3)[b]	**ECLASSA :=** ______________
Currents Scaling Decimal Places (0–3)	**DECPLA :=** ______________
Voltages Scaling Decimal Places (0–3)	**DECPLV :=** ______________
Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM :=** ______________
Make settings ANADBA and ANADBV when ECLASSA ≠ 0.	
Amperes Reporting Deadband Counts (0–32767)	**ANADBA :=** ______________
Volts Reporting Deadband Counts (0–32767)	**ANADBV :=** ______________
Make setting ANADBM when ECLASSA or ECLASSC is set to non-zero values.	
Miscellaneous Data Reporting Deadband Counts (0–32767)	**ANADBM :=** ______________
Minutes for Request Interval (I, M, 1–32767 minutes)	**TIMERQ :=** ______________
Seconds to Select/Operate Time-Out (0.0–30.0 seconds)	**STIMEO :=** ______________
Data Link Retries (0–15)	**DRETRY :=** ______________
Make setting DTIMEO when DRETRY > 0.	
Seconds to Data Link Time-Out (0–5 seconds)	**DTIMEO :=** ______________
Event Message Confirm Time-Out (1–50 seconds)	**ETIMEO :=** ______________
Make setting UNSOL when settings ECLASSA, ECLASSB, or ECLASSC are set to nonzero values.	
Enable Unsolicited Reporting (Y, N)	**UNSOL :=** ______________
Make settings PUNSOL, NUMEVE, AGEEVE, URETRY, and UTIMEO when UNSOL := Y.	
Enable Unsolicited Reporting at Power-Up (Y, N)	**PUNSOL :=** ______________
Number of Events to Transmit On (1–200)	**NUMEVE :=** ______________
Oldest Event to Tx On (0.0–99999 seconds)	**AGEEVE :=** ______________
Unsolicited Message Max Retry Attempts (2–10)	**URETRY :=** ______________
Unsolicited Message Offline Time-Out (1–5000 seconds)	**UTIMEO[c] :=** ______________
Minimum Seconds from DCD to TX (0.00–1.00 seconds)	**MINDLY :=** ______________
Maximum Seconds from DCD to TX (0.00–1.00 seconds)	**MAXDLY[d] :=** ______________
Settle Time from RTS On to TX (OFF, 0.00–30.00 seconds)	**PREDLY :=** ______________
Make setting PSTDLY when PREDLY ≠ OFF.	
Settle Time From TX to RTS OFF (0.00–30.00 seconds)	**PSTDLY :=** ______________

[a] SPEED := 57600 not allowed on Ports 1 or 2 if ordered as V-pin fiber-optic ports.
[b] Selecting 0 disables event data.
[c] UTIMEO must be set greater than or equal to ETIMEO.
[d] MAXDL must be greater than MINDLY.

SET PORT E Command

(Dual Ethernet Port in Slot 2; Hidden if Ethernet Option Not Included)

IP Address(zzz.yyy.xxx.www)	**IPADDR :=** ____________
Subnet Mask (zzz.yyy.xxx.www)	**SUBNETM :=** ____________
Default Router (zzz.yyy.xxx.www)	**DEFRTR :=** ____________
Enable Telnet (Y, N)	**ETELNET :=** ____________
Telnet Port (23, 1025–65534) *Shown only when ETELNET := Y.*	**TPORT :=** ____________
Telnet Time-Out (1–30 min) *Shown only when ETELNET := Y.*	**TIDLE :=** ____________
Send Auto Messages to Port (Y, N)	**AUTO :=** ____________
Fast Operate Enable (Y,N) *Shown only when ETELNET := Y.* Set FASTOP := Y to enable binary Fast Operate messages on the Telnet session. Set FASTOP := N to block binary Fast Operate messages. Refer to *Control Points* on page C.21 for the description of the SEL-2431 Fast Operate commands.	**FASTOP :=** ____________

Port E DNP3 Protocol

(see *Appendix D: DNP3 Communications*)

Enable DNP Sessions (0–6) *Note that the total number of DNP3 sessions is 6. This number is the combination of both the serial and Ethernet DNP3 sessions.*	**EDNP :=** ____________

NOTE: All DNP3 Protocol settings are hidden if EDNP := 0.

DNP TCP and UDP Port (1–65534)	**DNPNUM :=** ____________
DNP Address (0–65519)	**DNPADR :=** ____________

NOTE: For IP Sessions 1–6, the IP address of 0.0.0.0 is for the anonymous DNP. The anonymous DNP is only supported for TCP protocol. If an anonymous DNP is used, it must be the highest DNP session.

DNP IP Session 1

IP Address (zzz.yyy.xxx.www) (15 characters)	**DNPIP1 :=** ____________
Transport Protocol (UDP, TCP)	**DNPTR1 :=** ____________
UDP Response Port (REQ, 1–65534) *Hidden if DNPTR1 ≠ UDP.*	**DNPUDP1 :=** ____________
DNP Address to Report to (0–65519)	**REPADR1 :=** ____________
DNP Map (1–2)	**DNPMAP1 :=** ____________
Analog Input Default Variation (1–6)	**DVARAI1 :=** ____________
Class for Binary Event Data (0–3)[a]	**ECLASSB1 :=** ____________
Class for Counter Event Data (0–3)[a]	**ECLASSC1 :=** ____________
Class for Analog Event Data (0–3)[a]	**ECLASSA1 :=** ____________
Currents Scaling Decimal Places (0–3)	**DECPLA1 :=** ____________
Voltages Scaling Decimal Places (0–3)	**DECPLV1 :=** ____________

Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM1 :=** ______
Amperes Reporting Deadband Counts (0–32767) *Hidden if ECLASSA1 := 0.*	**ANADBA1 :=** ______
Volts Reporting Deadband Counts (0–32767) *Hidden if ECLASSA1 := 0*	**ANADBV1 :=** ______
Misc Data Reporting Deadband Counts (0–32767) *Hidden if ECLASSA1 := 0 and ECLASSC1 := 0.*	**ANADBM1 :=** ______
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ1 :=** ______
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO1 :=** ______
Seconds to Send Data Link Heartbeat (0–7200) *Hidden if DNPTR1 := UDP.*	**DNPINA1 :=** ______
Event Message Confirm Time-Out (1–50 s)	**ETIMEO1 :=** ______
Enable Unsolicited Reporting (Y, N) *Hidden if ECLASSA1 := 0, ECLASSB1 := 0, ECLASSC1 := 0, and ECLASSV1 := 0.*	**UNSOL1 :=** ______
Enable Unsolicited Reporting at Power-Up (Y, N) *Hidden if UNSOL1 := N.*	**PUNSOL1 :=** ______
Number of Events to Transmit On (1–200) *Hidden if UNSOL1 := N.*	**NUMEVE1 :=** ______
Oldest Event to Tx On (0.0–99999.0 s) *Hidden if UNSOL1 := N.*	**AGEEVE1 :=** ______
Unsolicited Message Max Retry Attempts (2–10) *Hidden if UNSOL1 := N.*	**URETRY1 :=** ______
Unsolicited Message Offline Time-Out (1–5000 s) *Hidden if UNSOL1 := N.*	**UTIMEO1 :=** ______

[a] Selecting 0 disables event data.

Session 2 (All DNP Session 2 Settings Are Hidden if EDNP < 2)

IP Address (zzz.yyy.xxx.www) (15 characters)	**DNPIP2 :=** ______
Transport Protocol (UDP, TCP)	**DNPTR2 :=** ______
UDP Response Port (REQ, 1–65534) *Hidden if DNPTR2 < UDP.*	**DNPUDP2 :=** ______
DNP Address to Report to (0–65519)	**REPADR2 :=** ______
DNP Map (1–2)	**DNPMAP2 :=** ______
Analog Input Default Variation (1–6)	**DVARAI2 :=** ______
Class for Binary Event Data (0–3)[a]	**ECLASSB2 :=** ______
Class for Counter Event Data (0–3)[a]	**ECLASSC2 :=** ______
Class for Analog Event Data (0–3)[a]	**ECLASSA2 :=** ______
Currents Scaling Decimal Places (0–3)	**DECPLA2 :=** ______
Voltages Scaling Decimal Places (0–3)	**DECPLV2 :=** ______
Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM2 :=** ______
Amperes Reporting Deadband Counts (0–32767) *Hidden if ECLASSA2 := 0.*	**ANADBA2 :=** ______
Volts Reporting Deadband Counts (0–32767) *Hidden if ECLASSA2 := 0.*	**ANADBV2 :=** ______

Misc Data Reporting Deadband Counts (0–32767) *Hidden if ECLASSA2 := 0 and ECLASSC2 := 0.*	**ANADBM2 :=** ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ2 :=** ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO2 :=** ________
Seconds to Send Data Link Heartbeat (0–7200) *Hidden if DNPTR2 := UDP.*	**DNPINA2 :=** ________
Event Message Confirm Time-Out (1–50 s)	**ETIMEO2 :=** ________
Enable Unsolicited Reporting (Y, N) *Hidden if ECLASSA2 := 0, ECLASSB2 := 0, ECLASSC2 := 0, and ECLASSV2 := 0.*	**UNSOL2 :=** ________
Enable Unsolicited Reporting at Power-Up (Y, N) *Hidden if UNSOL2 := N.*	**PUNSOL2 :=** ________
Number of Events to Transmit On (1–200) *Hidden if UNSOL2 := N.*	**NUMEVE2 :=** ________
Oldest Event to Tx On (0.0–99999.0 s) *Hidden if UNSOL2 := N.*	**AGEEVE2 :=** ________
Unsolicited Message Max Retry Attempts (2–10) *Hidden if UNSOL2 := N.*	**URETRY2 :=** ________
Unsolicited Message Offline Time-Out (1–5000 s) *Hidden if UNSOL2 := N.*	**UTIMEO2 :=** ________

[a] Selecting 0 disables event data.

Session 3 (All DNP Session 3 Settings Are Hidden if EDNP < 3)

IP Address (zzz.yyy.xxx.www) (15 characters)	**DNPIP3 :=** ________
Transport Protocol (UDP, TCP)	**DNPTR3 :=** ________
UDP Response Port (REQ, 1–65534) *Hidden if DNPTR3 < UDP.*	**DNPUDP3 :=** ________
DNP Address to Report to (0–65519)	**REPADR3 :=** ________
DNP Map (1–2)	**DNPMAP3 :=** ________
Analog Input Default Variation (1–6)	**DVARAI3 :=** ________
Class for Binary Event Data (0–3)[a]	**ECLASSB3 :=** ________
Class for Counter Event Data (0–3)[a]	**ECLASSC3 :=** ________
Class for Analog Event Data (0–3)[a]	**ECLASSA3 :=** ________
Currents Scaling Decimal Places (0–3)	**DECPLA3 :=** ________
Voltages Scaling Decimal Places (0–3)	**DECPLV3 :=** ________
Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM3 :=** ________
Amperes Reporting Deadband Counts (0–32767) *Hidden if ECLASSA3 := 0.*	**ANADBA3 :=** ________
Volts Reporting Deadband Counts (0–32767) *Hidden if ECLASSA3 := 0.*	**ANADBV3 :=** ________
Misc Data Reporting Deadband Counts (0–32767) *Hidden if ECLASSA3 := 0 and ECLASSC3 := 0.*	**ANADBM3 :=** ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ3 :=** ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO3 :=** ________

Seconds to Send Data Link Heartbeat (0–7200) *Hidden if DNPTR3 := UDP.*	**DNPINA3 :=** ______________
Event Message Confirm Time-Out (1–50 s)	**ETIMEO3 :=** ______________
Enable Unsolicited Reporting (Y, N) *Hidden if ECLASSA3 := 0, ECLASSB3 := 0, ECLASSC3 := 0, and ECLASSV3 := 0.*	**UNSOL3 :=** ______________
Enable Unsolicited Reporting at Power-Up (Y, N) *Hidden if UNSOL3 := N.*	**PUNSOL3 :=** ______________
Number of Events to Transmit On (1–200) *Hidden if UNSOL3 := N.*	**NUMEVE3 :=** ______________
Oldest Event to Tx On (0.0–99999.0 s) *Hidden if UNSOL3 := N.*	**AGEEVE3 :=** ______________
Unsolicited Message Max Retry Attempts (2–10) *Hidden if UNSOL3 := N.*	**URETRY3 :=** ______________
Unsolicited Message Offline Time-Out (1–5000 s) *Hidden if UNSOL3 := N.*	**UTIMEO3 :=** ______________

[a] Selecting 0 disables event data.

Session 4 (All DNP Session 4 Settings Are Hidden if EDNP < 4)

IP Address (zzz.yyy.xxx.www) (15 characters)	**DNPIP4 :=** ______________
Transport Protocol (UDP, TCP)	**DNPTR4 :=** ______________
UDP Response Port (REQ, 1–65534) *Hidden if DNPTR4 < UDP.*	**DNPUDP4 :=** ______________
DNP Address to Report to (0–65519)	**REPADR4 :=** ______________
DNP Map (1–2)	**DNPMAP4 :=** ______________
Analog Input Default Variation (1–6)	**DVARAI4 :=** ______________
Class for Binary Event Data (0–3)[a]	**ECLASSB4 :=** ______________
Class for Counter Event Data (0–3)[a]	**ECLASSC4 :=** ______________
Class for Analog Event Data (0–3)[a]	**ECLASSA4 :=** ______________
Currents Scaling Decimal Places (0–3)	**DECPLA4 :=** ______________
Voltages Scaling Decimal Places (0–3)	**DECPLV4 :=** ______________
Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM4 :=** ______________
Amperes Reporting Deadband Counts (0–32767) *Hidden if ECLASSA4 := 0.*	**ANADBA4 :=** ______________
Volts Reporting Deadband Counts (0–32767) *Hidden if ECLASSA4 := 0.*	**ANADBV4 :=** ______________
Misc Data Reporting Deadband Counts (0–32767) *Hidden if ECLASSA4 := 0 and ECLASSC4 := 0.*	**ANADBM4 :=** ______________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ4 :=** ______________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO4 :=** ______________
Seconds to Send Data Link Heartbeat (0–7200) *Hidden if DNPTR4 := UDP*	**DNPINA4 :=** ______________
Event Message Confirm Time-Out (1–50 s)	**ETIMEO4 :=** ______________

Enable Unsolicited Reporting (Y, N) *Hidden if ECLASSA4 := 0, ECLASSB4 := 0, ECLASSC4 := 0, and ECLASSV4 := 0.*	**UNSOL4 :=** ________
Enable Unsolicited Reporting at Power-Up (Y, N) *Hidden if UNSOL4:= N.*	**PUNSOL4 :=** ________
Number of Events to Transmit On (1–200) *Hidden if UNSOL4 := N.*	**NUMEVE4 :=** ________
Oldest Event to Tx On (0.0–99999.0 s) *Hidden if UNSOL4 := N.*	**AGEEVE4 :=** ________
Unsolicited Message Max Retry Attempts (2–10) *Hidden if UNSOL4 := N.*	**URETRY4 :=** ________
Unsolicited Message Offline Time-Out (1–5000 s) *Hidden if UNSOL4 := N.*	**UTIMEO4 :=** ________

[a] Selecting 0 disables event data.

Session 5 (All DNP Session 5 Settings Are Hidden if EDNP < 5)

IP Address (zzz.yyy.xxx.www) (15 characters)	**DNPIP5 :=** ________
Transport Protocol (UDP, TCP)	**DNPTR5 :=** ________
UDP Response Port (REQ, 1–65534) *Hidden if DNPTR5 < UDP.*	**DNPUDP5 :=** ________
DNP Address to Report to (0–65519)	**REPADR5 :=** ________
DNP Map (1–2)	**DNPMAP5 :=** ________
Analog Input Default Variation (1–6)	**DVARAI5 :=** ________
Class for Binary Event Data (0–3)[a]	**ECLASSB5 :=** ________
Class for Counter Event Data (0–3)[a]	**ECLASSC5 :=** ________
Class for Analog Event Data (0–3)[a]	**ECLASSA5 :=** ________
Currents Scaling Decimal Places (0–3)	**DECPLA5 :=** ________
Voltages Scaling Decimal Places (0–3)	**DECPLV5 :=** ________
Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM5 :=** ________
Amperes Reporting Deadband Counts (0–32767) *Hidden if ECLASSA5 := 0.*	**ANADBA5 :=** ________
Volts Reporting Deadband Counts (0–32767) *Hidden if ECLASSA5 := 0.*	**ANADBV5 :=** ________
Misc Data Reporting Deadband Counts (0–32767) *Hidden if ECLASSA5 := 0 and ECLASSC5 := 0.*	**ANADBM5 :=** ________
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ5 :=** ________
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO5 :=** ________
Seconds to send Data Link Heartbeat (0–7200) *Hidden if DNPTR5 := UDP.*	**DNPINA5 :=** ________
Event Message Confirm Time-Out (1–50 s)	**ETIMEO5 :=** ________
Enable Unsolicited Reporting (Y, N) *Hidden if ECLASSA5 := 0, ECLASSB5 := 0, ECLASSC5 := 0, and ECLASSV5 := 0.*	**UNSOL5 :=** ________
Enable Unsolicited Reporting at Power-Up (Y, N) *Hidden if UNSOL5 := N.*	**PUNSOL5 :=** ________

Number of Events to Transmit On (1–200) *Hidden if UNSOL5 := N.*	**NUMEVE5 :=** ______
Oldest Event to Tx On (0.0–99999.0 s) *Hidden if UNSOL5 := N.*	**AGEEVE5 :=** ______
Unsolicited Message Max Retry Attempts (2–10) *Hidden if UNSOL5 := N.*	**URETRY5 :=** ______
Unsolicited Message Offline Time-Out (1–5000 s) *Hidden if UNSOL5 := N.*	**UTIMEO5 :=** ______

[a] Selecting 0 disables event data.

Session 6 (All DNP Session 6 Settings Are Hidden if EDNP < 6)

IP Address (zzz.yyy.xxx.www) (15 characters)	**DNPIP6 :=** ______
Transport Protocol (UDP, TCP)	**DNPTR6 :=** ______
UDP Response Port (REQ, 1–65534) *Hidden if DNPTR6 < UDP.*	**DNPUDP6 :=** ______
DNP Address to Report to (0–65519)	**REPADR6 :=** ______
DNP Map (1–2)	**DNPMAP6 :=** ______
Analog Input Default Variation (1–6)	**DVARAI6 :=** ______
Class for Binary Event Data (0–3)[a]	**ECLASSB6 :=** ______
Class for Counter Event Data (0–3)[a]	**ECLASSC6 :=** ______
Class for Analog Event Data (0–3)[a]	**ECLASSA6 :=** ______
Currents Scaling Decimal Places (0–3)	**DECPLA6 :=** ______
Voltages Scaling Decimal Places (0–3)	**DECPLV6 :=** ______
Miscellaneous Data Scaling Decimal Places (0–3)	**DECPLM6 :=** ______
Amperes Reporting Deadband Counts (0–32767) *Hidden if ECLASSA6 := 0.*	**ANADBA6 :=** ______
Volts Reporting Deadband Counts (0–32767) *Hidden if ECLASSA6 := 0.*	**ANADBV6 :=** ______
Misc Data Reporting Deadband Counts (0–32767) *Hidden if ECLASSA6 := 0 and ECLASSC6 := 0.*	**ANADBM6 :=** ______
Minutes for Request Interval (I, M, 1–32767)	**TIMERQ6 :=** ______
Seconds to Select/Operate Time-Out (0.0–30.0)	**STIMEO6 :=** ______
Seconds to send Data Link Heartbeat (0–7200) *Hidden if DNPTR6 := UDP.*	**DNPINA6 :=** ______
Event Message Confirm Time-Out (1–50 s)	**ETIMEO6 :=** ______
Enable Unsolicited Reporting (Y, N) *Hidden if ECLASSA6 := 0, ECLASSB6 := 0, ECLASSC6 := 0, and ECLASSV6 := 0.*	**UNSOL6 :=** ______
Enable Unsolicited Reporting at Power-Up (Y, N) *Hidden if UNSOL6 := N.*	**PUNSOL6 :=** ______
Number of Events to Transmit On (1–200) *Hidden if UNSOL6 := N.*	**NUMEVE6 :=** ______

Oldest Event to Tx On (0.0–99999.0 s) **AGEEVE6 :=** ______________
Hidden if UNSOL6 := N.

Unsolicited Message Max Retry Attempts (2–10) **URETRY6 :=** ______________
Hidden if UNSOL6 := N.

Unsolicited Message Offline Time-Out (1–5000 s) **UTIMEO6 :=** ______________
Hidden if UNSOL6 := N.

[a] Selecting 0 disables event data.

SEL Synchrophasor Protocol Settings (Hidden if EPMU := N)

Enable PMU Processing (0–2) **EPMIP :=** ______________

PMU Output 1 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U) **PMOTS1 :=** ______________
Hidden if EPMIP: = 0.

PMU Output 1 Client IP Address (zzz.yyy.xxx.www) (15 characters) **PMOIPA1 :=** ______________
Hidden if PMOTS1: = OFF.

Note: PMOIPA1 cannot be set to the same address as IPADDR.

PMU Output 1 TCP/IP Data Port Number (1–65534) **PMOTCP1 :=** ______________
Shown only when EPMIP ≠ 0 and PMOTS1 :≠ UDP_S.

Note: PMOTCP1 cannot be set to the same number as PMOTCP2.

PMU Output 1 UDP/IP Data Port Number (1–65534) **PMOUDP1 :=** ______________
Shown only when EPMIP ≠ 0 and PMOTS1 :≠ TCP.

PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U) **PMOTS2 :=** ______________
Hidden if EPMIP := 0 or 1.

PMU Output 2 Client IP Address (zzz.yyy.xxx.www) (15 characters) **PMOIPA2 :=** ______________
Hidden if PMOTS2 := OFF.

Note: PMOIPA2 cannot be set to the same address as IPADDR.

PMU Output 2 TCP/IP Port Number (1–65534) **PMOTCP2 :=** ______________
Shown only when EPMIP := 2 and PMOTS2 :≠ UDP_S.

Note: PMOTCP2 cannot be set to the same number as PMOTCP1.

PMU Output 2 UDP/IP Data Port Number (1–65534) **PMOUDP2 :=** ______________
Shown only when EPMIP := 2 and PMOTS2 :≠ TCP.

SECTION 9

Communications

Introduction

The SEL-2431 Voltage Regulator Control has several communications port interfaces, as shown in *Table 9.1*. Use the communications ports to establish local and remote communications with the device over serial or Ethernet networks, with either copper or fiber medium.

The first part of this section describes the communications interfaces available on the SEL-2431. It also describes how to establish local communications with the device using the front serial port and the SEL ASCII communications protocol. Other parts of this section provide information about the communications protocols available on the various interfaces, as well as reference information to help you use communications ports to establish local and remote communications for engineering access, SCADA communications, and synchrophasor data collection. Use of actual communications protocols such as DNP is covered in various appendices of this manual.

Establishing Communications Using an EIA-232 Serial Port

To connect a PC serial port to an SEL-2431 serial port and enter device commands, you will need the following:

- ➤ A personal computer equipped with one available EIA-232 serial port with a serial communications cable or a personal computer equipped with one available USB port and a USB-to-serial adapter like the SEL-C662 cable.
- ➤ Terminal emulation software to control the computer serial port.
- ➤ An SEL-2431 voltage regulator control.

A variety of terminal emulation programs on personal computers can communicate with the voltage regulator control.

For the best display, use VT-100 terminal emulation or the closest variation.

The default settings for all serial ports are:

- ➤ Baud Rate = 9600
- ➤ Data Bits = 8
- ➤ Parity = N
- ➤ Stop Bits = 1

To change the port settings, use the **SET P** command (see *Section 8: Settings*) or the front panel. *Set/Show Menu* on page 10.29 provides details on making settings with the front panel.

Establishing Communications Using an Ethernet Port and Telnet

Factory-default settings for the Ethernet ports disable all Ethernet protocols except PING. Enable the Telnet protocols with the **SET P E** command using any of the serial ports.

See *SET PORT E Command* on page SET.22 for the Port E settings sheets.

Use the **SET P E** command to make the following settings:

- ➤ IPADDR = IP Address assigned by network administrator
- ➤ SUBNETM = Subnet mask assigned by network administrator
- ➤ DEFRTR = Default router IP Address assigned by network administrator
- ➤ ETELNET = Y

Leave all other settings at their default values.

Connect an Ethernet cable between your PC or a network switch and any Ethernet port on the device. Verify that the Link LED illuminates on the connected relay port. The SEL-2431 supports autocrossover, so nearly any Cat 5 Ethernet cable with RJ45 connectors, such as an SEL-C627 cable, will work. For multimode fiber-optic Ethernet ports, use the SEL-C807 62.5 µm fiber-optic cable with LC connectors. Use a Telnet application or QuickSet on the host PC to communicate with the relay. To terminate a Telnet session, use the command **EXI <Enter>** from any access level.

Communications Interfaces

The SEL-2431 supports two types of communications interfaces, serial (DB-9, 3pin Euro, V-pin, and ST connectors) and Ethernet (RJ45 and LC connectors). Location of communications ports and time-synchronization source (IRIG-B) options are shown in *Table 9.1*.

Port 1 communications cards can be ordered with the SEL-2431 or they can be ordered at a later date and installed in the field. Port 2 serial communications cards can be ordered with the SEL-2431 or installed in the field if the SEL-2431 was ordered with an X (Future Serial Compatible) in the communications port (Port 2) character of the Model Option Table. Port 2 dual Ethernet cards can be ordered with the SEL-2431 or installed in the field if the SEL-2431 was ordered with a “0” (Future Ethernet Compatible) in the communications port (Port 2) character of the Model Option Table. The communications card in Port 2/E cannot be changed from serial to Ethernet or from Ethernet to serial.

Table 9.1 SEL-2431 Communications Port Interfaces (Sheet 1 of 2)

Port	Communications Port Interface	Location	Feature	IRIG-B
Port F	EIA-232 (DB-9 Connector)	Front	Standard	No
Port 1	EIA-232 (DB-9 Connector)	Rear	Optional	Yes
Port 1	4-Wire EIA-485 (DB-9 Connector)	Rear	Optional	Yes
Port 1	2-Wire EIA-485 (3-pin Euro)	Rear	Optional	No
Port 1	200 µm, Multimode Fiber Optic, (V-pin Connectors)[a]	Rear	Optional	Yes[b]
Port 1	62.5 µm, Multimode Fiber Optic, (ST Connectors)[c]	Rear	Optional	Yes[b,d]
Port 2	EIA-232 (DB-9 Connector)	Rear	Optional	No

Table 9.1 SEL-2431 Communications Port Interfaces (Sheet 2 of 2)

Port	Communications Port Interface	Location	Feature	IRIG-B
Port 2	4-Wire EIA-485 (DB-9 Connector)	Rear	Optional	No
Port 2	2-Wire EIA-485 (3-pin Euro)	Rear	Optional	No
Port 2	200 µm, Multimode Fiber Optic, (V-pin Connectors)[a]	Rear	Optional	No
Port 2	62.5 µm, Multimode Fiber Optic, (ST Connectors)[c]	Rear	Optional	No
Port E[e]	Two 10/100BASE-T Copper 100 m Distance[f]	Rear	Optional[g]	No
Port E[e]	One 10/100BASE-T Copper 100 m Distance[f] and One 100BASE-FX Multimode Fiber 2 km Distance[h]	Rear	Optional[g]	No
Port E[e]	Two 100BASE-FX Multimode Fiber 2 km Distance[h]	Rear	Optional[g]	No
Port E[e]	Two 100BASE-LX Single-Mode Fiber 10 km Distance[h]	Rear	Optional[g]	No
Port E[e]	One 10/100BASE-T Copper 100 m Distance[f] and One 100BASE-LX Single-Mode Fiber 10 km Distance[h]	Rear	Optional[g]	No

[a] The 200 µm, Multimode Fiber Optic, (V-Pin Connectors) communication port is compatible with the SEL-2800 Fiber-Optic Transceiver and the SEL-2810 Fiber-Optic Transceiver With IRIG-B.
[b] This card accepts IRIG-B time, but the time will not be of sufficient accuracy for synchrophasors (TSOK may not stay asserted).
[c] The 62.5 µm, Multimode Fiber Optic, (ST Connectors) communication port is compatible with SEL-2812 Fiber-Optic Transceiver With IRIG-B.
[d] The 62.5 µm card (with ST connectors) can be configured to pass IRIG-B time code signals to the next device in a ring connection. See IRIG-B.
[e] When a dual Ethernet card is installed in the rear Port 2, it is called Port E rather than Port 2.
[f] Copper Ethernet ports use RJ45 connectors.
[g] Ethernet is available on units ordered with an Ethernet card installed or with the Future Ethernet Compatibility option. Ethernet is only field-upgradeable on units ordered with the Future Ethernet Compatibility option.
[h] Fiber Ethernet ports use LC connectors.

Ethernet Port

Use the Ethernet port to interface with an Ethernet network environment. SEL-2431 Ethernet port choices include dual copper, dual fiber-optic, or copper and fiber-optic configurations. With dual Ethernet ports, the unit acts as an unmanaged Ethernet switch. This means both links are enabled and the device responds to the messages it receives on either port. For messages not addressed to the device, it retransmits the message out the other port without modification.

The copper Ethernet ports in the SEL-2431 can take either a straight-through or crossover cable.

Figure 9.1 shows an example of a simple daisy-chained Ethernet network configuration. The advantage of daisy-chaining the devices is that an Ethernet switch does not need to be installed near the devices.

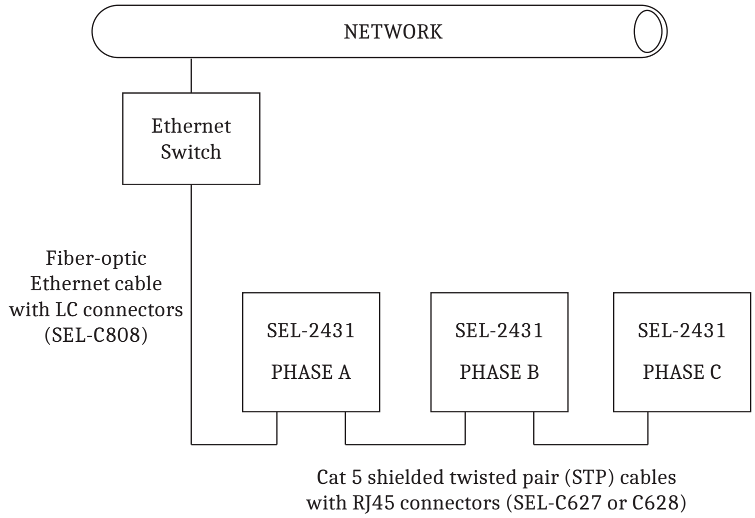


Figure 9.1 Simple Daisy-Chained Ethernet Network Configuration

Table 9.2 shows the fiber-optic Ethernet communications card parameters.

Table 9.2 Fiber-Optic Ethernet Communications Card Parameters

	Single-mode (LX10)	Multimode (FX)	
Standard:	100BASE-LX10	100BASE-FX	
Fiber Size:	9/125 µm	62.5/125 µm	50/125 µm
Maximum TX Power:	–8 dBm	–14 dBm	–14 dBm
Minimum TX Power:	–15 dBm	–20 dBm	–23.5 dBm
Link Budget:	10 dB	19 dBm	15.5 dBm
RX Min. Sensitivity:	–25 dBm	–39 dBm	
Source:	Laser	LED	
Optical Connector:	LC (IEC 61754-20)	LC (IEC 61754-20)	
Approximate Range:	10 km	2 km	

Serial (EIA-232 and EIA-485) Port

Use the EIA-232 port for communications distances of as far as 15 m (50 feet) in low-noise environments. Use the EIA-485 port for communications distances as far as 1200 m (4000 feet) maximum distance. To achieve this performance, ensure proper line termination at the receiver.

EIA-485 Serial Port

Two types of EIA-485 cards are available with the SEL-2431.

4-Wire EIA-485. The 4-wire card supports full duplex communications and supports the protocols listed in *Table 9.8*.

2-Wire EIA-485. The 2-wire card supports half duplex communications and supports the protocols listed in *Table 9.8*.

The surge withstand capability of this card is significantly higher than the 4-wire card. We recommend you use this card when the communications wires are routed a long distance or installed in an area susceptible to electrical noise.

Fiber-Optic Serial Port

Use the fiber-optic port for safety and for large (500 m to 8 km) communications distances.

IRIG-B

Demodulated IRIG-B time-code signal can only be brought into the SEL-2431 via Communications Port 1 on the communications cards listed in *Table 9.1*.

An IRIG-B time-code signal can be passed from one ST fiber-optic communications card to another. This can be useful in a fiber-optic DNP ring to keep all devices in the ring synchronized to the same time reference. To pass IRIG-B on from an ST fiber-optic communications card, install jumper J1, as shown in *Figure 9.2*. Note that jumper J1 is not installed when the ST fiber-optic communications card is shipped from the factory. Although an IRIG-B signal may be brought into the device through a fiber-optic communications card, the quality of the time signal will not be sufficient for PMU quality time (PMDOK will not be asserted consistently).

⚠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.

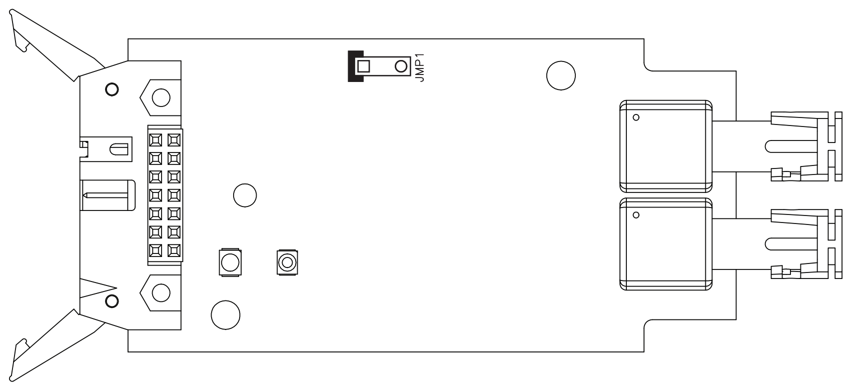


Figure 9.2 Fiber-Optic Communications Card IRIG-B Jumper Location

+5 Vdc Power Supply

Port power can provide as much as 0.5 A total from all of the +5 Vdc pins of all EIA-232 serial communications card ports. *Figure 9.3* shows the location of jumper JMP1. When jumper JMP1 is in place, Pin 1 of the EIA-232 serial communications port is +5 Vdc. When jumper JMP1 is removed, Pin 1 is not connected.

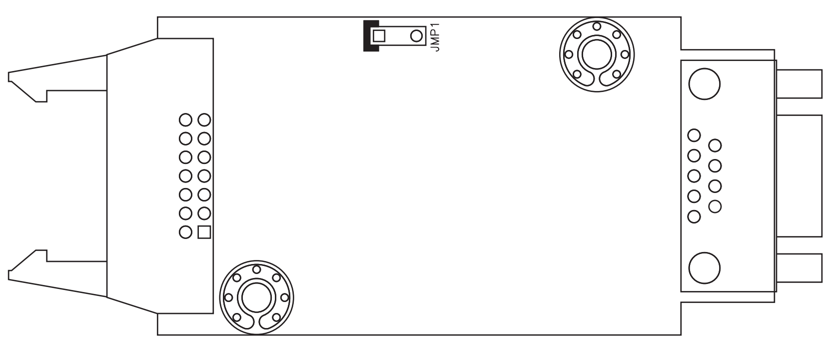


Figure 9.3 EIA-232 Serial Communications Card +5 Vdc Jumper Location

Port Connector and Communications Cables

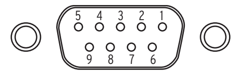


Figure 9.4 EIA-232 or 4-Wire EIA-485 Serial Port DB-9 Connector Pinout

Table 9.3 EIA-232 Serial Port Pin Functions

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

Table 9.4 4-Wire EIA-485 Serial Port Pin Functions

Pin	Port 1	Port 2
1	+TX	+TX
2	–TX	–TX
3	N/C	N/C
4	+IRIG-B	N/C
5	GND	GND
6	–IRIG-B	N/C
7	+RX	+RX
8	–RX	–RX
9	GND	GND

Table 9.5 EIA-232/4-Wire EIA-485 Serial Port Pin Function Definitions

Pin Function	Definition
N/C	No Connection
+5 Vdc (0.5 A limit)	5 Vdc Power Connection
RXD, RX	Receive Data
TXD, TX	Transmit Data
IRIG-B	IRIG-B Time-Code Input
GND	Ground
RTS	Request to Send
CTS	Clear to Send

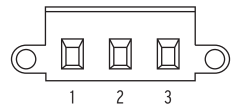


Figure 9.5 2-Wire EIA-485 Serial Port Connector Pinout

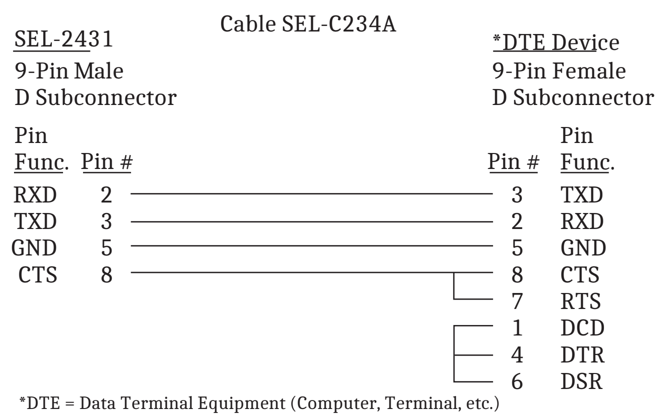
Table 9.6 2-Wire EIA-485 Serial Port Pin Functions

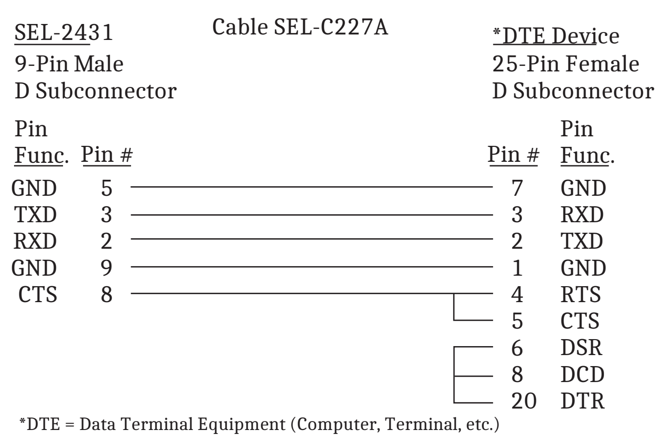
Pin	Definition
1	Ground
2	–TX/RX
3	+TX/RX

For long-distance communication as long as 500 meters and for electrical isolation of EIA-232 serial communications ports, use the SEL-2800 series of fiber-optic transceivers. Contact SEL for more details on these devices.

The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-2431 to other devices. Information on these and other cables are available by using the SEL-5801 Cable Selector Program. Contact the factory for more information.

SEL-2431 to Computer





SEL-2431 to Modem

Cable SEL-C222

SEL-2431 9-Pin Male D Subconnector			*DCE Device 25-Pin Female D Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
GND	5	—	7	GND
TXD	3	—	2	TXD (IN)
RTS	7	—	20	DTR (IN)
RXD	2	—	3	RXD (OUT)
CTS	8	—	8	CD (OUT)
GND	9	—	1	GND

*DCE = Data Communications Equipment (Modem, etc.)

SEL-2431 to SEL Communications Processor

Cable SEL-C273A

SEL Communications Processor 9-Pin Male D Subconnector			SEL-2431 9-Pin Male D Subconnector	
Pin Func.	Pin #		Pin #	Pin Func.
RXD	2	—	3	TXD
TXD	3	—	2	RXD
IRIG+	4	—	4	IRIG+
GND	5	—	5	GND
IRIG-	6	—	6	IRIG-
RTS	7	—	8	CTS
CTS	8	—	7	RTS

Serial Fiber-Optic Communications Interfaces

Table 9.7 shows the fiber-optic communications card parameters.

Table 9.7 Serial Fiber-Optic Communications Card Parameters

	ST Connector	V-Pin Connector
Wavelength	850 nm	650 nm
Optical Connector	ST	V-pin
Fiber Type	Multimode	Multimode
Link Budget	16 dB	9 dB
Typical TX	–12 dbM	–30 dbM
RX Min. Sensitivity	–24 dbM	–39 dbM
Fiber Size	50–200 µm	200 µm
Approximate Range	4 km–1.2 km	500 m
Data Rate	0–57.6 kbps	0–19.2 kbps
Time Code	IRIG-B[a]	IRIG-B[a]

[a] Only Port 1 can be used for IRIG-B time code.

Communications Protocol

Serial Protocols

The SEL-2431 serial ports support the protocols and command sets shown in *Table 9.8*.

Table 9.8 PROTO Setting and Command Sets on Serial Ports

PROTO Setting Value	Command Set	Description
SEL[a]	SEL ASCII	Commands and responses
SEL[a]	SEL Compressed ASCII	Commands and comma-delimited response
SEL[a]	Fast Meter	Binary meter and digital element commands and response
SEL[a]	Fast Operate	Binary operation command
DNP[b]	DNP3 Level 2 Slave	Binary commands and response
PMU[a,c]	IEEE C37.118	Synchrophasor data

[a] Not available on ports with 2-Wire EIA-485 cards.
[b] Available on the two rear ports.
[c] Only available if Port 1 contains an EIA-232 or 4-Wire EIA-485 card.

Hardware Flow Control

All EIA-232 serial ports support RTS/CTS hardware handshaking (hardware flow control).

To enable hardware handshaking, use the **SET P** command or front-panel `Set Port` submenu to set RTSCTS := Y. Disable hardware handshaking by setting RTSCTS := N.

- ➤ If RTSCTS := N, the voltage regulator control permanently asserts the RTS line.
- ➤ If RTSCTS := Y, the voltage regulator control deasserts RTS when it is unable to receive characters.
- ➤ If RTSCTS := Y, the voltage regulator control does not send characters until the CTS input is asserted.

Ethernet Protocols

The SEL-2431 dual Ethernet cards support the following protocols:

- ➤ DNP3 Level 2
- ➤ C37.118 Synchrophasors
- ➤ SEL ASCII and Compressed ASCII over Telnet
- ➤ SEL Fast Meter over Telnet
- ➤ SEL Fast Operate over Telnet

Session Limits

The SEL-2431 supports multiple simultaneous sessions of each supported protocol, as shown in *Table 9.9*. Ethernet will support as many as four simultaneous sessions. One of the four is reserved for Telnet if ETELNET := Y.

Table 9.9 Protocol Session Limits

Protocol	Sessions Supported
DNP3	Supports six total DNP sessions, combined serial and Ethernet
Telnet/SEL	Each serial port can have an SEL session, if PROTO is set to SEL, and Ethernet can have as many as four simultaneous Telnet sessions
PMU	Supports two total PMU sessions, combined serial and Ethernet

SEL Communications Protocols

SEL ASCII protocol is described in *SEL ASCII Protocol Details*. On a serial port, this protocol is referred to as SEL protocol. On an Ethernet port, it is referred to as a Telnet session.

SEL Compressed ASCII protocol provides compressed versions of some of the ASCII commands. The commands are described in *SEL ASCII Protocol Details* and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Meter protocol supports binary messages to transfer metering and digital element messages. ASCII commands that support the protocol are described in *SEL ASCII Protocol Details* and the protocol is described in *Appendix C: SEL Communications Processors*.

SEL Fast Operate protocol supports binary messages to transfer operation messages. The protocol is described in *Appendix C: SEL Communications Processors*.

DNP3 Level 2 Slave Communications

The voltage regulator control provides Distributed Network Protocol (DNP) slave support. DNP3 is described in *Appendix D: DNP3 Communications*.

IEEE C37.118 Synchrophasor Protocol

The voltage regulator control supports the C37.118 protocol (when provided with an IRIG time source on Port 1) as described in *Appendix H: Synchrophasors*.

SEL ASCII Protocol Details

Message Format

SEL ASCII protocol is designed for manual and automatic communication.

All commands received by the voltage regulator control must be of the following form:

<command><CR> or <command><CRLF>

NOTE: The **<Enter>** key on most keyboards is configured to send the ASCII character 13 (**<Ctrl+M>**) for a carriage return. This manual instructs you to press the **<Enter>** key after commands, which sends the proper ASCII code to the SEL-2431.

A command transmitted to the voltage regulator control consists of the command followed by either a CR (carriage return) or a CRLF (carriage return and line feed). You can truncate commands to the first three characters. For example, **SHOW 1 <Enter>** becomes **SHO 1 <Enter>**. Use upper- and lowercase characters without distinction, except in passwords.

The voltage regulator control transmits all messages in the following format:

<STX><Message Line 1><CRLF>
<Message Line 2><CRLF>
•
•
•
<Last Message Line><CRLF>< ETX>

Each message begins with the start-of-transmission character (ASCII 02) and ends with the end-of-transmission character (ASCII 03). Each line of the message ends with a carriage return and line feed.

Software Flow Control

The voltage regulator control implements XON/XOFF flow control. You can use the XON/XOFF protocol to control the voltage regulator control during data transmission. When the voltage regulator control receives XOFF during transmission, it pauses until it receives an XON character. If there is no message in progress when the voltage regulator control receives XOFF, it blocks transmission of any message presented to its buffer. Messages will be accepted after the voltage regulator control receives XON.

The voltage regulator control transmits XON (ASCII hex 11) and asserts the RTS output (if hardware handshaking is enabled) when the voltage regulator control input buffer drops below 25 percent full.

The voltage regulator control transmits XOFF (ASCII hex 13) when the buffer is more than 75 percent full. If hardware handshaking is enabled, the voltage regulator control deasserts the RTS output when the buffer is approximately 95 percent full. Automatic transmission sources should monitor for the XOFF character to avoid overwriting the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and can resume when the voltage regulator control sends XON.

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

Control characters can be sent from most keyboards with the following keystrokes:

- XOFF: **<Ctrl+S>** (hold down the **<Ctrl>** key and press **S**)
- XON: **<Ctrl+Q>** (hold down the **<Ctrl>** key and press **Q**)
- CAN: **<Ctrl+X>** (hold down the **<Ctrl>** key and press **X**)

Automatic Messages

When the serial port AUTO setting is Y, the voltage regulator control sends automatic messages to indicate specific conditions. The automatic messages are described in *Table 9.10*.

Table 9.10 Serial Port Automatic Messages

Condition	Description
Power Up	The voltage regulator control sends a message containing the present date and time, device and terminal identifiers, and the Access Level 0 prompt when the voltage regulator control is turned on.
Self-Test Warning or Failure	The SEL-2431 sends a status report each time a self-test warning or failure condition is detected (see *STATUS Command (Voltage Regulator Control Self-Test Status)* on page 9.29).

Access Levels

Commands can be issued to the SEL-2431 via the serial port to view metering values, change voltage regulator control settings, etc. The available serial port commands are listed in the *Command Summary*. These commands can be accessed only from the corresponding access level as shown in the *Command Summary*. The access levels are:

- Access Level 0 (the lowest access level)
- Access Level 1
- Access Level 2 (the highest access level)
- Access Level C (restricted access level, should be used under direction of SEL only)

NOTE: In this manual, commands you type appear in bold/uppercase: **SET**. Computer keys you press appear in bold/brackets: **<Enter>**. Voltage regulator control front-panel pushbuttons you press appear in bold/uppercase: **SETTINGS**.

Serial Port Time-Out

The serial port time-out function automatically returns the access level to Level 0 for any ports that have been inactive for a period of time exceeding the port setting T_OUT. There are separate T_OUT settings for each serial port (see *SET PORT p (p = F, 1, or 2) Command (Serial Ports Only)* on page SET.20).

Access Level 0

Once serial port communication is established with the SEL-2431, the voltage regulator control sends the following prompt:

```
=
```

This is referred to as Access Level 0. Only a few commands are available at Access Level 0 (see the *Command Summary*). One is the **ACC** command. Enter the **ACC** command at the Access Level 0 prompt:

```
=ACC <Enter>
```

The **ACC** command takes the SEL-2431 to Access Level 1. See *Access Commands (ACCESS, 2ACCESS, and CAL)* on page 9.15 for more detail.

Access Level 1

When the SEL-2431 is in Access Level 1, the voltage regulator control sends the following prompt:

```
=>
```

See the *Command Summary* for the commands available from Access Level 1. The voltage regulator control can go to Access Level B or Access Level 2 from this level.

The **2AC** command places the voltage regulator control in Access Level 2. See *Access Commands (ACCESS, 2ACCESS, and CAL)* on page 9.15 for more detail. Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```

Access Level 2

When the voltage regulator control is in Access Level 2, the SEL-2431 sends the prompt:

```
=>>
```

See the *Command Summary* at the end of this manual for the commands available from Access Level 2.

Any of the Access Level 1 commands are also available in Access Level 2.

Access Level C

The CAL access level is intended for use by the SEL factory, and for use by SEL field service personnel to help diagnose troublesome installations. A list of commands available at the CAL level is available from SEL upon request. Do not enter the CAL access level except as directed by SEL.

The **CAL** command allows the relay to go to Access Level C (see *Access Commands (ACCESS, 2ACCESS, and CAL)* on page 9.15 for more detail). Enter the **CAL** command at the Access Level 2 prompt:

```
=>>CAL <Enter>
```

Command Summary

The *Command Summary* lists the serial port commands alphabetically. Much of the information available from the serial port commands is also available via the front-panel pushbuttons.

Access Level Functions

The serial port commands at the different access levels offer varying levels of control:

- ➤ The Access Level 0 commands provide the first layer of security. In addition, Access Level 0 supports several commands required by SEL communications processors.
- ➤ The Access Level 1 commands are primarily for reviewing information only (settings, metering, etc.), not changing it.
- ➤ The Access Level 2 commands are primarily for changing voltage regulator control settings.
- ➤ The Access Level C commands are restricted and should be used under the direction of SEL only.

The SEL-2431 responds with `Invalid Access Level` when a command is entered from an access level lower than the specified access level for the command. The voltage regulator control responds with `Invalid Command` to commands that are not available or are entered incorrectly.

Header

Many of the command responses display the following header at the beginning:

```
[DID Setting]                                Date: mm/dd/yyyy  Time: hh:mm:ss.sss
[TID Setting]
```

Table 9.11 Command Response Header Definitions

Item	Definition
[DID Setting]:	This is the DID (Device Identifier) setting. The voltage regulator control is shipped with the default setting DID = SEL-2431 (see *Group Settings for Device and Terminal Identification* on page 8.17).
[TID Setting]:	This is the TID (Terminal Identifier) setting. The voltage regulator control is shipped with the default setting TID = VOLTAGE REG (see *Group Settings for Device and Terminal Identification* on page 8.17).
Date:	This is the date when the command response was given, except for voltage regulator control response to the **EVE** (Event) command, when it is the date the event occurred. You can modify the date display format (Month/Day/Year, Year/Month/Day, or Day/Month/Year) by changing the DATE_F Global setting.
Time:	This is the time when the command response was given, except for voltage regulator control response to the **EVE** command, when it is the time the event occurred.

Command Explanations

This section lists ASCII commands alphabetically. Commands, command options, and command variables to enter are shown in bold. Lowercase italic letters and words in a command represent command variables that are determined based on the application. For example, remote bit number *nn* = 01–16, and *level*.

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the control functions corresponding to the command or examples of the control response to the command.

The *Command Summary* provides a convenient reference.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return **<CR>** character, or a carriage return character followed by a line feed character **<CR> <LF>**, to command the voltage regulator control to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a **<CR>**. For example, to send the **ACCESS** command, type **ACC <Enter>**.

Tables in this section show the access level(s) (0, 1, 2) where the command or command option is active.

Access Commands (ACCESS, 2ACCESS, and CAL)

The **ACC**, **2AC**, and **CAL** commands provide entry to the multiple access levels. Different commands are available at the different access levels as shown in the *Command Summary*. Commands **ACC**, **2AC**, and **CAL** are explained together because they operate similarly. See *Access Levels* on page 9.12 for a discussion of placing the voltage regulator control in an access level.

Command	Description
ACC	Moves from Access Level 0 to Access Level 1
2AC	Moves from Access Level 1 to Access Level 2
CAL	Moves from Access Level 2 to Access Level C

Password Requirements

Passwords are required if the main board password jumper is *not* in place (password jumper is OFF). Passwords are not required if the main board password jumper *is* in place (password jumper is ON). Refer to the *SEL-2431 Voltage Regulator Control Field Reference Guide* for password jumper information. See *PASSWORD Command (View/Change Passwords)* on page 9.25 for the list of default passwords and for more information on changing passwords.

Access Level Attempt (Password Required)

Assume the following conditions:

- ➤ Password jumper is OFF (not in place)
- ➤ Access Level is 0

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password jumper is not in place, the voltage regulator control prompts you for the Access Level 1 password:

```
Password: ? @@@@@@@@
```

The voltage regulator control is shipped with the default Access Level 1 password shown in *PASSWORD Command (View/Change Passwords)* on page 9.25. At the prompt, enter the default password and press the **<Enter>** key. The voltage regulator control responds with the following:

```
SEL-2431                                  Date: 08/29/2003  Time: 08:00:00.000
VOLTAGE REG


Level 1
=>
```

The => prompt indicates the voltage regulator control is now in Access Level 1.

If the entered password is incorrect, the voltage regulator control prompts you for the password again (`Password: ?`). The voltage regulator control prompts for the password as many as three times. If the requested password is incorrectly entered three times, the voltage regulator control pulses the SALARM Device Word bit for one second and remains at Access Level 0 (= prompt).

Access Level Attempt (Password Not Required)

Assume the following conditions: password jumper is ON (in place), Access Level is 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the password jumper is in place, the voltage regulator control does not prompt you for a password and goes directly to Access Level 1. The voltage regulator control responds with the following:

```
SEL-2431                                   Date: 08/29/2003  Time: 08:00:00.000
Voltage Reg


Level 1
=>
```

The two previous examples demonstrate going from Access Level 0 to Access Level 1. The procedure to go from Access Level 1 to Access Level 2 and from Access Level 2 to Access Level C is much the same, with command **2AC** or **CAL** entered at the access level screen prompt. The voltage regulator control pulses the SALARM Device Word bit for one second after a successful Level 2 or Level C access or if access is denied.

BNAMES Command

The **BNA** command produces ASCII names of all device status bits reported in the Fast Meter Data Block (A5D1) message in Compressed ASCII format.

Command	Description	Access Level
BNA	Display ASCII names of all device status bits.	0

CASCII Command

The **CAS** command produces the Compressed ASCII configuration message. This configuration instructs an external computer on the method for extracting data from other Compressed ASCII commands.

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0

CEVENT Command (Compressed Event Report)

The **CEV** command provides event report data in a Compressed ASCII response. Use this command to retrieve data that can be displayed by PC software in oscillographic form. See *Section 11: Analyzing Events* for further details on event reports.

Command (Parameters in [ ] Are Optional)	Description	Access Level
CEV [*n*]	Return event report *n* (including settings and summary) with 4 samples/cycle analog data and 4 samples/cycle digital data.	1

Parameter	Description
n	Append parameter *n* to specify the event report number to be returned with the default equal to 1 (most recent). Use the **HISTORY** command to determine the event report number of the event you want to display.

CHISTORY Command

The **CHI** command is the **HISTORY** command for the Compressed ASCII command set.

Command	Description	Access Level
CHI	Return the data as contained in the History report in Compressed ASCII format.	1

CLD Command (Compressed Load Profile)

The **CLD** command generates a control signal profile report in Compressed ASCII format.

Command	Description	Access Level
CLD	Returns the control signal profile in Compressed ASCII.	1

CONTROL Command (Control Remote Bit)

The **CON** command is a two-step command for controlling remote bits, which are Device Word bits RB01–RB16.

Command	Description	Access Level
CON *nn*[a] *k*[b]	Remote bit Set, Clear, or Pulse	2

[a] Parameter nn is RB01–RB16.
[b] Parameter k is S, C, or P.

k Parameter	Description
S	Set Remote Bit (“ON” position)
C	Clear Remote Bit (“OFF” position)
P	Pulse Remote Bit for 1-cycle (“MOMENTARY” position)

For example, use the following step to set Remote bit RB05.

```
=>>CON RB05 S <Enter>
```

CONTROL O Command (Control Digital Output)

The **CON O** command is a two-step command for controlling digital outputs (OUT101–OUT104).

Command (Parameters in [ ] Are Optional)	Description	Access Level
CON O *n*[a] [*m*[b]]	Digital output pulse	2

[a] Parameter n is OUT101–OUT104.
[b] Parameter m is time duration, ranging from 1–30 seconds. Default is 1 second if not specified.

For example, use the following step to pulse OUT101 for five seconds.

```
=>>CON O OUT101 5 <Enter>
```

COPY Command (Copy Setting Group)

Copy Group settings and general Logic settings from setting Group *m* to setting Group *n* with the **COP *m n*** command.

Command	Description	Access Level
COPY *m n*	Copy settings from instance *m* of the Group settings to instance *n* of the Group settings.	2

Parameter	Description
m	Parameter *m* is a number from 1–4.
n	Parameter *n* is a number from 1–4.

Setting group numbers range from 1 to 4. After entering settings into one setting group with the **SET** and **SET L** commands, copy this group to the other groups with the **COP** command. Use the **SET** and **SET L** commands to modify the copied settings.

The voltage regulator control disables for a few seconds and the SALARM Device Word bit pulses if you copy settings into the active group. This is similar to a group change (see *Multiple Setting Groups* on page 6.14).

For example, to copy settings from Group 1 to Group 3, issue the following command:

```
=>>COP 1 3 <Enter>

Copy 1 to 3
Are you sure (Y/N) ? Y <Enter>

Please wait...
Settings copied
=>>
```

COUNTER Command (View SELOGIC Counters)

The **COU** command displays the present value of the SELOGIC counters.

Command	Description	Access Level
COU *k*	Display the present value of the counters *k* times.	1

NOTE: The counter data displayed by the **COU** command may not be from the same processing interval for each counter.

The **COU** command is convenient to use while testing the SELogic counter settings—see *Counters* on page 6.10. Below is a sample of the **COU** command response:

```
=>COU <Enter>

SEL-2431                                  Date: 08/05/2003  Time: 12:07:32.532
VOLTAGE REG                               Time Source: internal

     SC01     SC02     SC03     SC04     SC05     SC06     SC07     SC08
        0       14        0        0        0        0        0        0


=>
```

CPROFILE Command (Compressed Profile)

The **CPR** command generates a control signal profile report in Compressed ASCII format.

Command	Description	Access Level
CPR	Returns the control signal profile in Compressed ASCII.	1

CSTATUS Command (Compressed Status)

The **CST** command generates a voltage regulator control status report in Compressed ASCII format.

Command	Description	Access Level
CST	Return the voltage regulator control status in Compressed ASCII.	1

DATE Command (View/Change Date)

Use the **DATE** command to view and set the voltage regulator control date.

Command	Description	Access Level
DATE	Display the internal clock date.	1
DATE *date*	Set the internal clock date (DATE_F set to MDY, YMD, or DMY).	1

The voltage regulator control can overwrite the date entered by using other time sources such as IRIG and DNP. Enter the **DATE** command with a date to set the internal clock date.

Separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons. Set the year in 4-digit form (for dates 2000–2099). Global setting DATE_F sets the date format.

DNAMES Command

The **DNA** command produces the ASCII names of all Device Word bits reported in a Fast Meter message in Compressed ASCII format.

Command	Description	Access Level
DNA	Display ASCII names of all Device Word bits digital I/O.	0

FILE Command

The **FILE** command provides a safe and efficient means of transferring files between intelligent electronic devices (IEDs) and external support software (ESS). Use the **FILE** commands for sending settings to the SEL-2431 and receiving settings from the voltage regulator control.

Command	Description	Access Level
FILE DIR	Return a list of files.	1
FILE READ *filename*	Transfer settings file *filename* from the voltage regulator control to the PC.	1
FILE WRITE *filename*	Transfer settings file *filename* from the PC to the voltage regulator control.	1
FILE SHOW *filename*	Filename 1 displays contents of the file *filename*.	1

GROUP Command

Use the **GRO** command to view the present group number or the **GRO *n*** command to change the active settings group number.

Command	Description	Access Level
GRO	Display the presently active group.	1
GRO *n*	Change the active group to Group *n*.	B

When you change the active group, the voltage regulator control responds with a confirmation prompt: `Are you sure (Y/N)?` Answer **Y <Enter>** to change the active group. The voltage regulator control asserts the Device Word bit SALARM for one second when you change the active group (see *Multiple Setting Groups* on page 6.14).

If any of the SELOGIC control equations SS1–SS4 are set when you issue the **GROUP *n*** command, the group change fails. The voltage regulator control responds: `No group change: SELogic equations SS1-SS4 have priority over GROUP command`. For information on SELOGIC control equations SS1–SS4, see *Multiple Setting Groups* on page 6.14.

HELP Command

The **HELP** command gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for help on each command.

Command	Description	Access Level
HELP	Display a list of each command available at the present access level with a one-line description.	1
HELP *command*	Display information on the command *command*.	1

HISTORY Command

Use the **HIS** command to view a list of one-line descriptions of voltage regulator control events or clear the list (and corresponding event reports) from nonvolatile memory.

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1
HIS *n*	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list beginning at event *n*.	1
HIS C	Clear/reset the event history and all corresponding event reports from nonvolatile memory.	1
HIS R	Clear/reset the event history and all corresponding event reports from nonvolatile memory.	1

For more information on event reports, see *Event History* on page 11.6.

IDENTIFICATION

Use the **ID** command to extract device identification codes.

Command	Description	Access Level
ID	Return a list of device identification codes.	0

L_D Command (Load Firmware)

Use the **L_D** command to load firmware. See *Appendix A: Firmware and Manual Versions* for information on changes to the firmware and instruction manual. See *Appendix B: Firmware Upgrade Instructions* for further details on downloading firmware.

Command	Description	Access Level
L_D	Download firmware to the control.	2

Only download firmware from the front port.

LDP Command (Signal Profile Report)

Use the **LDP** commands to view and manage the Load Profile report. See *Signal Profile Recorder* on page 7.28.

Command	Description	Access Level
LDP ***row1 row2*** **LDP** ***date1 date2***	Use the **LDP** command to display a numeric progression of all signal profile report rows. Use the **LDP** command with parameters to display a numeric or reverse numeric subset of the signal profile rows.	1
LDP C	Use this command to clear the signal profile report from nonvolatile memory.	1

NOTE: The Profile (**PRO**) command is also available and functions the same as the **LDP** command.

Settings SPLIST01–SPLIST16 must contain analog quantities. Otherwise `the command is not available` is displayed.

Parameter	Description
row1 row2	Append *row1* to return a chronological progression of the first *row1* rows. Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row1* and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows.
date1 date2	Append *date1* to return all rows with this date. Append *date1* and *date2* to return all rows between *date1* and date beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting DATE_F.

LOWER Command

Use the **LOW** command to lower the tap voltage regulator by one position.

Command	Description	Access Level
LOW	Lower the tap on the voltage regulator by one position.	2

The voltage regulator control will not lower the tap position if the current tap position is at the TAPMIN Group setting (see *Group Settings for Device and Terminal Identification* on page 8.17).

MAP Command (Display DNP3 Maps)

The **MAP** command is only available if DNP3 has been selected as the protocol on a serial port. The **MAP** command accesses the port DNP3 settings and is similar to the **SHOW D** command. However, unlike the **SHOW D** command, the **MAP** command displays DNP3 information by port number and also reports the effective scale factor and dead-band value for each analog input and counter item. You can issue the **MAP** command with the *port* parameter (from 1 to 2) to view the DNP3 settings for that port number.

Command	Description	Access Level
MAP *port*	Show the serial DNP3 settings for Port *port*.	1

See *Figure D.8* for a sample **MAP** command response.

METER Command (Metering Data)

The **MET** command provides access to control metering data.

Command	Description	Access Level
MET *c n*	Display metering data.	1
MET *c* **R**	Reset metering data.	2

Parameter	Description
c	Parameter for identifying meter class.
n	Parameter used to specify number of times (1–32767) to repeat the meter response.

c	Meter Class
	Fundamental Metering
D[a]	Demand Metering
E[a]	Energy Metering
M[a]	Maximum/Minimum Metering
H[a]	Harmonic Metering

[a] Reset Metering available.

For more information on metering and example responses for each meter class, see *Section 7: Metering and Monitoring*.

On issuing the **MET *c* R** command for resetting metering quantities in class *c*, the control responds: `Reset Metering Quantities (Y,N) ?` Type **Y <Enter>** to confirm. The metering quantities will be reset and the voltage regulator control responds: `Reset Complete`.

To reset demand meter quantities, issue the following command:

```
=>MET D R D <Enter>
Demand Reset
Are you sure (Y,N)? Y <Enter>
Reset Complete

=>
```

To reset peak demand meter quantities, issue the following command:

```
=>MET D R P <Enter>
Peak Demand Reset
Are you sure (Y,N)? Y <Enter>
Reset Complete

=>
```

MET PM—Synchrophasor Metering

The **MET PM** command (available when TSOK = logical 1 and EPMU = Y) displays the synchrophasor measurements. For more information, see *Appendix H: Synchrophasors*.

Command	Description	Access Level
MET PM	Display synchrophasor measurements.	1
MET PM ***time***	Display synchrophasor measurements at specific time.	1
MET PM HIS	Display the most recent **MET PM** synchrophasor report.	1

Use the **MET PM** command to help with commissioning. The command:

```
=>MET PM [time] <Enter>
```

NOTE: Ensure that port setting AUTO = Y on the active communications port for the **MET PM <time>** response to be displayed at <time>. Otherwise use **MET PM HIS** to view a previously triggered MET PM report.

triggers a synchrophasor meter command at precisely the time specified. Parameter `time` must be in 24-hour format, e.g., 15:11:00.000. Compare magnitudes and phases of quantities displayed in response to the **MET PM** command to reports from other devices triggered at the same instant to verify correct phasing and polarity of current and voltage connections. To help facilitate comparing meter reports between several devices, the command:

```
=>MET PM HIS <Enter>
```

recalls the most recently triggered synchrophasor meter report. For exploratory testing, the command:

```
=>MET PM k <Enter>
```

repeats the **MET PM** command *k* times. The trigger times of the *k* reports are not carefully controlled, but the trigger times are still accurately displayed in the reports.

The output from an SEL-2431 is shown:

```
=>MET PM <Enter>

SEL-2431                                 Date: 10/04/2010   Time: 13:51:51.000
Voltage Reg

                                                                 PMDOK = 1
Time Quality   Maximum time synchronization error:     0.000 (ms)  TSOK = 1

Synchrophasors
                Load Voltage     Source Voltage
MAG (kV)           7.086            7.082
ANG (DEG)         -2.813           -2.812

                Load Current
MAG (A)            0.104
ANG (DEG)         90.000

FREQ (Hz) 59.980
Rate-of-change of FREQ (Hz/s)    0.02

Digitals

SV08    SV07    SV06    SV05    SV04    SV03    SV02    SV01
 0       0       0       0       0       0       0       0
=>
```

PARTNUMBER Command (Set Part Number)

Use the **PAR** command to change the SEL-2431 part number.

Command	Description	Access Level
PAR	Set SEL-2431 part number.	2

You can use the **PAR** command when installing SEL-2431 accessories such as communication cards. Follow the instructions provided with your upgrade kit.

PASSWORD Command (View/Change Passwords)

Use the **PAS** command to inspect or change existing passwords.

Command	Description	Access Level
PAS *level new-password*	Set a password *new-password* for Access Level *level*.	2

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

Parameter	Description
level	Parameter *level* represents the voltage regulator control Access Level 1 or 2.
new-password	New password.

The factory-default passwords are as shown in *Table 9.12*.

Table 9.12 Factory-Default Passwords for Access Levels 1 and 2

Access Level	Factory-Default Password
1	OTTER
2	TAIL
C	CLARKE

To change the password for Access Level 1 to #Ot3579!ijd7, enter the following command:

```
=>>PAS 1 <Enter>

Old PW: ? OTTER <Enter>
New PW: ? #Ot3579!ijd7 <Enter>
Confirm New PW: ? #Ot3579!ijd7 <Enter>

=>>
```

Similarly, use **PAS 2** or **PAS C** to change the Level 2 or Level C password.

Table 9.13 Valid Password Characters

Alpha	A B C D E F G H I J K L M N O P Q R S T U V W X Y Z a b c d e f g h i j k l m n o p q r s t u v w x y z
Numeric	0 1 2 3 4 5 6 7 8 9
Special	! " # $ % & ' ( ) * + , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

Passwords can contain as many as 12 characters. Upper- and lowercase letters are treated as different characters. Strong passwords consist of 12 characters, with at least one special character or digit and mixed case sensitivity, but do not form a name, date, acronym, or word. Passwords formed in this manner are less susceptible to password guessing and automated attacks. Examples of valid, distinct strong passwords include:

- #0t3579!ijd7
- $A24.68&,mvj
- (Ih2dcs)36dn
- *4u-Iwg+?lf_

After entering new passwords, type **PAS <Enter>** to confirm that you entered the password correctly. Make sure that the passwords are what you intended, and record the new passwords.

PRO Command (Profile Report)

Use the **PRO** commands to view and manage the Load Profile report (see *Signal Profile Recorder* on page 7.28).

NOTE: The **PRO** command functions identically to the **LDP** command.

Command	Description	Access Level
PRO *row1 row2* **PRO *date1 date2***	Use the **PRO** command to display a numeric progression of all signal profile report rows. Use the **PRO** command with parameters to display a numeric or reverse numeric subset of the signal profile rows.	1
PRO C	Use this command to clear the signal profile report from nonvolatile memory.	1

Settings SPLIST01–SPLIST16 must contain analog quantities. Otherwise `the command is not available` is displayed.

Parameter	Description
row1 row2	Append *row1* to return a chronological progression of the first *row1* rows. Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row1* and ending with *row2*. Enter the smaller number first to display a numeric progression of rows through the report. Enter the larger number first to display a reverse numeric progression of rows.
date1 date2	Append *date1* to return all rows with this date. Append *date1* and *date2* to return all rows between *date1* and date beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting DATE_F.

PULSE Command (Pulse Output Contact)

The **PUL** command pulses any of the output contacts for a specified time.

Command	Description	Access Level
PUL OUT*nnn*	Pulse output OUT*nnn* for 1 second.	2
PUL OUT*nnn s*	Pulse output OUT*nnn* for *s* seconds.	2

Parameter	Description
nnn	101–104
s	Parameter *s* is time in seconds, with a range of 1–30.

QUIT Command

Use the **QUIT** command to revert to Access Level 0.

Command	Description	Access Level
QUI	Go to Access Level 0.	0

Access Level 0 is the lowest access level; the SEL-2431 performs no password check to descend to this level (or to remain at this level).

RAISE Command

Use the **RAISE** command to raise the tap on the voltage regulator by one position.

Command	Description	Access Level
RAI	Raise the tap on the voltage regulator by one position.	2

The voltage regulator control will not raise the tap position if the current tap position is at the TAPMAX Group setting (see *Section 8: Settings*.)

R_S Command (Restore Factory Defaults)

Use the **R_S** command to restore factory-default settings.

Command	Description	Access Level
R_S	Restore the factory-default settings and passwords and reboot the system.[a]	2

[a] Only available after a settings or critical RAM failure.

SER Command (Sequential Events Recorder Report)

Use the **SER** commands to view and manage the Sequential Events Recorder report. See *Sequential Events Recorder (SER)* on page 11.8 for further details on SER reports.

Command	Description	Access Level
SER ***row1*** **SER** ***row1 row2*** **SER** ***date1*** **SER** ***date1 date2***	Use the **SER** command to display a chronological progression of all available SER rows (as many as 1024 rows). Row 1 is the most recently triggered row and row 1024 is the oldest. Use the **SER** command with parameters to display a chronological or reverse chronological subset of the SER rows.	1
SER C	Use the SER clear command to clear/reset the SER records.	1
SER D	Use the SER delete command to list chattering SER elements that the control is removing from the SER records.	1

Parameter	Description
row1 row2	Append *row1* to return a chronological progression of the first *row1* rows. Append *row1* and *row2* to return all rows between *row1* and *row2*, beginning with *row2* and ending with *row1*. Enter the smaller number first to display a chronological progression of rows through the report. Enter the larger number first to display a reverse chronological progression of rows.
date1 date2	Append *date1* to return all rows with this date. Append *date1* and *date2* to return all rows between *date1* and date beginning with *date1* and ending with *date2*. Enter the oldest date first to display a chronological progression through the report. Enter the newest date first to display a reverse chronological progression. Date entries are dependent on the date format setting DATE_F.

If the requested SER report rows do not exist, the voltage regulator control responds with `No SER data`.

SET Command (Change Settings)

The **SET** command is for viewing or changing the voltage regulator control settings (see *Table 8.2* and *Settings Changes Via the Serial Port* on page 8.3).

Command	Description	Access Level
SET *n s*	Set the Group *n* settings, beginning at the first setting in each instance (*n* = 1–4); *n* defaults to the active setting group if not listed.	2
SET D *n*	Set DNP map *n* settings. *n* specifies the map number (1 or 2); defaults to 1 if not listed.	2
SET L *n s*	Set general Logic settings for setting group *n* (*n* = 1, 2, 3, or 4); *n* defaults to the active setting group if not listed.	2
SET G *s*	Set Global settings.	2
SET P *n s*	Set serial Port settings. *n* specifies the port (1, 2, 3, or F); *n* defaults to the active port if not listed.	2
SET R *s*	Set Report settings.	2
SET F *s*	Set Front Panel settings.	2

Parameter	Description
s	Append *s*, the name of the specific setting you want to view to jump to this setting. If *s* is not entered, the control starts at the first setting.
TERSE	Append TERSE to skip the settings display after the last setting. Use this parameter to speed up the **SET** command. If you want to review the settings before saving, do not use the TERSE option.

Editing keystrokes for the **SET** command are listed in *Table 9.14*.

Table 9.14 SET Command Editing Keystrokes

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

The control checks each setting to ensure that it is within the allowed range. If the setting is not within in the allowed range, the voltage regulator control generates an `Out of Range` message and prompts you for the setting again.

When all the settings are entered, the voltage regulator control displays the new settings and prompts you for approval to enable them. Answer **Y <Enter>** to enable the new settings. The voltage regulator control is disabled for as long as one second while it saves the new settings. The SALARM Device Word bit is set momentarily and the **ENABLED** LED extinguishes while the voltage regulator control is disabled.

SHOW Command (Show/View Settings)

When showing settings, the voltage regulator control displays the settings label and the present value from nonvolatile memory for each setting class.

Command	Description	Access Level
SHO *n s*	Show settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.	1
SHO D *n*	Show DNP map *n* settings. *n* specifies the map number (1 or 2); defaults to 1 if not listed.	1
SHO L *n s*	Show general Logic settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.	1
SHO G *s*	Show Global settings.	1
SHO P *n s*	Show serial Port settings. *n* specifies the port (1, 2, 3, or F); *n* defaults to the active port if not listed.	1
SHO R *s*	Show Report settings.	1
SHO F *s*	Show Front Panel settings.	1

Parameter	Description
s	Append *s*, the name of the specific setting you want to view to jump to this setting. If *s* is not entered, the voltage regulator control starts with the first setting.

STATUS Command (Voltage Regulator Control Self-Test Status)

The **STA** command displays the status report.

Command	Description	Access Level
STA *k*	Display the voltage regulator control self-test information *k* times (*k* = 1–32767). Defaults to 1 if *k* is not specified.	1
STA S	Display the memory and execution utilization for the SELOGIC control equations.	1
STA C/STA R	Reboot the voltage regulator control and clear self-test warning and failure status results.	2

STA (View)

Below is a sample SEL-2431 status output:

```
=>STA <Enter>

                                         Date: 02/12/2007   Time: 11:22:47

STATUS REPORT

FID = SEL-2431-R100-V0-Z001001-D20070601                CID = D973
Part Num = 24310X11XX2XXXXXXXXX        Serial Num = 000000000000

SELF TESTS (W=Warn, F=Fail)

Power Supply Voltages
  PS1.5V  PS3.3V  PS5V  PSN5V  PS5VA  PSN5VA  PS12V
    OK      OK      OK    OK     OK     OK      OK

Memory
  HMI   RAM   CR_RAM  NON_VOL  CLOCK
    OK    OK    OK      OK       OK

Channel Offsets
  MASTER  ILLOW  ILHIGH  IMH   IMR   IML   VS1   VS2
   OK      OK      OK    OK    OK    OK    OK    OK

Device  Enabled

=>
```

Serial Number	Voltage Regulator Control Serial Number.
FID	Firmware identifier string containing the module firmware revision number.
CID	Firmware checksum identifier.
Power Supply Voltages[a]	Display power supply voltages in Vdc for the power supply outputs.
Integrated Circuit and Board Status	HMI—Front-panel board status. RAM, ROM, CR_RAM, NON_VOL, FLASH—These tests verify the SEL-2431 memory components. The columns display OK if memory is functioning properly; the columns display FAIL if the memory area has failed. CLOCK—Real-time clock circuit status. A/D—Analog to Digital convert status. Option Cards—option card status.
Channel Offsets[a]	Display measured dc offset voltages in millivolts for the current and voltage channels. The MOF (master) status is the dc offset in the A/D circuit when a grounded input is selected.

[a] W (Warning) or F (Failure) is appended to the values to indicate an out-of-tolerance condition.

Refer to *Table 12.1* for self-test thresholds and corrective actions.

STA S (View SELOGIC Utilization)

Below is a sample of the SEL-2431 **STA S** response. See SELOGIC *Control Equation Capacity* on page 6.1.

```
=>STA S <Enter>

                                         Date: 02/12/2007   Time: 11:25:54

Part Number = 24310X11XX2XXXXXXXXX

SELogic Available Capacity
Act. Group:
                1    2    3    4
Execution (%)    1    4    7   10
Group (%)        2    5    8   11
Logic (%)        3    6    9   12

Global (%)   13
FP (%)       14
Report (%)   15

=>
```

STA C (Clear)

The **STA C** or **STA R** command reboots the SEL-2431. Thus, this command clears a transient status failure in the unlikely event that a transient status failure occurs.

TAP Command

The **TAP** command displays the number of total and per tap operations, allows preloading these operations counters, and viewing or changing the preset tap position.

Command	Description	Access Level
TAP	The **TAP** command shows: ➤ Current value of tap position stored in control ➤ Total tap change position counts ➤ Year-to-date control tap change position counts ➤ Sliding 24-hour control tap change position counts since last reset ➤ 33 individual tap change total counts ➤ 33 individual tap change total counts since last reset ➤ Last tap counter reset date and time	1
TAP W	Allows preloading of total and 33 individual tap count data.	1
TAP R	Clears resettable tap counter data.	1
TAP P	Shows current value of tap position stored in control.	1
TAP P *x*	Sets current value of tap position to *x* (*x* = –16 to +16, 0, N).	1

For more information on the tap operations counters and example responses, see *Tap Operations Counter* on page 7.22.

TARGET Command (Display Device Word Bit Status)

The **TAR** command displays the status of front-panel target LEDs or Device Word bits, whether they are asserted or deasserted.

Command	Description	Access Level
TAR *name k* **TAR *n k***	Use **TARGET** without parameters to display Device Word row 0 or last displayed target row.	1
TAR R	Shows Device Word Row 0.	1

Parameter	Description
name	Display the Device Word row with Device Word bit *name*.
n k	Show Device Word row number *n* (0–51) and repeat *k* times (1–32767).

The elements are represented as Device Word bits and are listed in rows of eight, called Device Word rows. The first four rows represent the front-panel status and trip target LEDs, and correspond to *Table 9.15*. All Device Word rows are described in *Table E.1* and *Table E.2*.

Device Word bits are used in SELOGIC control equations. See *Device Word Bits* on page 6.2.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL devices.

Table 9.15 Front-Panel Targets and the TAR Command

TAR 0 (Front-Panel LEDs)	*	ENABLED	ALARM	*	VRIPROG	INHIESV	REVERSE	TAPNEUT
TAR 1 (Front-Panel LEDs)	*	VMAXLMT	HBND	IN_BND	LBND	VMINLMT	*	*
TAR 2 (Front-Panel LEDs)	PB01LED	PB02LED	PB03LED	PB04LED	PB05LED	PB06LED	PB07LED	*
TAR 3 (Front-Panel LEDs)	REMOTE	LOCAL	AUTO	MANUAL	MRAISE	MLOWER	*	*

TIME Command (View/Change Time)

The **TIME** command returns information about the SEL-2431 internal clock. You can also set the clock if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

Command	Description	Access Level
TIME	Display the present internal clock time.	1
TIME *hh:mm*	Set the internal clock to *hh:mm*.	1
TIME *hh:mm:ss*	Set the internal clock to *hh:mm:ss*.	1

Parameter	Description
hh	Hours from 0–23.
mm	Minutes from 0–59.
ss	Seconds from 0–59.

Use the **TIME *hh:mm*** and **TIME *hh:mm:ss*** commands to set the internal clock time. If you enter a valid time, the voltage regulator control updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the SEL-2431 responds `Invalid Time`.

TRIGGER Command (Trigger Event Report)

Use the **TRI** command to trigger the SEL-2431 to record data for high-resolution oscillography and event reports.

Command	Description	Access Level
TRI	Trigger event report data capture.	1

When you issue the **TRI** command, the SEL-2431 responds `Triggered`. If the event did not trigger within one second, the voltage regulator control responds `Did not trigger`.

See *Event Reporting* on page 11.2 for further details on event reports.

VERSION Command (Show SEL-2431 Configuration and Firmware Version)

The **VER** command provides voltage regulator control configuration and information such as nominal current input ratings.

Command	Description	Access Level
VER	Display information about the configuration of the voltage regulator control.	1

Below is an example of the **VER** command for an SEL-2431:

```
=>VER <Enter>

FID:  SEL-2431-R1xx-V0-Zxxxxxx-D2007xxxx
CID:  D973
Partnumber:  24310X11XX2XXXXXXXXX
Serial Number:  000000000000
SELboot:
   BFID:  SLBT-2431-R1xx-V0-Zxxxxxx-D2007xxxx
   Checksum:  D49B
Mainboard:
   Code Flash Size:  8 MBytes:
   Data Flash Size:  8 MBytes:
   RAM Size:  8 MBytes:
Front Panel:  Installed
Analog Inputs:
   Current:  One 0.2 Amp Phase CT
   Voltage:  Two 120 Vac PTs
Interface Boards:
   None
Communications:
   Front Port:  EIA-232
   Rear Port 1:  None
   Rear Port 2:  None
Extended Relay Features:
   None

=>
```

Command Summary

Command	Description
Access Level 0	
ACCESS	Go to Access Level 1.
BNAMES	ASCII names of all voltage regulator control status bits in Compressed ASCII format (Fast Meter).
CASCII	Display the Compressed ASCII configuration message.

Command	Description
DNAMES	ASCII names of all Device Word bits in Compressed ASCII format (Fast Meter).
ID	Display the firmware ID, user ID, device code, part number, and configuration information.
QUIT	Reduce access level to Access Level 0 (exit voltage regulator control).
Access Level 1	
2ACCESS	Go to Access Level 2.
CEVENT *n*	Display the Compressed ASCII event report for event *n*.
CHISTORY	Display the Compressed ASCII version of the **HISTORY** command.
COUNTER *k*	Show the SELOGIC counter values. Enter *k* for repeat count.
CPROFILE	Display the Compressed ASCII version of the **PROFILE** command.
CSTATUS	Display the Compressed ASCII version of the **STATUS** command.
DATE	Show date.
DATE *date*	Enter date in accordance with Date Format setting DATE_F = MDY, YMD, or DMY.
FILE DIR|READ|SHO	Transfer data from the voltage regulator control to a PC.
GROUP	Display active settings group number.
HELP	Display available commands or command help at each access level.
HISTORY C	Clear the brief summary and corresponding event reports.
HISTORY R	Clear the brief summary and corresponding event reports.
HISTORY *n*	Show brief summary of the *n* latest event reports.
LDP *date1 date2*	Show rows in the Signal Profile report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
LDP *row1 row2*	Show rows *row1* through *row2* in the Signal Profile report.
LDP C	Clear the Signal Profile Report.
MAP *p*	Display DNP3 map for Port *p*.
METER D	Display demand and peak demand data. Select **MET D R D** or **MET D R P** to reset.
METER E	Display energy metering data. Select **MET E R** to reset.
METER H	Display THD and harmonic metering data.
METER *k*	Display fundamental (instantaneous) metering data. Enter *k* for repeat count.
METER M	Display maximum/minimum metering data. Select **MET M R** to reset.
METER D R D	Reset demand metering data.
METER E R	Reset energy metering data.
METER M R	Reset maximum metering data.
METER D R P	Reset peak demand metering data.
PROFILE *date1 date2*	Show rows in the Signal Profile report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
PROFILE *row1 row2*	Show rows *row1* through *row2* in the Signal Profile report.
PROFILE C	Clear the Signal Profile Report.
SER C	Clear/reset recently SER records.
SER *date1 date2*	Show rows in the Sequential Events Recorder (SER) event report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
SER *row1 row2*	Show rows *row1* through *row2* in the Sequential Events Recorder (SER) event report.
SHOW D *n*	Show DNP map *n* settings (*n* = 1–2).
SHOW F	Show Front Panel settings.
SHOW G	Show Global settings.

Command	Description
SHOW L *n*	Show SELOGIC control equation settings for settings Group *n* (*n* = 1–6).
SHOW *n*	Show "regular" settings for settings Group *n* (*n* = 1–6).
SHOW P *n*	Show Port settings for Port *n* (*n* = 1, 2, 3, F).
SHOW R	Show Report settings.
STATUS *k*	Show voltage regulator control self-test status. Enter *k* for repeat count (defaults to 1).
STATUS S	Display the memory and execution utilization for the SELOGIC control equations.
TAP	Display the tap position change counts (total and per-tap position).
TAP P	Display the present tap position stored in the voltage regulator control's memory.
TAP P *x*	Change the present tap position stored in the voltage regulator control's memory to *x*.
TAP R	Reset all tap position counters.
TAP W	Preload tap position counter values.
TARGET *n k*	Display control elements for a row in the Device Word table. If *n* is a row number from the Device Word table, display row *n*. If *n* is an element name, display the row containing element *n*. Enter *k* for repeat count.
TIME	Show or set time (24-hour time). Show the present time by entering **TIME**. Set the present time by entering **TIME *xx:xx:xx***.
TRIGGER	Trigger an event report.
VERSION	Show firmware version and options.
Access Level 2	
CAL	Enter Access Level C. If the main board Access jumper is not in place, the relay prompts for the entry of the Access Level C password. Access Level C is reserved for SEL use only.
CONTROL RB*nn k*	Set, clear, or pulse internal Remote Bit *nn* (*nn* is the Remote Bit number from 01–16). Parameter *k* can be the following: **S** To set Remote Bit *nn* (assert RB*nn*). **C** To clear Remote Bit *nn* (deassert RB*nn*). **P** To pulse Remote Bit *nn* (assert RB*nn* for 1 cycle).
CONTROL O *n m*	Pulse digital output *n* (*n* is the output contact from OUT101–OUT104). Parameter *m* is the time duration from 1–30 seconds, 1 second is default if unspecified.
COPY *m n*	Copy settings and logic equations from settings Group *m* to settings Group *n*.
FILE WRITE	Transfer settings files from a PC to the voltage regulator control.
GROUP *n*	Change active settings group to settings Group *n* (*n* = 1–4).
L_D	Download firmware to the voltage regulator control.
LOWER	Lower the tap position of the regulator by one position.
PAR	Set SEL-2431 part number.
PAS 1 *xxxxxx*	Change Access Level 1 password to *xxxxxx*.
PAS 2 *xxxxxx*	Change Access Level 2 password to *xxxxxx*.
PAS C *xxxxxx*	Change Access Level C password to *xxxxxx*.
PULSE OUT*nnn s*	Pulse output contact OUT*nnn* (*nnn* = 101–104, 201, 202) for *s* (1–30) seconds. Parameter OUT*nnn* must be specified; *s* defaults to 1 if not specified.
RAISE	Raise the tap position of the regulator by one position.
R_S	Restore the factory-default setting and passwords and reboot the voltage regulator control (only available if there is a diagnostic failure).
SET D *n*	Change DNP map *n* settings (*n* = 1–2).
SET F	Change Front-Panel settings.
SET G	Change Global settings.
SET L *n*	Change SELOGIC control equation settings for settings Group *n* (*n* = 1–6).

Command	Description
SET *n*	Change “regular” settings for settings group *n* (*n* = 1 –6).
SET P *n*	Change Port settings for Port *n* (*n* = 1, 2, F).
SET R	Change Report settings.
STATUS C/R	Clear status warning or failure and reboot the voltage regulator control.

SECTION 10

Front-Panel Operations

This section provides supplemental material for *Section 3: Front-Panel Interface* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*.

Operation and Indication LEDs

The SEL-2431 Operation and Indication LEDs are located on the front panel of the control. *Table 10.1* lists the details for each LED, including the driving logic.

Table 10.1 Operation and Indication LED Definitions and Logic

LED Name	Color	Description	Driving Logic
NEUTRAL POSITION	Yellow	Voltage regulator signals that it is in the neutral position. This LED circuitry is 120 Vac powered and may still operate when the control is not enabled.	Neutral input detected. TAPNEUT = logical 1
ENABLED	Green	Voltage regulator control is enabled.	ENABLED = logical 1
ALARM	Red	Follows state of programmable Front Panel setting ALARM.	ALARM = logical 1
VOLTAGE REDUCTION	Yellow	Voltage reduction in progress.	VRIPROG = logical 1
AUTO INHIBIT	Yellow	Illuminates when automatic tap changes are inhibited.	INHIBIT or MANUAL = logical 1
REVERSE POWER	Yellow	Reverse system power flow detected.	REVERSE = logical 1
VOLTAGE HIGH LIMIT[a]	Red	When illuminated, the system load-side terminal voltage exceeds voltage limit setting VMAX. When flashing at 0.5 Hz, the system load-side terminal voltage exceeds the runback voltage threshold.	VMAXLMT = logical 1 (RBKFH OR RBKRH) = logical 1
HIGH BAND	Yellow	Regulated voltage is above the high-band threshold.	HBND = (HBNDFWD OR HBNDREV) = logical 1
IN BAND	Green	Regulated voltage is between the high-band threshold and low-band threshold.	IN_BND = (IN_BNDF OR IN_BNDR) = logical 1
LOW BAND	Yellow	Regulated voltage is below the low-band threshold.	LBND = (LBNDFWD OR LBNDREV) = logical 1
VOLTAGE LOW LIMIT	Red	When illuminated, the system load-side terminal voltage is below voltage limit setting VMIN. When flashing at 0.5 Hz, the system load-side terminal voltage is below the runback voltage threshold.	VMINLMT = logical 1 (RBKFL OR RBKRL) = logical 1

[a] The voltage band indicator LEDs are all extinguished when the operating mode (selected by Group setting OPMODE) is in an inhibited operating region, for example, when reverse power is detected during locked-forward operating mode.

Type A USB Port

The SEL-2431 comes standard with a Type A USB port to interface with USB flash drives. The use of this port is outlined in *Section 3: Front-Panel Interface* of the *SEL-2431 Voltage Regulator Control Field Reference Guide*. This section provides some details not provided in that document.

Disabling the USB Feature

The Type A USB port can be disabled by setting EUSB := N (Front Panel Settings). For security reasons, this setting cannot be accessed from the front-panel interface.

Logging On Using a USB Authentication Key

As outlined in *Section 3: Front-Panel Interface* of the *SEL-2431 Voltage Regulator Control Field Reference Guide*, you can store the USB authentication key for the SEL-2431 on the USB flash drive and use it to gain Level 2 access to the front panel of the SEL-2431. See *Appendix I: Cybersecurity Features* for more information.

Automatic Backup Feature

During Automatic Backup, the SEL-2431 can write event data to the average USB flash drive at the rate listed in *Table 10.2*. If events are triggered at a faster rate, some data may not be completely written to the USB flash drive, but will still be accurately recorded in the internal memory of the SEL-2431. If the USB flash drive contains .CEV files that are invalid, that means too many event reports were triggered too close together.

Table 10.2 Data Rate of Automatic Backup Feature

Data Rate	Rate Per Hour
Event Reports	30
SER	100

File Format of Reports

The reports stored on the USB flash drive by the SEL-2431 will be "human-readable." These reports may be read by any PC that can read text files from a USB flash drive. For more information about viewing and analyzing the event report files, see *Section 11: Analyzing Events*.

As outlined in *Section 3: Front-Panel Interface* of the *SEL-2431 Voltage Regulator Control Field Reference Guide*, there are two ways that the SEL-2431 stores reports to the USB flash drive.

Read Reports

During the Read Reports operation, the SEL-2431 makes a copy of the reports presently stored in the device's onboard memory to the USB flash drive.

All report files, except the event reports, will be stored in the following folder on the USB flash drive:

/REPORTS/<user specified subfolder>/

The event reports will be stored in the following folder:

/REPORTS/<user specified subfolder>/EVENTS/YYYYMMDD/

where:
YYYY = four-digit year
MM = two-digit month
DD = two-digit day

The event reports' file names will be based on the time that the event happened, and will be:

HHmmSSss.CEV

where:

HH = two-digit hour (24 hour clock)
mm = two-digit minute
SSss = four-digit second (including hundredths of a second)

Automatic Report Backup

When Automatic Report Backup is enabled, the SEL-2431 will write all report files to the onboard memory of the SEL-2431 as well as to the USB flash drive. This may result in thousands of files being stored on the USB flash drive over the course of several years, so the folder structure is designed to make it easy to locate the exact report file you want to find.

All report files, except the Event Reports, will be stored in the following folder on the USB flash drive, based on the date that the report was written:

/REPORTS/<user specified subfolder>/YYYY/MM/

The event reports will be stored in the following folder:

/REPORTS/<user specified subfolder>/YYYY/MM/EVENTS/DD/HH/

where:

YYYY = four-digit year
MM = two-digit month
DD = two-digit day
HH = two-digit hour (24 hour clock)

The event reports' file names will be based on the time that the event happened, and will be:

HHmmSSss.CEV

where:

HH = two-digit hour (24 hour clock)
mm = two-digit minute
SSss = four-digit second (including hundredths of a second)

Front Panel Settings VTJ_MODE and VTJ_L for VOLTMETER Test Terminals

NOTE: Measurement errors may be caused if a non-high impedance voltmeter is used that causes current to flow from the VOLTMETER terminals.

The VOLTMETER + terminal is impedance-protected, as shown in *Figure C.1* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*. The internal switch shown in series with this terminal selects the voltage to monitor, V_{S1} or V_{S2} (refer to *Figure B.1–Figure B.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for the origin of these voltage connections).

The internal switch is controlled by Front Panel setting VTJ_MODE.

If the control is disabled, the internal switch will select V_{S1} regardless of other conditions or settings.

Front Panel Setting VTJ_MODE = AUTO (Factory-Default Setting)

The internal switch selects voltage V_{S2} if the following are true:

- Regulator is a Siemens/Howard Type A voltage regulator, a second voltage source (V_{S2}) is available (Global setting 2ND_PT = Y), and the power flow is forward
- Or the regulator is one of the types in *Figure B.2–Figure B.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*, a second voltage source (VS2) is available (Global setting 2ND_PT = Y), and power flow is reverse

Otherwise, the internal switch selects voltage V_{S1}.

Simply, with Front Panel setting VTJ_MODE = AUTO, the internal switch directs the present load-side voltage (depending on power flow direction) to the VOLTMETER terminals. If power flow is in reverse, then the conventional source side becomes the present load side.

Front Panel Setting VTJ_MODE = MANUAL

Front Panel setting (SELOGIC) VTJ_L now influences the selection of the voltage to monitor, in lieu of power flow direction. All other criteria being true:

- Front Panel setting (SELOGIC) VTJ_L evaluating to logical 1 causes an attempt to be made to select the L (designated load) terminal for voltage monitoring
- Otherwise, an attempt is made to select the S (designated source) terminal for voltage monitoring

Thus, the internal switch selects voltage V_{S2} if the following are true:

- Regulator is a Siemens/Howard Type A voltage regulator, a second voltage source (V_{S2}) is available (Global setting 2ND_PT = Y), and Front Panel setting VTJ_L evaluates to logical 1
- Or the regulator is one of the types in *Figure B.2–Figure B.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*, a second voltage source (VS2) is available (Global setting 2ND_PT = Y), and Front Panel setting VTJ_L evaluates to logical 0

Otherwise, the internal switch selects voltage V_{S1}.

Simply, with Front Panel setting VTJ_MODE = MANUAL, the internal switch directs the conventional load-side voltage to the VOLTMETER terminals, if Front Panel setting VTJ_L evaluates to logical 1. If VTJ_L evaluates to logical 0, then the internal switch directs the conventional source-side voltage to the VOLTMETER terminals.

This logic lends itself to being controlled by one of the programmable pushbuttons on the front panel of the SEL-2431. Set the pushbutton output to operate a programmable latch (one push to set the latch, following push to reset the latch). Then, set VTJ_L to the latch output. Program the associated pushbutton LED to also follow the latch output. Each press of the configured pushbutton then causes the internal switch to change position, direction conventional load-side or source-side voltage to the VOLTMETER terminals. The voltage at the voltmeter terminals is included in the default rotating display as the Analog Quantity VMETER.

Front Panel SELogic Settings REMOTSV, LOCALSV, AUTOSV, and MANULSV for Control Configuration

Figure 10.1 explains pushbutton/LED (mode) operation for the **CONTROL CONFIGURATION** portion of the SEL-2431 front panel (see *Figure 1.1*):

- **REMOTE/LOCAL** pushbutton toggles between LEDs (modes) **REMOTE** and **LOCAL**
- **AUTO/MANUAL** pushbutton toggles between LEDs (modes) **AUTO** and **MANUAL**

These **REMOTE**, **LOCAL**, **AUTO**, and **MANUAL** LEDs (modes) have corresponding Device Word bits (of the same name; see *Table E.1*), which assert to logical 1 when the respective LED illuminates. *Figure 10.1* further shows how SELogic Front Panel settings REMOTSV, LOCALSV, AUTOSV, and MANULSV can change the operation of the **REMOTE/LOCAL** and **AUTO/MANUAL** pushbuttons and corresponding LEDs (modes).

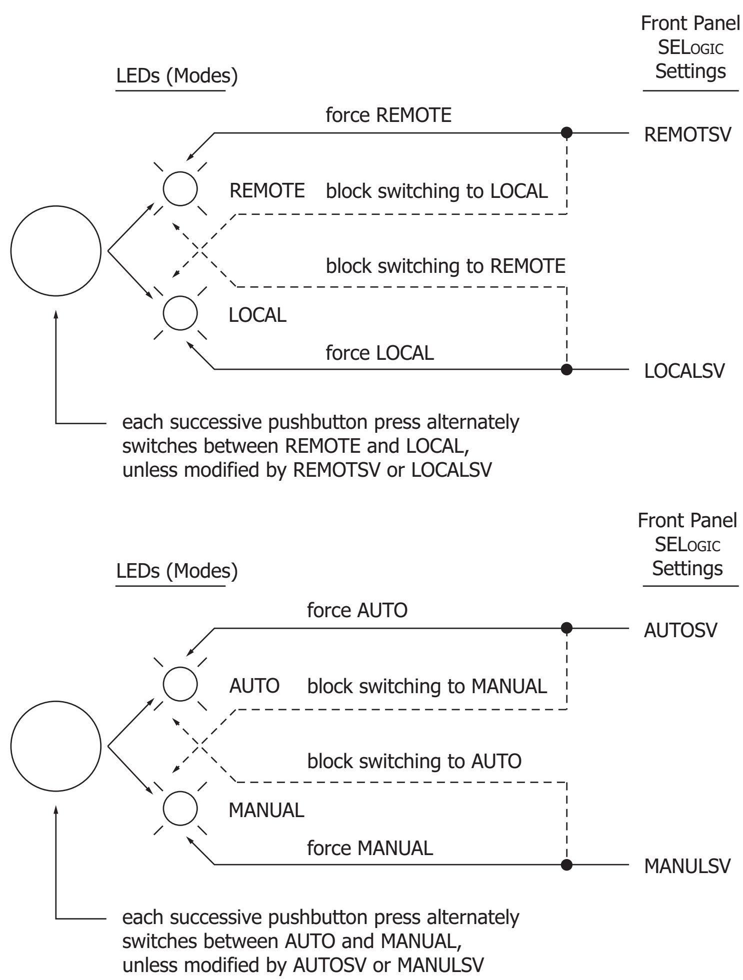


Figure 10.1 Effect of Front Panel SELogic Settings REMOTSV, LOCALSV, AUTOSV, and MANULSV on REMOTE/LOCAL and AUTO/MANUAL Pushbuttons/ LEDs (Modes)

The factory-default Front-Panel SELOGIC settings are:

- REMOTSV := NA
- LOCALSV := MANUAL #FORCE TO LOCAL WHEN MANUAL SELECTED
- AUTOSV := NA
- MANULSV := NA

With these default settings, there is no extra modification of the **AUTO/MANUAL** pushbutton (AUTOSV := NA and MANULSV := NA). Each press of the **AUTO/MANUAL** pushbutton alternately toggles between the automatic mode (**AUTO** LED illuminated) and the manual mode (**MANUAL** LED illuminated).

But, there is a modification of the **REMOTE/LOCAL** pushbutton (LOCALSV := MANUAL). If the SEL-2431 is in the manual mode (**MANUAL** LED illuminated), then the local mode (**LOCAL** LED illuminated) is forced. As long as the manual mode is active, any press of the **REMOTE/LOCAL** pushbutton has no effect—the local mode remains active (**LOCAL** LED remains illuminated).

To make the control-configuration pushbuttons independent and controlled by their own pushbutton action only, make the following Front Panel SELOGIC settings:

- REMOTSV := NA
- LOCALSV := NA
- AUTOSV := NA
- MANULSV := NA

Display and Front-Panel Pushbuttons

Display Points

Use the 32 display points to show the status of Device Word bits or display the value of analog quantities. Set EDP to the required number of display points to enable the display point settings.

NOTE: When the display is scrolling through the display points, manually scroll up or down by pressing the **Up Arrow** or **Down Arrow** pushbuttons, respectively.

See *Table E.1* for a list of digital quantities that can be used with display points. Select the following:

- Device Word bit
- Alias
- String to display when bit is set
- String to display when bit is cleared

See *Table F.1* for a list of analog quantities that can be used with display points. Select the following:

- Alias
- Analog quantity and scaling, intermixed with programmable text

Setting Syntax

NOTE: DPxx indicates DP01 . . . DP32.

Use the following syntax to display the given entry (Device Word bits or analog quantities) exactly as seen in the navigational menu (name, value, and units).

DPxx := **Name** (see examples later in this section)

Use the following syntax to display the given entry (Device Word bits or analog quantities) as seen in the navigational menu, replacing the name of the value with the given alias string. Device Word bits require one row, while analog quantities require two rows.

DPxx := **Name, "Alias"** (see examples later in this section)

Use the following syntax to display the given entry (Device Word bits only), with the given alias. If the Device Word bit is asserted (logical 1), the LCD displays the set string in the place of the value. If the Device 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 the item is not visible when the bit matches that state. If an empty line is required in this case, instead of hiding the line altogether, then use empty curly braces ({ }) for the Set or Clear String. This entry requires at most one display row.

DPxx := **Name, "Alias", "Set String", "Clear String"** (see examples later in this section)

Use the following syntax to display the given entry (analog quantities only) 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, the field grows (to the left of the decimal point) to accommodate the number. All display points formatted in this manner occupy one, and only one, line on the display at all times. You can use multiple display points to simulate multiple lines.

DPxx := **Name, "Text1 {Width.Decimal,Scale} Text2"** (see examples later in this section)

Device Word Bits Settings Examples

The following settings examples use optoisolated inputs IN101 and IN102 in the display points settings. Local bits (LB01–LB16), latch bits (LT01–LT16), Remote bits (RB01–RB16), setting group indicators (SG1–SG6), and any other Device Word bits can also be used. These examples use the following syntax:

DPxx := **Name, "Alias", "Set String", "Clear String"**

Example 10.1 Continually Display a Message

To always display the message `SEL-2431 CONTROL` on the rotating display, enter the display point setting DP01 as follows:

Setting	
DP01 = 1, "SEL-2431 CONTROL"	`SEL-2431 CONTROL`

Example 10.2 REMOTE/LOCAL Indication

Enter front-panel display point setting DP02 as follows to display `REMOTE MODE` when Device Word bit REMOTE asserts and display `LOCAL MODE` when Device Word bit REMOTE deasserts.

Example 10.2 REMOTE/LOCAL Indication (Continued)

Settings	REMOTE Is Asserted	REMOTE Is Deasserted
DP02 = REMOTE, , “REMOTE MODE”, “LOCAL MODE”		
	REMOTE MODE	LOCAL MODE

Example 10.3 Inhibit Indication

Use one of the following setting methods to display the control inhibit status.

Settings	INHIBIT Is Asserted	INHIBIT Is Deasserted
DP03 = INHIBIT		
	INHIBIT=1	INHIBIT=0
DP03 = INHIBIT, , “CONTROL INHIBITED”, “CONTROL ENABLED”		
	CONTROL INHIBITED	CONTROL ENABLED
DP03 = INHIBIT, “REG CONTROL”, “BLOCKED”, “ENABLED”		
	REG CONTROL=BLOCKED	REG CONTROL=ENABLED

Example 10.4 Display Only One Message

Enter settings INHIBIT and DP03 as follows to display `REG CONTROL ENABLED` when INHIBIT deasserts, but display nothing when input INHIBIT asserts.

Settings	IN102 Is Asserted	IN102 Is Deasserted
DP03 = INHIBIT, , “REG CONTROL ENABLED”		
	REG CONTROL ENABLED	

Analog Quantities Settings Examples

These examples use the following setting syntax:

DPxx := **Name, “Text1 {Width.Decimal,Scale} Text2”**

Example 10.5 Display Line Current

Set display point DP04 using one of the following methods to display IL current magnitude.

Example 10.5 Display Line Current (Continued)

Setting	
DP04 = IL	IL xxx.x A
DP04 = IL, "IL={7.2} A pri"	IL=xxxx.xx A pri
DP04 = IL, "IL={6.2,1000} kA pri"	IL=xxx.xx kA pri
DP04 = IL, "Line Current"	LINE CURRENT xxx.x

Front-Panel Text Symbol Matrix

Figure 10.2 shows the display structure for modifying existing values, constituting of a Setting Name (DID) and an Editable Value (SEL-2431, for example).

```
DID
        SEL-2431
```

Figure 10.2 Front-Panel Display Structure

Replace existing values of the Editable Value with any symbol from a set of approved symbols called the symbol matrix. *Figure 10.3* shows the symbol matrix for text inputs and four editorial functions (Space, Delete [Del], Clear [Clr], and Accept).

```
Space Del Clr Accept
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
! " # $ % & ' (
) * + , - . / :
; < = > ? @ [ \
] ^ _ ` { | } ~
```

Figure 10.3 Symbol Matrix for a Text Input

The Space function inserts a space and the Del function deletes the character pointed to by the block cursor. If the block cursor is beyond the end of the current value in the input field, the last character of the item is deleted and the block cursor is moved left one character. If the input filed is empty, the Del function has no effect. The Clr function deletes all characters in the setting value, and the Accept function accepts the new value of the setting and exits the page. Inputting text has two modes of operation, as shown in *Table 10.3*.

Table 10.3 Two Modes of Text Input Operations

Mode of Operation	Description
Cursor Movement	Cursor movement mode allows the cursor to be moved in the input field.
Symbol Selection	Symbol selection mode allows the symbol under the cursor to be inserted into the input field.

In cursor movement mode, the left and right arrows move the cursor in the input field. If the cursor is at the first position in the field and a left event occurs, the event is ignored. If the cursor is at the end of the current setting value, but not at the end of the field, and the right event occurs, a space is inserted at the end of the setting value. If the cursor is at the end of the field and the right arrow is pushed, the event is ignored. Pushing the **ESC** pushbutton discards the current value and returns to the previous. Pushing the **ENT** pushbutton accepts the new value and exits the page. Pressing the **Up Arrow** or **Down Arrow** pushbuttons switches the mode to symbol modification.

As an example, change the default DID setting from SEL-2431 to MILAN by navigating as followings: **ESC** > Set/Show **ENT** > Device **ENT** > ID Settings **ENT** > DID **ENT** to end up with the display as shown in *Figure 10.4*.

```
DID=SEL-2431
Space Del Clr
```

Figure 10.4 Display to Change the Default DID Setting

Press the **Down Arrow** pushbutton four times to reach the display shown in *Figure 10.5*. In symbol modification mode, a solid black rectangle cursor (block cursor) is placed at the cursor position in the settings value (SEL-2431) and the underline cursor is placed in the symbol matrix (Space). This rectangle blinks at a frequency of 1 Hz. The cursor wraps at the edges of the matrix: left to right, right to left, top to bottom, and bottom to top. Use the **Right Arrow** pushbutton to position the cursor under the letter M.

```
DID=SEL-2431
I J K L M N O P
```

Figure 10.5 Navigate to the Row in the Symbol Matrix Containing Letter M

Press the **ENT** pushbutton to insert the letter M into the setting value at the position indicated by the block cursor. This moves the block cursor and the symbol it points to one symbol to the right, as show in *Figure 10.6*.

```
DID=MSEL-2431
I J K L M N O P
```

Figure 10.6 Insert Letter M into the Setting Value

The back arrow returns the mode to cursor movement. Continue to enter the remainder of the text.

```
DID=MILANSEL-2431
I J K L M N O P
```

Figure 10.7 Complete Entry of New Text, With the Old Text Still Visible

Press the **Up Arrow** pushbutton three times, and the **Right Arrow** pushbutton once to position the cursor under the delete (`Del`) function. Press the **ENT** pushbutton eight times to delete the remainder of the previous text (see *Figure 10.8*). Press the **Down Arrow** pushbutton once and the **ENT** pushbutton once to accept the new settings, resulting in the display shown in *Figure 10.9*.

```
DID=MILAN
Space Del Clr
```

Figure 10.8 Complete Entry of New Text

```
DID
     MILAN
```

Figure 10.9 Acceptance of New Text

Accepting the new settings does not save the settings at the same time. Press the **ESC** pushbutton twice to see the display shown in *Figure 10.10*. Press the **Left Arrow** pushbutton once to move the cursor to the Yes position, then press the **ENT** pushbutton to save the new settings.

```
Save Changes?
Yes No
```

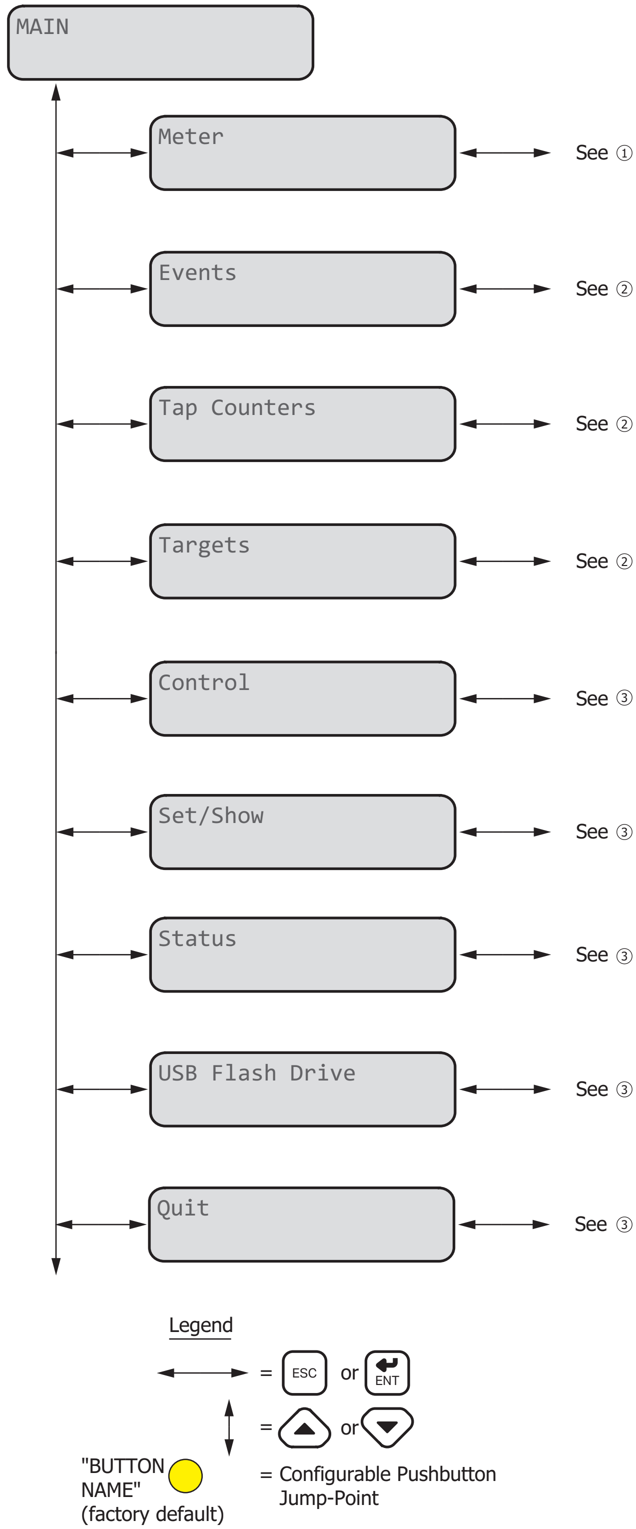
Figure 10.10 Save the New Text Settings

Front-Panel Menus and Screens

SEL-2431 Menu Structure

Figure 10.11–Figure 10.17 show the detailed SEL-2431 front-panel menu structure. *Figure 10.18–Figure 10.36* describe major items of the menu hierarchy with usage details. Menus and displays are available for most SEL-2431 functions. From the `Main` menu, you can navigate to one of the following specific menus:

- Meter
- Events
- Tap Counters
- Targets
- Control
- Set/Show
- Status
- Quit



① See *Figure 10.12*. ② See *Figure 10.13*. ③ See *Figure 10.14*.

Figure 10.11 Main Menu Navigation

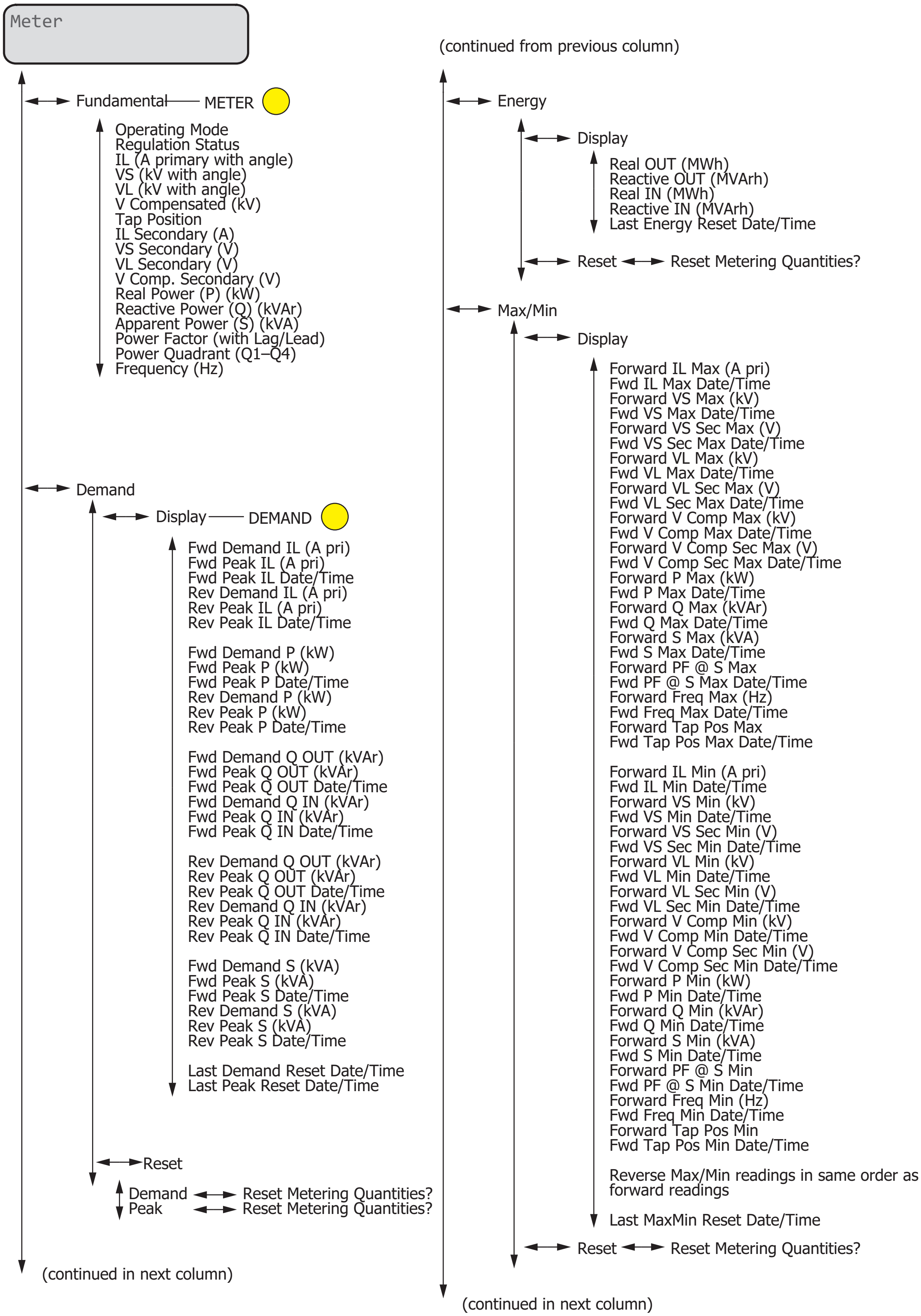


Figure 10.12 Meter Menu

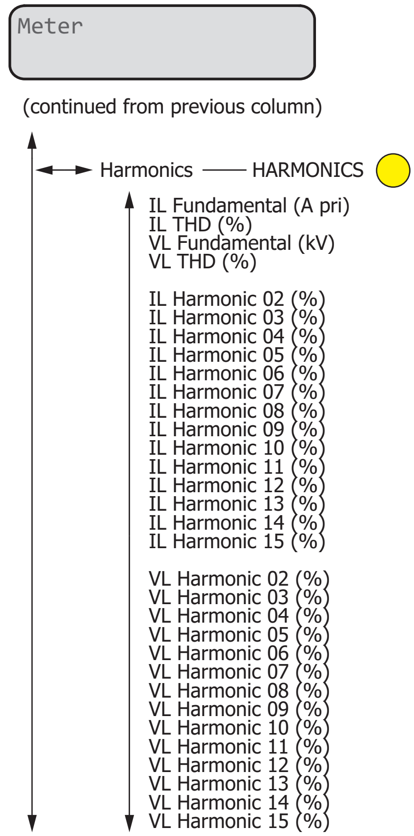


Figure 10.12 Meter Menu (Continued)

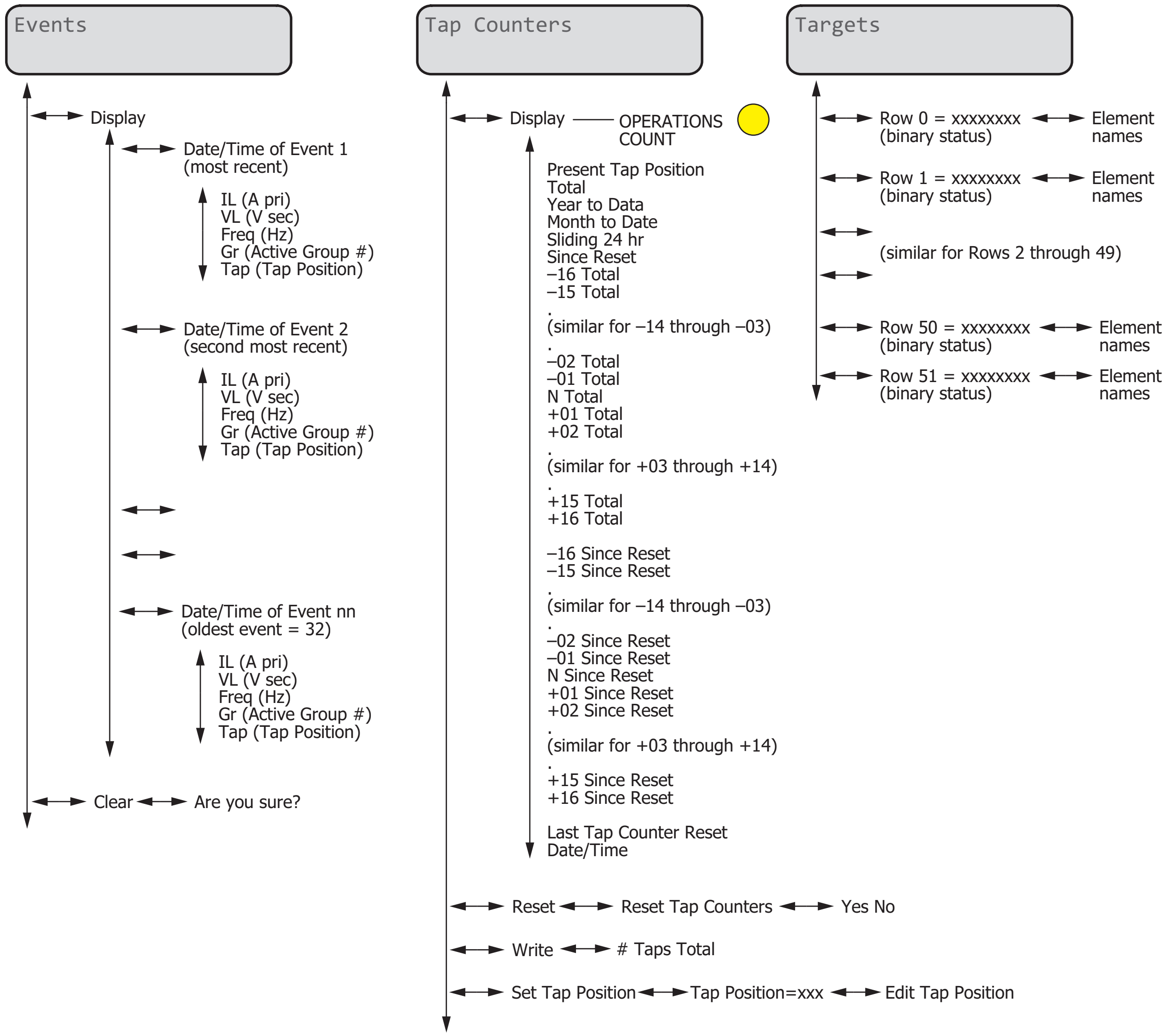
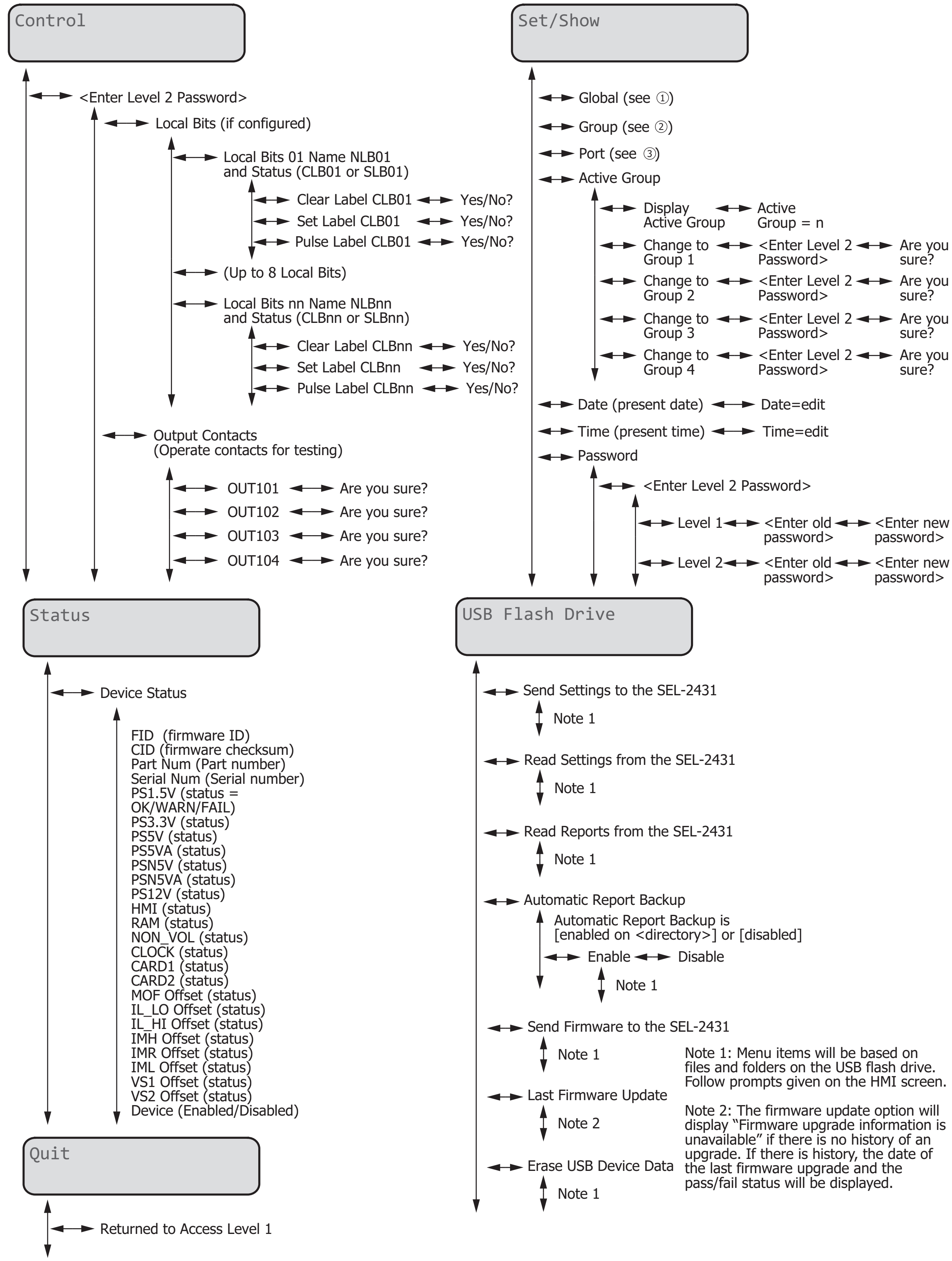


Figure 10.13 Events, Tap Counters, and Targets Menus



① See *Figure 10.15*. ② See *Figure 10.16* and *Figure 10.17*. ③ See *Figure 10.17*.

Figure 10.14 Control, Set/Show, Status, USB Flash Drive, and Quit Menus

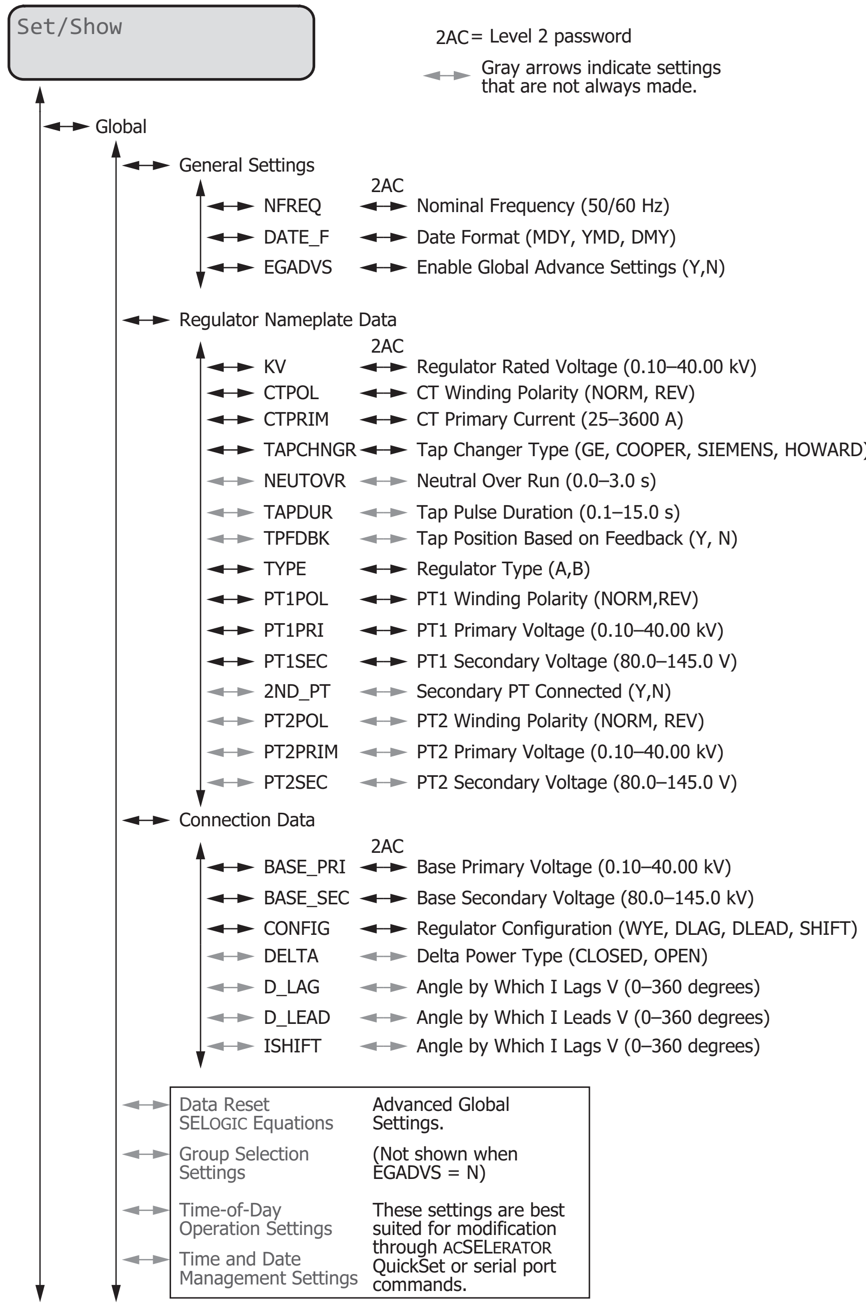


Figure 10.15 Global Settings Submenu

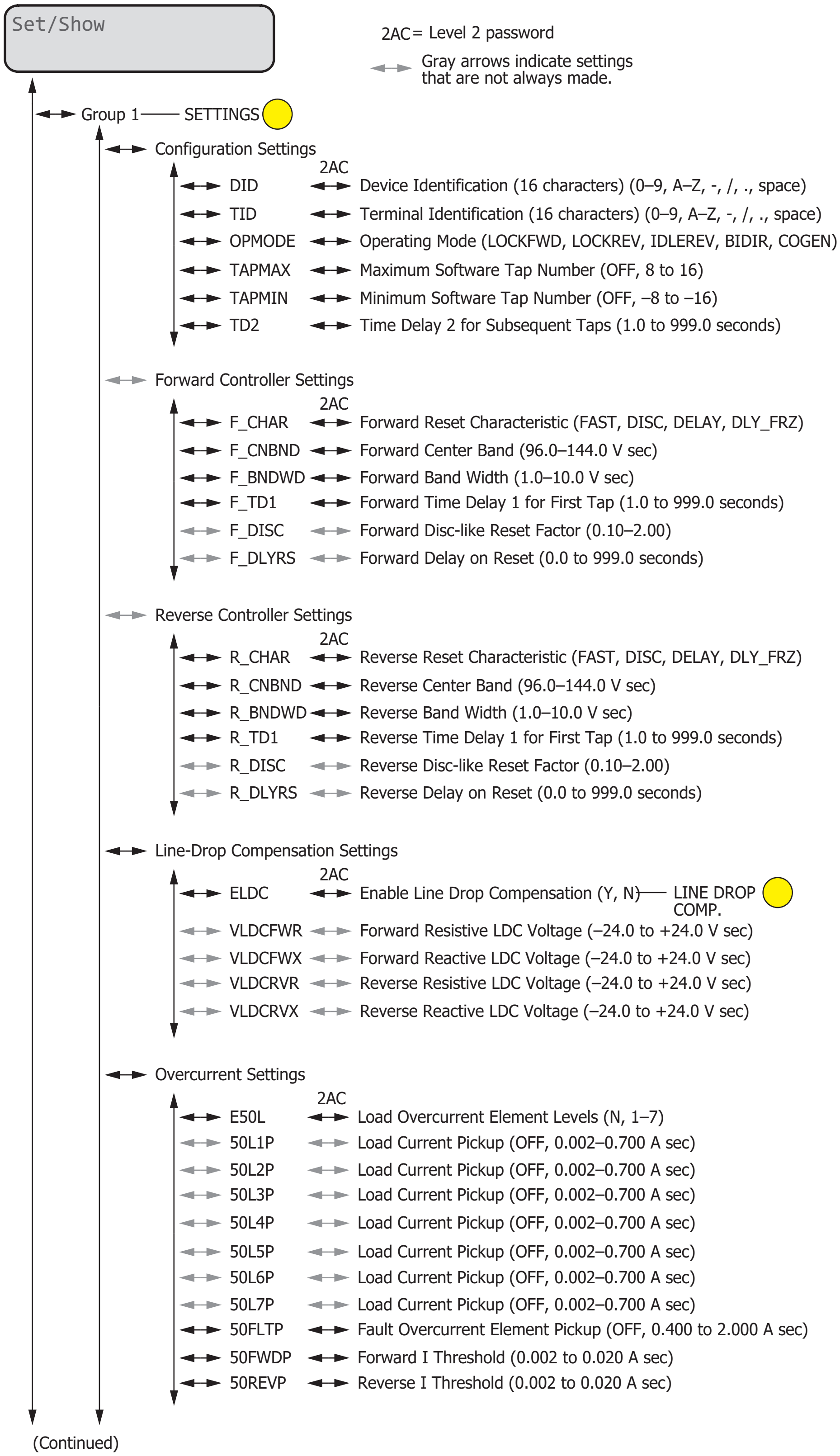


Figure 10.16 Group Settings Submenu

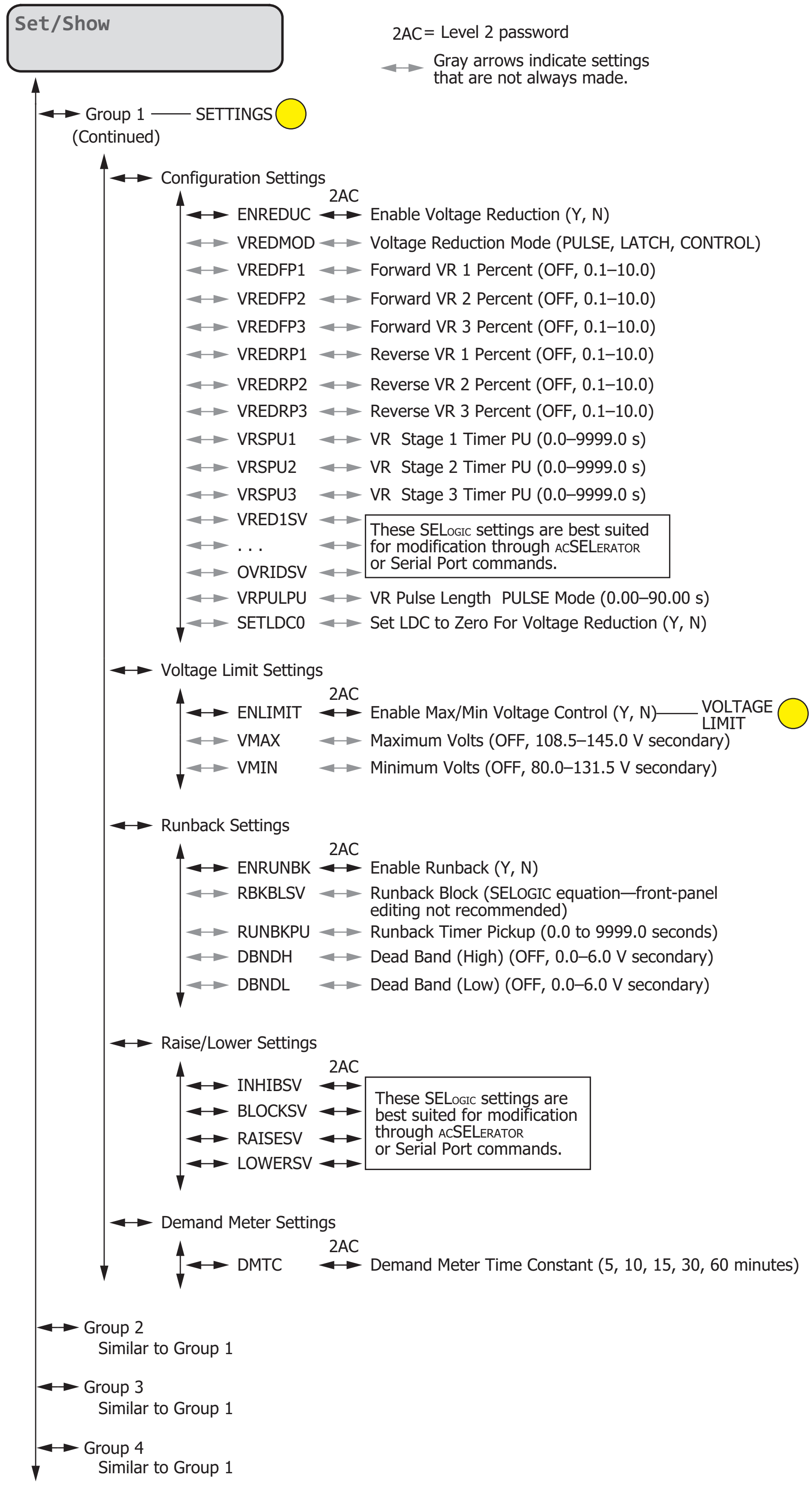


Figure 10.16 Group Settings Submenu (Continued)

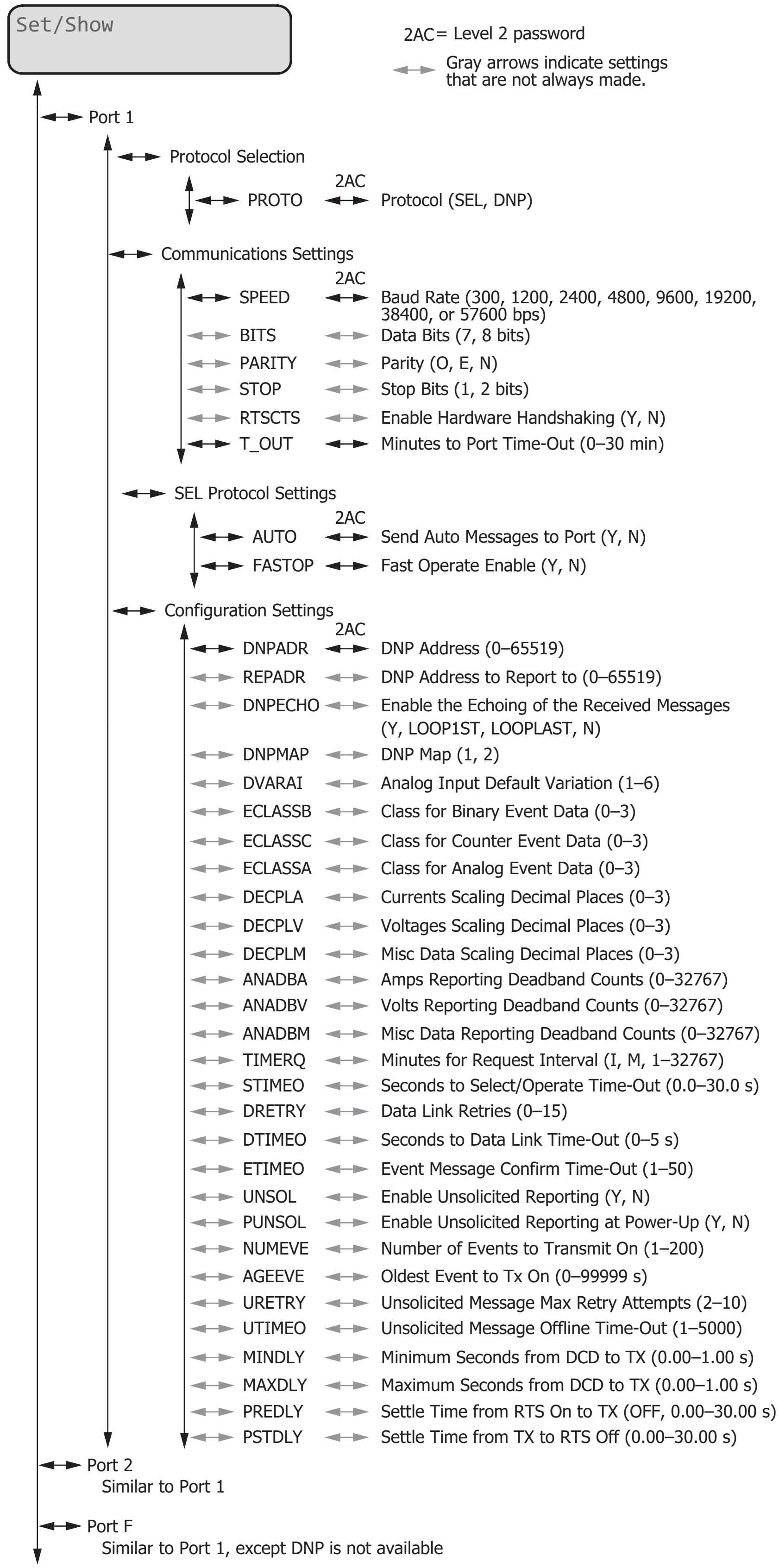


Figure 10.17 Port Settings Submenu

Meter Menu

Select the `Meter` menu item on the `Main` menu to access the analog metering data. See *METER Command (Metering Data)* on page 9.23 for formatting information.

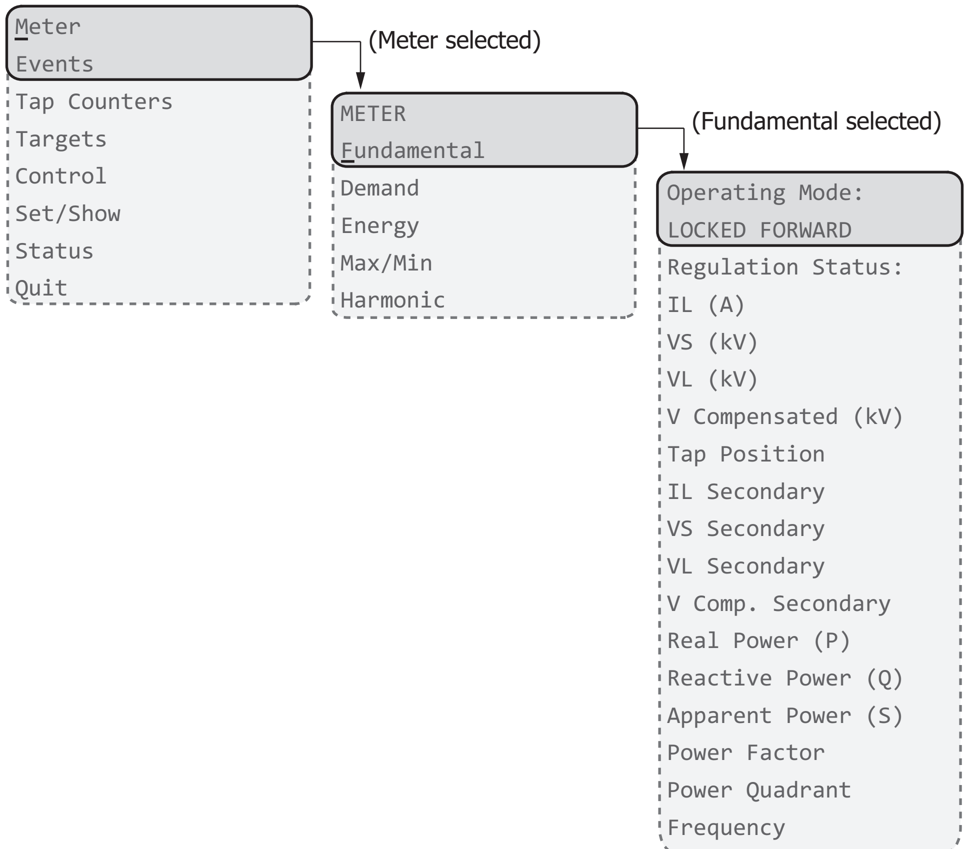


Figure 10.18 Main Menu and Meter Submenu

Events Menu

Figure 10.19 shows the `Events` menu of the SEL-2431. With this selection you can see an event summary, trigger an event, and clear existing events.

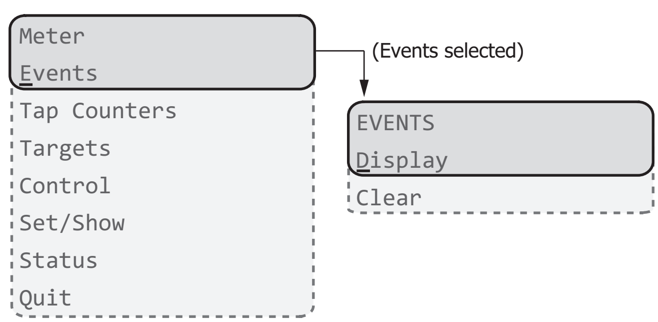


Figure 10.19 Main Menu and Events Submenu

If there is no event data available, the device displays `No Data Available` on the LCD, as shown in *Figure 10.20*.

```
No Data Available
```

Figure 10.20 Device Response When No Events Are Available

Figure 10.21 shows the response to the event summary. Use the **Left Arrow** and **Right Arrow** pushbuttons to read the date and time of the event.

```
DISPLAY
07/01/2007 21:40
```

Figure 10.21 Event Summary

Select `Clear` from the `Events` menu to clear all saved events in the device.

```
Clearing Complete
```

Figure 10.22 Events Cleared

Tap Counters Menu

Figure 10.23 shows the `Tap Counters` menu item on the `Main` menu and the sub-menus to access the tap counter data.

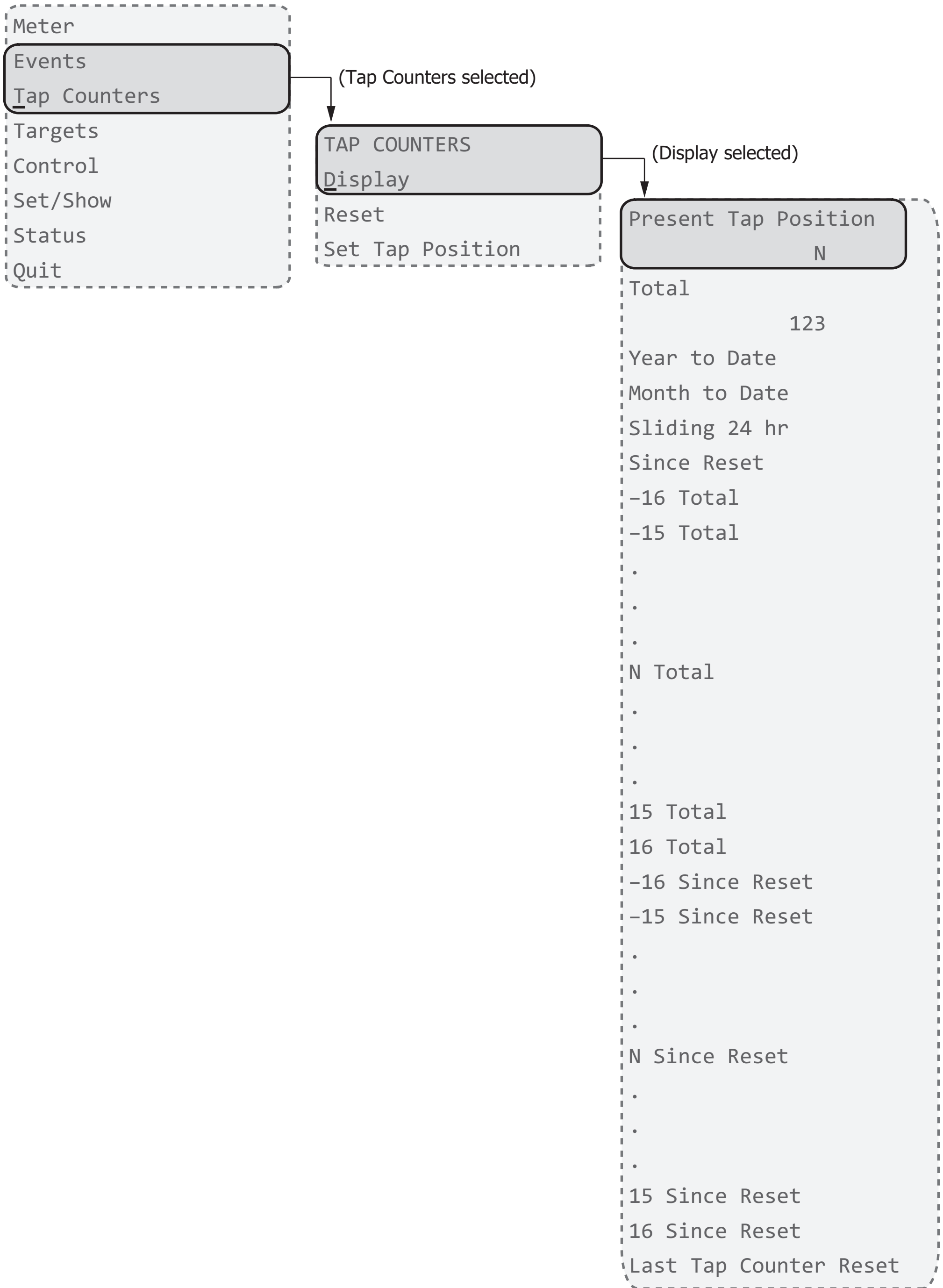


Figure 10.23 Main Menu and Tap Submenu

Similar `Tap Counter` menus are available to reset tap counts, preload or write tap counts, and to observe the present tap position.

Targets Menu

Figure 10.24 shows the `Targets` menu item on the `Main` menu and the submenus to access the target rows (Device Word bits).

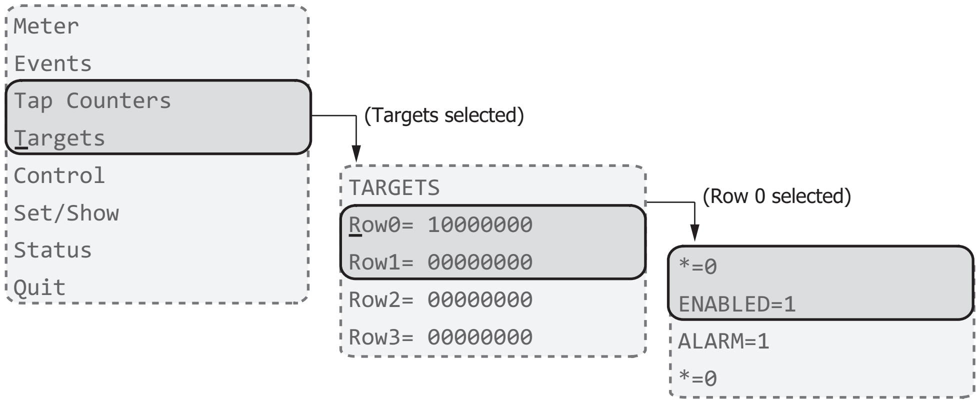


Figure 10.24 Main Menu and Target Submenu

Device Word bits are variables that are either asserted (logical 1) or deasserted (logical 0). *Table 10.4* shows an extract from the Device Word bit table (*Appendix E: Device Word Bits*). Target rows display eight Device Word bits from left to right as these appear in *Appendix E: Device Word Bits*. For example, Row 10 shows RB01–RB08 and Row 11 shows RB09–RB16, as shown in *Table 10.4*.

Table 10.4 Row 10 and Row 11 of the Device Word Bits

Row	7	6	5	4	3	2	1	0
10	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
11	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16

Figure 10.25 shows the display when all sixteen Remote bits are deasserted. *Figure 10.26* shows the display after asserting RB09 and RB10. If you press **ENT** once more, the specific Device Word bits are displayed, as shown in *Figure 10.27*.

```
Row 10=00000000
Row 11=00000000
```

Figure 10.25 RB01–RB16 Deasserted

```
Row 10=00000000
Row 11=11000000
```

Figure 10.26 RB09 and RB10 Asserted

```
RB09=1
RB10=1
```

Figure 10.27 RB09 and RB10 Status

Control Menu

The SEL-2431 provides a means to assert selected output contact through the `Main > Control` menu as shown in *Figure 10.28*. For control from the front panel, the relay uses variables known as local bits. Local bits take the place of traditional panel switches, and perform isolation, open, close or pulse operations.

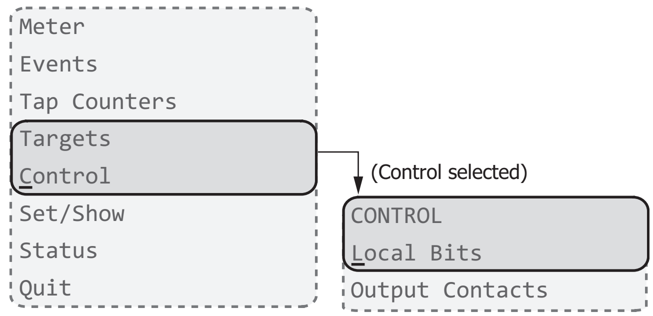


Figure 10.28 Main Menu and Control Submenu

Local Bits: Menu

Use the `Local Bits` menu option to operate as many as eight local control switches. These local control switches replace traditional panel-mounted control switches. The SEL-2431 saves the output states of the local control switches in nonvolatile memory and restores these states at power-up.

NOTE: Any unused local control bits default to the clear (logical 0) state. Also, any reconfigured local bit retains the existing bit setting after you change the bit setting. Disabling a local bit sets that bit to the clear (logical 0) state.

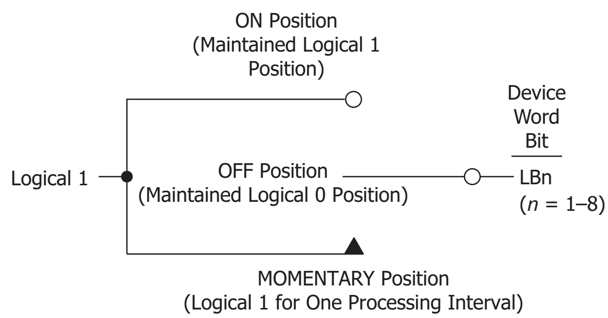


Figure 10.29 ON/OFF/MOMENTARY Local Control Switch

The output of the switch in *Figure 10.29* is a Device Word bit (LB01–LB08), called a local bit, and repeats for each local bit.

Local Bits: Switch Types

Use the settings in *Table 10.5* to create menu items that aid in using on, off, or momentary switches. Set ELB to the required number of local bits to enable the local bits settings. Use the **SET F** command.

Table 10.5 Local Bits Labels

Local Bits Switch Position	Label Setting	Setting Definition	Logic State
	NLB*n*	Name of local bit	
OFF	CLB*n*	“Clear” local bit LB*n*	Logical 0
ON	SLB*n*	“Set” local bit LB*n*	Logical 1
MOMENTARY	PLB*n*	“Pulse” local bit LB*n*	Logical 1 for one processing interval

Setting NLB*n*, the local bit name, must always contain a valid name. Enter other local bit label settings to configure the local bit switch type in accordance with *Table 10.6*. Enter **NA** to clear a setting.

Table 10.6 Local Bits Switch Configuration

Local Bits Switch Type	Label NLBn	Label CLBn	Label SLBn	Label PLBn
ON/OFF	x	x	x	
OFF/MOMENTARY	x	x		x
ON/OFF/MOMENTARY	x	x	x	x

ON/OFF Switch

Local bit LB*n* can be in the ON (LB*n* = logical 1) or OFF (LB*n* = logical 0) position.

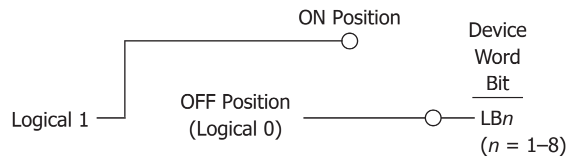


Figure 10.30 ON/OFF Local Control Switch

OFF/MOMENTARY Switch

Local bit LB*n* is maintained in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1 cycle).

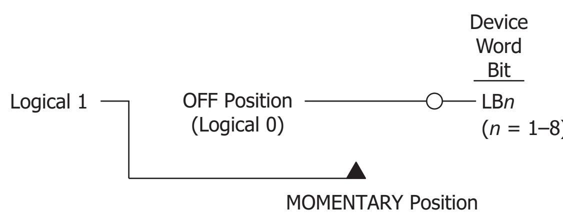


Figure 10.31 OFF/MOMENTARY Local Control Switch

ON/OFF/MOMENTARY Switch

Local bit LB*n* can be in the ON (LB*n* = logical 1) position, OFF (LB*n* = logical 0) position, or is maintained in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1 cycle).

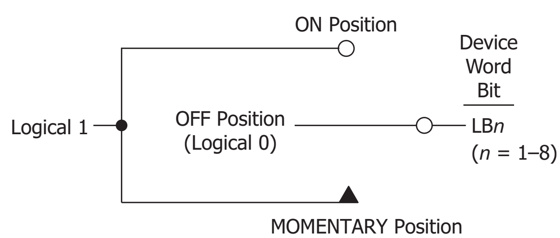


Figure 10.32 ON/OFF/MOMENTARY Local Control Switch

Local Bits: Operation

Table 10.7 shows examples of the local bit displays using setting names.

Table 10.7 Local Bits Menu

Select the `Local Bits` menu item on the `CONTROL` menu to access the local control switches.	CONTROL Local Bits
The LCD displays a menu empty of local bits if no local bits are enabled or programmed.	LOCAL BITS
The LCD will display a menu of local bits in numerical order if at least one local bit is enabled and programmed. The menu also shows the present position of the local control switches. Use the cursor keys to move to the desired local bit and press **ENT** to select it.	LOCAL BITS NLB01 = CLB01 NLB02 = CLB02 ⋮ NLB31 = CLB31 NLB32 = CLB32
Use the cursor keys to move to the desired position (SLB01, CLB01, or PLB01) and press **ENT** to select that position.	NLB01 = CLB01 SLB01 PLB01
Use the cursor keys to move to `Yes` and press **ENT** to activate that position. The local bit present state updates to the new position.	SLB01 No Yes

Local Bits: Nonvolatile State

The SEL-2431 stores local bit states in nonvolatile memory and retains these switch states during power-off conditions. When power is restored, the voltage regulator control restores the local bit states. If a local control switch is in the ON position (corresponding local bit is asserted to logical 1) when power is lost, this switch returns to the ON position (corresponding local bit is still asserted to logical 1) when power is restored. If a local control switch is in the OFF position (corresponding local bit is deasserted to logical 0) when power is lost, this switch returns to the OFF position (corresponding local bit is still deasserted to logical 0) when power is restored. This feature makes the local bit feature behave as a traditional installation with panel-mounted control switches. *If power is lost to the panel, the front-panel control switch positions remain unchanged.*

If a local bit is routed to a programmable output contact and control power is lost, the SEL-2431 stores the state of the local bit in nonvolatile memory but the output contact goes to the de-energized state. When the control power is reapplied to the voltage regulator control, the programmed output contact returns to the local bit state after voltage regulator control initialization.

Local Bits: Application Example

An example of voltage reduction enable/disable functions using local bit LB01 follows. The following label settings configure the local bit as an OFF/ON switch (enable local bit first with Front Panel setting ELB := 1 or greater).

Table 10.8 Local Bits Example Settings

Local Bit	Function	Setting
LB01	Name	NLB01 = VOLTAGE REDUCTION
	OFF Position	CLB01 = STAGE 1 OFF
	ON Position	SLB01 = STAGE 1 ON
	MOMENTARY Position	PLB01 = “”

Use the following steps to change the local bit state.

Select the `Local Bits` menu item on the `Control` menu to access the local control switches.	LOCAL BITS VOLTAGE REDUCTION = STAGE 1 OFF
Select the desired local bit (by pressing the **Down Arrow** if necessary), then press **ENT**.	VOLTAGE REDUCTION = STAGE 1 OFF STAGE 1 ON
Press the **ENT** button.	STAGE 1 ON? Yes No
Press the left navigation arrow to select `Yes`.	STAGE 1 ON? Yes No
Voltage Reduction is now enabled.	VOLTAGE REDUCTION = STAGE 1 ON STAGE 1 OFF

Set local bit 1 (LB01) into group setting voltage reduction level 1 SELOGIC equation VRED1SV := LB01. When local bit 1 (LB01) asserts, voltage reduction will be enabled. When LB01 deasserts, voltage reduction will be disabled.

Local Bits: Application Ideas

The preceding settings example is for an OFF/ON switch. Local bits can also be used for other applications, such as the following:

- ➤ Voltage limit enable/disable
- ➤ Runback enable/disable
- ➤ Remote control supervision

Output Contacts Menu

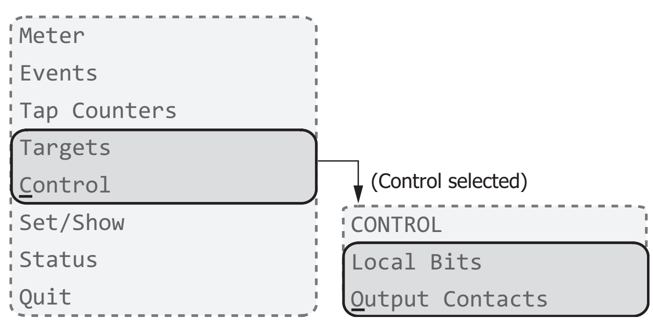


Figure 10.33 Output Contacts Submenu

Use the Output Contacts menu option to pulse an output contact for one second. If the output contact is already asserted (energized), the command will not be completed and the following message will be displayed: Command is not available.

Set/Show Menu

Figure 10.34 shows the Set/Show menu of the SEL-2431 and *Figure 10.25* shows major items from selected submenus.

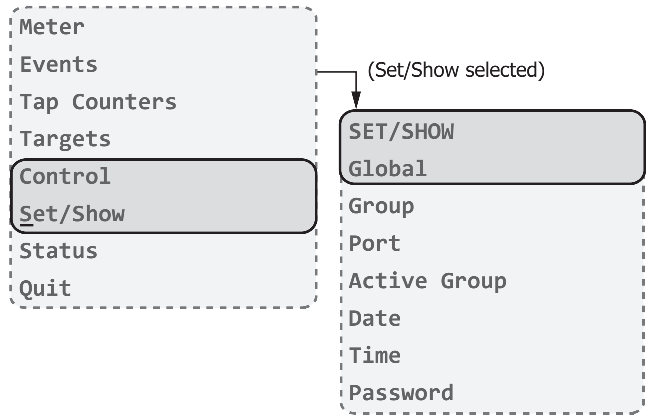


Figure 10.34 Main Menu and Set/Show Submenu

Each settings class includes headings that create subgroups of associated settings. Select the heading that contains the setting of interest, then navigate to the particular setting. View or edit the setting by pressing **ENT**. For text settings, use the four navigation pushbuttons to scroll through the available alphanumeric and special character settings matrix. For numeric settings, use the **Left Arrow** and **Right Arrow** pushbuttons to select the digit to change and the **Up Arrow** and **Down Arrow** pushbuttons to change the value. Press **ENT** to enter the new setting. Setting changes can also be made using the ASCII **SET** commands via a communications port.

Figure 10.35 shows the complete Set/Show submenu. Password, the last submenu, shows the first three screens when changing the password. Follow the steps described in *Front-Panel Text Symbol Matrix* on page 10.9 to complete the change.

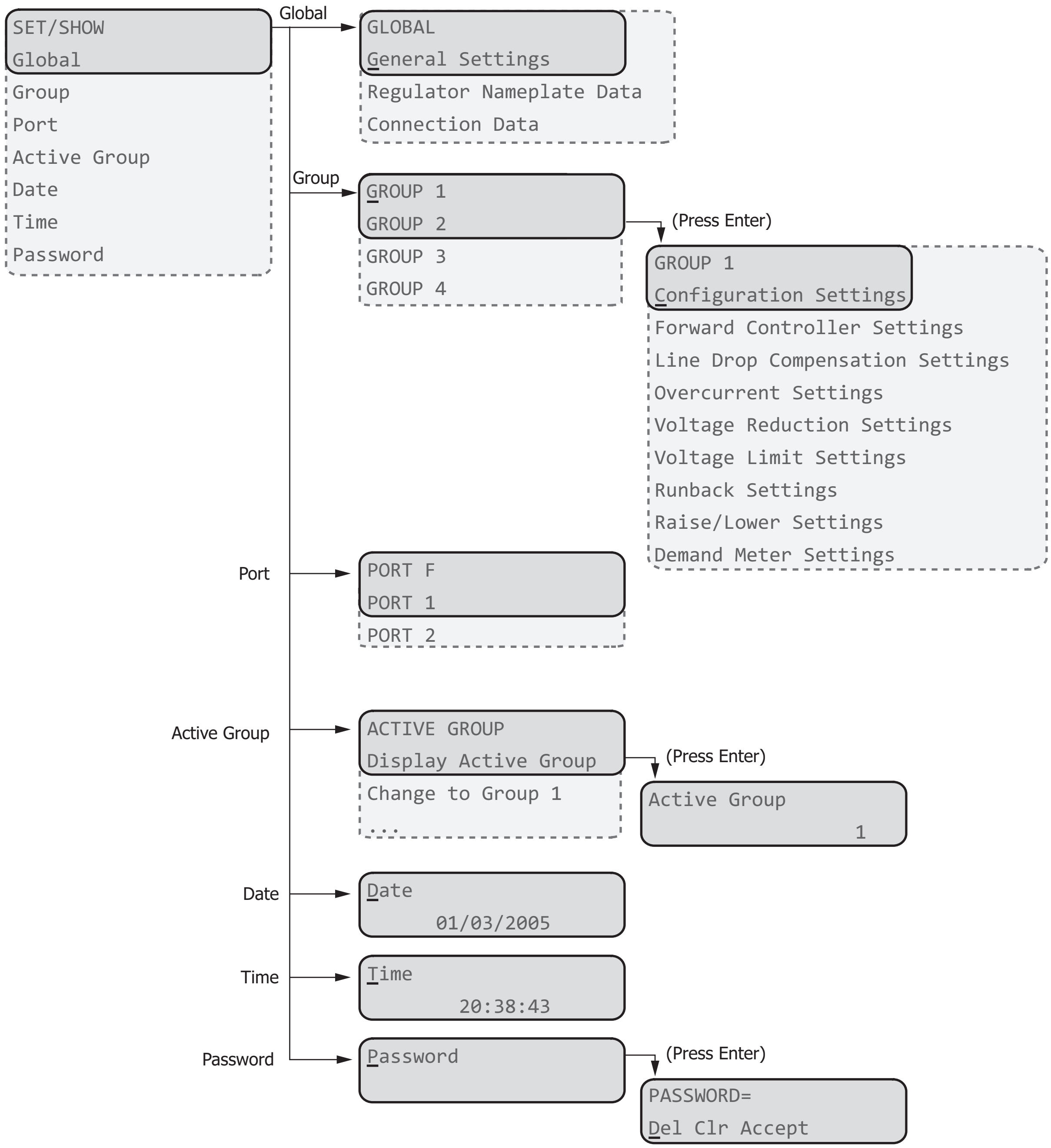


Figure 10.35 Set/Show Menu

Status

Display SEL-2431 status indicators as shown in *Figure 10.26*.

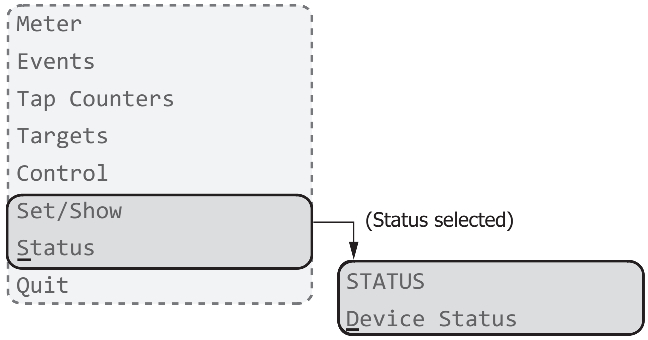


Figure 10.36 Main Menu and Status Submenu

Quit

Exit the present access level and return to Access Level 1.

Front-Panel Settings for Operator Control Pushbuttons and LEDs

Figure 10.37 shows the operator control pushbuttons section of the SEL-2431 front panel and corresponding front-panel operator control pushbutton settings PB*nn*HMI and operator control LED settings PB*nn*LED.

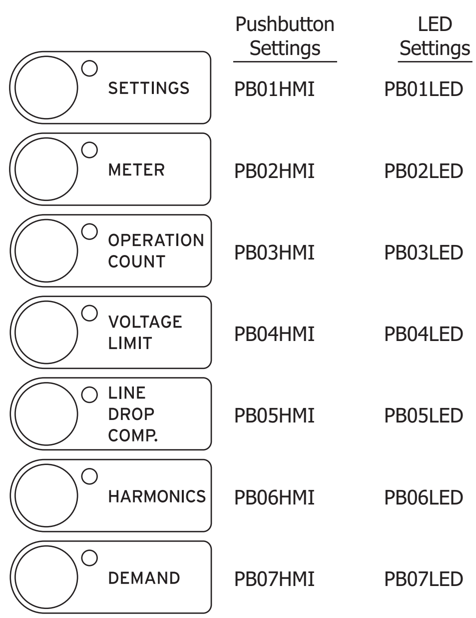


Figure 10.37 Operator Control Pushbuttons and Indicator LEDs

Table 10.9 below lists the possible functions of the operator control pushbuttons. *Table 10.9* also lists the equivalent serial port command. Refer to *Section 8: Settings* for information on setting front-panel pushbutton functions into Front Panel settings PB01HMI–PB07HMI.

Table 10.9 Operator Control Pushbutton Functions

PBnnHMI Setting Option	Function	Equivalent Serial Port Command
OFF	No action taken	
GRP	Jump to start of active group settings	**SET**
GLB	Jump to start of Global settings	**SET G**
MET	Jump to fundamental metering report	**MET**
OP_CNT	Jump to tap report	**TAP**
V_LIM	Jump to voltage limit settings	**SET ENLIMIT**
LDC	Jump to line drop compensation settings	**SET ELDC**
HARM	Jump to harmonic metering report	**MET H**
DEMAND	Jump to demand report metering report	**MET D**

As an example, to get to the forward controller settings via the navigation menu, you would execute the following keystrokes:

1. **ENT**—Go to main navigation menu
2. **Down Arrow**
3. **Down Arrow**
4. **Down Arrow**
5. **Down Arrow**
6. **Down Arrow**—Navigate down to the Set/Show menu
7. **ENT**—Select the Set/Show menu
8. **Down Arrow**—Navigate down to the Group settings
9. **ENT**—Select Group settings
10. **ENT**—Select group 1
11. **Down Arrow**—Navigate down to forward controller settings
12. **ENT**—Select forward controller settings to start at the F_CHAR Group setting

By pressing factory-default operator control **SETTINGS**, which defaults to PB01HMI := GRP, you jump to keystroke #10, and save nine keystrokes. Continue to press **SETTINGS** to scroll through Group settings categories. The other operator control pushbuttons operate similarly.

SECTION 11

Analyzing Events

Overview

The SEL-2431 Voltage Regulator Control provides several tools (listed below) to analyze device operations and power system conditions. Use these tools to help diagnose the cause of device operations.

- Event Reporting
  - History Reports
  - Event Reports (Compressed ASCII format)
- Sequential Events Recorder Reports
- Load Parameter Calculation Reports

All reports are stored in nonvolatile memory, ensuring that a loss of power to the SEL-2431 will not result in lost data (see *Event Reporting* on page 11.2 for more information on number and length of reports).

Event Reporting

Analyze events with the following event reporting functions:

- Event History—The SEL-2431 stores an indexed history of event reports in nonvolatile memory. Use the **HISTORY** command to obtain the event history. The event history includes some of the event summary information with which you can identify a specific event report.
- Event Reports—These detailed reports are stored in nonvolatile memory for later retrieval and detailed analysis.

Each time an event occurs, the relay creates a new event history record and event report. Event report information includes the following:

- Date and time of the event
- Individual sample analog inputs (currents and voltages)
- Digital states of all Device Word bits (listed in *Appendix E: Device Word Bits*)
- Event summary, including the front-panel LED states at the time of trigger
- Group, Logic, Global, and Report settings

Compressed ASCII Event Reports and History

The SEL-2431 provides Compressed ASCII event reports to facilitate event report storage and display. SEL communications processors and Analytic Assistant take advantage of the Compressed ASCII format, as show in *Table 11.1*.

Table 11.1 Compressed ASCII Event Commands

Command	Description
CHI	Displays Compressed ASCII event history information.
CEV	Displays Compressed ASCII event reports.

See the *CEVENT Command (Compressed Event Report)* on page 9.17 and *SEL Compressed ASCII Commands* on page C.1. Compressed ASCII Event Reports contain all of the Device Word bits.

Sequential Events Recorder (SER)

The SER report captures detailed digital element state changes. Settings allow as many as 96 Device Word bits to be monitored, in addition to the automatically generated triggers for device power up and settings changes. State changes are time-tagged to the nearest millisecond. SER report data are useful in commissioning tests and during operation for system monitoring and control. SER information is stored when state changes occur.

Event Reporting

The SEL-2431 provides Compressed ASCII event reports with analog data sampled every quarter of a power system cycle and digital data sampled once every power system cycle.

The recorded analog data are from a fundamental filter, so it does not include harmonics. Each event report includes the following:

- ➤ Analog (current and voltage)/Digital Section
- ➤ Event Summary
- ➤ Group Settings
- ➤ Logic Settings
- ➤ Global Settings
- ➤ Report Settings

Depending on the PT connections, the report shows either line-to-neutral voltages or line-to-line voltages.

Pre-Trigger

The SEL-2431 provides a fixed event report length of 30 cycles and selectable pre-trigger length. Pre-trigger length is the first part of the total event report length and precedes the event report triggering point. Pre-trigger length is 1–29 cycles. Changing the PRE setting has no effect on the stored reports.

The event report settings are contained in the Report settings class, as shown in *Report Settings* on page SET.18. Use the **SHO R** or **SET R** command to view or modify the report settings, as described in *Section 8: Settings*.

The factory-default report settings are shown in *Figure 8.5*.

Table 11.2 Number of Events

Event Report Length	Number of Events
30 cycles	32

Triggering

The SEL-2431 triggers (generates) an event report when any of the following occur:

- Programmable SELOGIC control equation setting ER asserts to logical 1 (in Report settings)
- The device receives the serial port command **TRI** (Trigger Event Reports)

Programmable Event Report Trigger SELOGIC Equation

Enter as many as 15 elements (as many as 14 nested parentheses) in the programmable SELOGIC control equation event report trigger setting ER to trigger event reports (**SET R**). When the ER equation asserts from a logical 0 to logical 1, the relay generates an event report (if the SEL-2431 is not already generating a report that encompasses the new transition).

The factory-default ER setting responds to voltage regulator error conditions, but not for routine voltage regulator automatic operations. See the default logic setting for SV01 in *Figure 8.3* for the list of elements. These default settings allow the event history to contain data of interest, rather than being full of normal regulator operations.

Retrieving Compressed Event Reports

Via Serial Port Command

Use a terminal emulator program configured to capture the serial port data, and issue the **CEV** ***n*** command, where *n* is the desired event report (as listed by the **HISTORY** command). Save the downloaded file using a .CEV extension.

Using QuickSet

You can also use QuickSet for downloading events. See *Event Analysis* on page 2.12 for more details.

TRI (Trigger Event Report) Command

The sole function of the **TRI** serial port command is to generate event reports, primarily for testing purposes. See *TRIGGER Command (Trigger Event Report)* on page 9.33 for more information on the **TRI** (Trigger Event Report) command.

Event Summary Data

The SEL-2431 compressed event report header contains the summary values for currents and voltages at the time of event trigger, as shown in *Table 11.3*. View these values by opening the .CEV file using Analytic Assistant software and choosing the **View > Summary Data** menu item.

Table 11.3 Compressed Event Summary Data

Summary Data Label	Description	Units or Definition
EVENT	Trigger method for event report	ER = Report setting ER, TRIG = command TRIG
VS	Normal source-side (S-to-SL bushing) voltage at time of trigger (may be measured or calculated)	V secondary (adjusted base)
IL	IL current at time of trigger	A primary
VL	Normal load-side (L-to-SL) bushing voltage at time of trigger	V secondary (adjusted base)
VCMP[a]	Compensated voltage at time of trigger	V secondary (adjusted base)
GROUP	Setting group at time of trigger	Group 1, 2, 3, or 4
TAP_POS	Tap position at time of trigger	–16 to –1, N, 1 to 16
VR	Voltage Reduction state at time of trigger	. (= none), 1, 2, or 3
RP	Reverse Power indicator at time of trigger	* = REVERSE asserted, . = REVERSE deasserted
BND	Band indicators at time of trigger	Hi = HBND, In = IN_BND, Lo = LBND, . = all three are Off
LIM	Voltage High/Low Limit Indicators at time of trigger	Hi = VMAXLMT, Lo = VMINLMT, . = Both are Off
IM	Motor Control status at time of trigger	Rse = MRAISE, Lwr = MLOWER, . = Both are Off
CNTRL	Control Configuration at time of trigger	RM = Remote and Manual, RA = Remote and Auto, LM = Local and Manual, LA = Local and Auto
OPCNTT	Operations Counter at time of trigger	none

[a] See *Figure 7.1* for VCMP operating details.

Oscillography

The compressed event reports contain 30-cycles of oscillographic data for the signals listed in *Table 11.4*. The analog values are stored at a rate of 4 samples per power system cycle.

Additionally, every SEL-2431 Device Word bit is included in the digital section of the compressed event report, and these are stored at a rate of 1 sample per power system cycle, corresponding to the SEL-2431 control processing interval.

NOTE: When using SEL-5601 to view SEL-2431 oscillographic analog and digital data, the digital data transitions may appear 3/4 of a cycle early.

View these analog and digital values in a graph by opening the .CEV file using Analytic Assistant, and choosing **View > Graph** menu item. View these analog values as phasors by opening the .CEV file using Analytic Assistant and choosing **View > Phasors** menu item.

Table 11.4 Compressed Event Report Oscillographic Data (Sheet 1 of 2)

Summary Data Label	Description	Units or Definition
VS (kV)[a]	Normal source-side (S-to-SL bushing) voltage (as measured)	kV primary
IL[b]	IL current	A primary
VL (kV)	Normal load-side (L-to-SL bushing) voltage	kV primary
IMR[c]	Motor Raise Current	A

Table 11.4 Compressed Event Report Oscillographic Data (Sheet 2 of 2)

Summary Data Label	Description	Units or Definition
IML[c]	Motor Lower Current	A
IMH[d]	Motor Holding Switch Current	A
TAP_POS[e]	Tap position	–16 to –1, N, 1 to 16

[a] The VS (kV) analog value is from the measurement channel V_{S1} or V_{S2}, depending on the voltage regulator type. If there is no voltage signal connected, this channel will show zero volts.

[b] The IL current analog channel is not affected by the Global settings CONFIG or DELTA. If the control is installed on a line-to-line connected voltage regulator, the phase of the IL channel oscillographic data will appear shifted by ±30 degrees.

[c] The IMR or IML motor raise or lower current channel only shows activity when the voltage regulator is performing a tap operation.

[d] The IMH motor holding switch current channel only shows activity when the control is connected to a Cooper/McGraw Edison voltage regulator, and a tap change is in progress.

[e] Not an oscillographic quantity. Included in this table for convenience.

Oscillography Channel VS Detail

Event report oscillography channel VS is always active, even when the Global nameplate settings are configured for a single voltage input. This allows for troubleshooting during commissioning procedures. When the SEL-2431 is in service, oscillography channel VS may be ignored when using a voltage regulator with only a single voltage output (for oscillography channel VL).

Notes accompanying *Figure B.1–Figure B.4* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* explain the correspondence of event report oscillography channels VS and VL with voltages deemed V_{S1} and V_{S2} from the various voltage regulators. This V_{S1} and V_{S2} nomenclature extends to the internal voltage inputs of the SEL-2431 (see the lower left corner of *Figure C.1* in the *SEL-2431 Voltage Regulator Control Field Reference Guide).*

When the **CONTROL POWER** switch is in the **EXTERNAL** position for testing, oscillography channels VS and VL receive the same signal, and both channels show up in event report oscillography. If the SEL-2431 is being bench-tested, the VS and VL oscillography voltage signals may differ if there is not a wiring harness attached to the J1 connector to provide a neutral reference for the V_{S2} voltage input (see *Figure C.1* in the *SEL-2431 Voltage Regulator Control Field Reference Guide).*

When Global setting 2NDPT := N, the PT2PRIM and PT2SEC settings are hidden, and oscillography channel VS uses the PT1PRIM and PT1SEC Global settings for primary scaling. If the V_{S2} input is energized with the same signal that energizes V_{S1} (for example, through a jumper as shown at the top of *Figure B.9* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*), the VS oscillography values exactly match the VL oscillography values, but do not represent the real VS-terminal primary signal. Further, the SEL-2431 voltage control algorithms, metering functions, and event summary value VS (shown in *Table 11.3*) operate from a calculated VS value (VS calculated from VL, with adjustment by known tap position and load), and the oscillography channel VS signal has no effect on control operation.

Event History

The event history report gives you a quick look at recent activity. The SEL-2431 labels each new event in reverse chronological order with 1 as the most recent event. See *Figure 11.1* for a sample event history. Use this report to view the events that are presently stored in the SEL-2431. The event history contains the following:

- Standard report header
  - Device and terminal identification
  - Date and time of report
- Event number, date, time, current, voltage VL, frequency, group, tap position, and select front-panel LED status

```
=>HIS <Enter>

SEL-2431                                  Date: 02/14/2007   Time: 12:11:22
Voltage Reg

FID = SEL-2431-R100-V0-Z001001-D20070601

#      DATE         TIME    EVENT  IL  VL      FREQ  GR  TAP  VR  RP  BAND  OUT  CC
                                  (A) (sec)   (Hz)
1  02/14/2007  09:05:34.991 TRIG  114  121.0  60.0  2   +02  .   .   In..  .    LA
2  02/11/2007  22:01:29.089 ER    113  121.0  60.0  2   +04  .   .   In..  .    LA
3  02/11/2007  07:45:22.371 ER    140  121.4  60.0  2   +06  .   .   In..  .    LA
4  01/27/2007  03:51:58.903 ER      1  122.0  60.2  1    N   .   .   Hi..  .    LA
5  01/22/2007  17:22:32.371 ER     71  122.0  60.0  1   -02  .   .   Hi..  Lwr  LM
6  01/13/2007  11:47:20.573 ER     91  120.7  59.9  1   +01  .   .   Hi..  .    LM


=>
```

Figure 11.1 Example Event History

The HISTORY report column definitions are shown in *Table 11.5*.

Table 11.5 Event History Data (Sheet 1 of 2)

Summary Data Label	Description	Units or Definition
#	Event report reference number	1 to 32
DATE	Date event was triggered	
TIME	Time event was triggered	
EVENT	Event report event type	ER = Generated by SELOGIC setting ER TRIG = Generated by **TRIGGER** command
IL	IL current at time of trigger	A primary
VL	Normal load-side (L-to-SL bushing) voltage at time of trigger	V secondary (adjusted base)
FREQ	Frequency at time of trigger	Hz
GR	Setting group at time of trigger	Group 1, 2, 3, or 4
TAP	Tap position at time of trigger	–16 to –1, N, 1 to 16
VR[a]	Voltage Reduction state at time of trigger	. = none, 1, 2, or 3
RP[a]	Reverse Power indicator at time of trigger	* = REVERSE asserted . = REVERSE deasserted

Table 11.5 Event History Data (Sheet 2 of 2)

Summary Data Label	Description	Units or Definition
BAND[a]	Band indicator at time of trigger	First two characters: Hi = HBND In = IN_BAND Lo = LBND .. = none Last two characters: HL = VMAXLMT LL = VMINLMT .. = none
OUT[a]	Motor outputs at time for trigger	Rse = RAISE Lwr = LOWER . = both are off
CC[a]	Control Configuration at time of trigger	RM = Remote Manual LA = Local Auto RA = Remote Auto LM = Local Manual

[a] Not available on front-panel menu History screens.

Viewing the Event History

Access the history report from the communications ports, using the **HIS** command or the **Tools > Events > Get Event Files** menu within QuickSet. View and download history reports from Access Level 1 and higher.

Use the **HIS** command from a terminal to obtain the event history. You can specify the number of the most recent events that the voltage regulator control returns (see *HISTORY Command* on page 9.21 for more information on the **HIS** command).

Use the front-panel `Main > Events > Display` menu to display event history data on the SEL-2431 front-panel display.

Clearing

NOTE: Clearing the history report with the **HIS C** command also clears all event data within the SEL-2431 event memory.

Use the **HIS C** command to clear or reset history data from Access Levels 1 and higher, as shown in *Figure 11.2*. Clear/reset history data at any communications port. This will clear all event summaries, history records, and reports.

```
=>HIS C <Enter>
History Clear
Are you sure (Y,N)? Y <Enter>
Clearing Complete

=>
```

Figure 11.2 Clearing Event Data

SEL-2431 Event Report Uses

The ability to monitor the voltage regulator motor currents and power system currents and voltages may be valuable when troubleshooting the following issues:

- Voltage regulator misoperation
- Voltage regulator mechanism problems
- Utility system power quality problems
- Certain power system reliability issues

The SEL-2431 is not designed to analyze power system faults, because the current transformers used in voltage regulators may saturate during fault conditions, which would result in misleading data. Additionally, there is no backup power for the SEL-2431, so a power system disturbance may lower the power supply voltage enough to shut down the voltage regulator control. By contrast, a recloser control, such as the SEL-351R or SEL-651R, is well suited to monitor power system faults.

Analog RMS Scaling

The oscillographic quantities listed in *Table 11.4* are not scaled like a traditional oscilloscope display (peak responding), but they are scaled by $1/\sqrt{2}$ (RMS responding).

This means that the observed peak value of a waveform viewed in Analytic Assistant represents the RMS value of the signal, instead of the peak value.

For example, if a steady 12.5 kV voltage is measured by the VL channel, the compressed event report sine wave will appear to have peaks at +12.5 kV and –12.5 kV, rather than at +17.67 kV and –17.67 kV, as a traditional oscilloscope would display it. The peak value = $\sqrt{2}$ • RMS value.

Use Analytic Assistant to display the signal magnitudes of the oscillographic channels, and the calculations automatically account for the RMS scaling.

Sequential Events Recorder (SER)

The SEL-2431 SER (Sequential Events Recorder) report gives you detailed information on relay states and relay element operation. The SER captures and time tags state changes of Device Word bits and relay conditions. These conditions include power up, relay enable and disable, settings changes, and chattering element automatic removal and reinstatement.

The SER records as many as 1024 state changes of as many as 96 Device Word bits specified in the SER trigger list. SER data are stored in nonvolatile memory, ensuring that a loss of power to the SEL-2431 will not result in lost data.

Processing Rate and Time-Stamping Resolution

The SEL-2431 samples analog and digital signals at a rate dependent on the power system frequency. The SER records state changes in Device Word bits, which are updated once every power system cycle.

- For 60 Hz nominal system, the processing rate is approximately 4.67 ms
- For 50 Hz nominal systems, the processing rate is approximately 5.00 ms

The SER time-stamps the state changes with 1 ms resolution. See *Specifications* on page 1.7 for more details.

SER Report

Figure 11.3 shows the following data contained in the SER report:

- Device and terminal identification
- Date and time of report
- SER number
- SER date and time

- ➤ Device element or condition
- ➤ Element state

```
=>SER <Enter>
SEL-2431                                   Date: 05/10/2007   Time: 15:15:10
Voltage Reg

Serial No = 0000000000      FID = SEL-2431-Rxxx-V0-Z001001-Dyyyymmdd
CID = 8F57

#      DATE         TIME                ELEMENT                   STATE
19  05/09/2007  16:22:44.796  SER Archive Cleared
18  05/10/2007  13:59:29.849  Device Powered Up
17  05/10/2007  13:59:29.849  SPEN                          Asserted
16  05/10/2007  13:59:29.866  BLOCKSV                       Asserted
15  05/10/2007  13:59:32.149  BLOCKSV                       Deasserted
14  05/10/2007  15:13:08.874  MANUAL                        Deasserted
13  05/10/2007  15:13:08.874  AUTO                          Asserted
12  05/10/2007  15:13:52.980  IN_BND                        Deasserted
11  05/10/2007  15:13:52.980  HBND                          Asserted
10  05/10/2007  15:13:53.180  IN_BND                        Asserted
9   05/10/2007  15:13:53.180  HBND                          Deasserted
8   05/10/2007  15:13:53.330  IN_BND                        Auto Removed
7   05/10/2007  15:13:53.330  HBND                          Auto Removed
6   05/10/2007  15:14:20.833  MANUAL                        Asserted
5   05/10/2007  15:14:20.833  AUTO                          Deasserted
4   05/10/2007  15:14:40.116  HBND                          Auto Reinstated
3   05/10/2007  15:14:40.116  HBND                          Deasserted
2   05/10/2007  15:14:40.116  IN_BND                        Auto Reinstated
1   05/10/2007  15:14:40.116  IN_BND                        Asserted

SER
Number                        Element or Condition          Element State
```

Figure 11.3 Sample SER Report

Each entry in the SER includes the SER row number, date, time, element name, and element state. In the SER report, the oldest information has the highest number, i.e., the newest information is the Number 1 entry (IN_BND in *Figure 11.3*).

The element state field contains one of the values listed in *Table 11.6*.

Table 11.6 SER Element State Definitions

Element State	Meaning
Asserted	Element state changed to logical 1 after being at logical 0
Deasserted	Element state changed to logical 0 after being at logical 1
Auto Removed[a]	Element removed from SET recording because of excessive chatter
Auto Reinstated[a]	Previously removed element now included in SER recording because chatter subsided

[a] See *Figure 11.1*.

When using a computer terminal, you can change the order of the SER records in the SER report. See *SER Command (Sequential Events Recorder Report)* on page 9.27 for more information.

SER Triggering

To capture element state changes in the SER report, enter the element name (Device Word bit) into one of the 96 trigger list locations.

The SER settings are contained in the Report settings class, as shown in *Report Settings* on page SET.18. Use the **SHO R** or **SET R** command to view or modify the report settings, as described in *Section 8: Settings*.

The factory-default report settings are shown in *Figure 8.5*, and contain SER triggers for several operating conditions or errors, but not for routine voltage regulator automatic operations. This allows the SER to contain data of interest, rather than being full of normal raise and lower operations.

Depending on the type of voltage regulator connected to the SEL-2431, and the specific application, some of the default Device Word bits may never appear in the SER. For example, Device Word bit TAP_OFF may only appear when Global setting TAPCHNGR := SIEMENS or HOWARD. There is no problem leaving extra entries in the SER Trigger List, unless all 96 trigger list positions are needed.

See *Table E.2* for more information on SEL-2431 Device Word bits.

In addition to the programmable SER trigger lists, the SEL-2431 control adds preprogrammed messages to the SER for certain occurrences, as listed in *Table 11.7*.

Table 11.7 Preprogrammed SER Message Definitions

Occurrence or Action	Message in SER
Clearing the SER (**SER C** command)	SER Archive Cleared
SEL-2431 initializes	Device Powered Up
SEL-2431 shuts down when using STA C or L_D command	Device Powered Down[a]
Changes made to settings (other than DNP or serial port setting)	Device Settings Changed
Active settings group switched	Device Group Changed
DATE or **TIME** command issued	Device Time Changed
Daylight-saving time start or end (automatic adjustment)	Daylight Savings Time Change
Access gained when passwords disabled	Passwords Disabled via Jumper[b]
2AC command successful	2AC Access Granted
ACC or **2AC** command unsuccessful	Level ACC/2AC Access Denied
Event report triggered and stored in memory	Event Report Triggered[c]
SER recording suspended while storing report is non-volatile memory.	SER Data Loss Begin[d]
SER recording resumes after being suspended	SER Data Loss End[d]
Access Level 1 or 2 password changed	Level ACC/2AC Password Changed

[a] Message not recorded for shutdown on loss of control power.
[b] See Jumpers and Clock Battery in Section 2: Installation of the SEL-2431 Voltage Regulator Control Field Reference Guide.
[c] The time shown will differ from the event time recorded in the HISTORY report. The SER records when the event report storage has been completed, rather than when the event report was triggered.
[d] The SER data are temporarily stored in high-speed memory, and then transferred to slower nonvolatile memory. If new SER data occur faster than this process, the data loss begin and end messages indicate that SER data are missing.

Viewing and Clearing SER Reports

The device displays the SER records in ASCII formats. To retrieve SER information, type **SER <Enter>** at Access Level 1 or higher to see a report similar to that shown in *Figure 11.3* (see *SER Command (Sequential Events Recorder Report)* on page 9.27 for details on the SER command). *Figure 11.4* shows how to clear the SER report.

```
=>SER C <Enter>
SER Clear
Are you sure (Y,N)? Y <Enter>
Clearing Complete

=>
```

Figure 11.4 Clearing the SER Data

Automatic Deletion and Reinstatement

The SER also includes an automatic deletion and reinstatement function. When the autodeletion function is enabled, the SEL-2431 automatically deletes oscillating SER items from SER recording. This function prevents overfilling the SER buffer with "chattering" information.

Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function, and select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element. The control removes an item from all SER recordings once a point has changed state more than SRDLCNT times in an SRDLTIM period.

Once deleted from the SER recording, the SEL-2431 ignores the item for a 10 • SRDLTIM period. At the end of this period, the SEL-2431 checks the chatter criteria and, if the point does not exceed the criteria, the device automatically reinstates the item for SER recording, and includes an entry describing the state of the element when it was reinstated. See *Figure 11.3* for an example of two SER elements being auto removed and reinstated.

To see a list of deleted SER points, use the **SER D** command (see *SER Command (Sequential Events Recorder Report)* on page 9.27). *Figure 11.5* shows two example SER D reports, related to the SER example shown in *Figure 11.3*. In the first report, issued at 15:13:57, two elements had been autoremoved and are listed. By the time the second SER D report was issued, the elements had been reinstated, and are no longer listed as "currently removed".

```
=>SER D <Enter>

SEL-2431                              Date: 05/10/2007   Time: 15:13:57
Voltage Reg

Chattering elements currently removed from SER:

  HBND
  IN_BND

Oscillation settings:
SRDLCNT (Counts)    2
SRDLTIM (Seconds)   5.0

=>
=>SER D <Enter>

SEL-2431                              Date: 05/10/2007   Time: 15:15:05
Voltage Reg

Chattering elements currently removed from SER:


Oscillation settings:
SRDLCNT (Counts)    2
SRDLTIM (Seconds)   5.0

=>
```

Figure 11.5 Example SER D Command Response With and Without Autodeletion

Figure 11.6 shows the response to the **SER D** command when automatic deletion and reinsertion is disabled.

```
=>SER D <Enter>
Automatic removal of chattering SER elements not enabled.

=>
```

Figure 11.6 SER D Command Response When ESERDEL := N

SECTION 12

Testing and Troubleshooting

Overview

This section contains guidelines for determining and establishing test routines for the SEL-2431 Voltage Regulator Control. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. The voltage regulator control incorporates self-tests to help you diagnose potential difficulties should these occur. *Voltage Regulator Control Troubleshooting* on page 12.8 contains a quick-reference table for common voltage regulator control operation problems.

NOTE: The SEL-2431 is factory calibrated. If you suspect that the voltage regulator control is out of calibration, please contact the factory.

Topics, tests, and troubleshooting procedures presented in this section include the following:

The SEL-2431 is factory calibrated; this section contains no calibration information. If you suspect that the voltage regulator control is out of calibration, contact your Technical Service Center or the SEL factory.

Testing Philosophy

Voltage regulator control testing is typically divided into two categories:

- Tests performed at the time the relay is installed or commissioned
- Tests performed periodically once the relay is in service

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

Commissioning Testing

When: Installing a new voltage regulator control system.

Goals:

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

What to test:

1. All connected or monitored inputs and outputs
2. Polarity of ac connections
3. Simple check of elements

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

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

At commissioning time:

1. Use the voltage regulator control **METER** command to verify the ac current and voltage magnitude and polarity.
2. Use the **PULSE** command to verify voltage regulator control output contact operation.
3. Use the **TARGET** command to verify optoisolated input operation.
4. Use the **RAISE** and **LOWER** commands to verify proper operation of the voltage regulator tap mechanism.

Maintenance Testing

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

Goals:

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

What to test: Anything not shown to have operated during the past maintenance interval.

SEL voltage regulator controls use extensive self-testing capabilities and feature detailed metering, event reporting, and Sequential Event Recorder (SER) functions that lower the dependence on routine maintenance testing.

1. Use the SEL voltage regulator control reporting functions as maintenance tools.

   Periodically verify that the voltage regulator control is making correct and accurate current and voltage measurements by comparing the voltage regulator control Meter output to other meter readings on that line.

2. Review voltage regulator control event reports and SER in detail.

   Using the event report current, voltage, and voltage regulator control element data, you can determine that the voltage regulator control elements are operating properly. Even motor raise and lower (and hold, for Cooper) currents can be observed.

   See *Routing of Abnormal Tap-Changer Outputs in Factory-Default Settings* on page 5.14.

3. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

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

Use event report and SER data to determine areas requiring attention. Slow or varying tap-changer operating time can be detected through detailed analysis of voltage regulator control event reports and SER.

Because SEL voltage regulator controls are microprocessor based, their operating characteristics do not change over time. Operating times are affected only by the voltage regulator control settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

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

Testing Methods and Tools

Test Features

The following features assist you during voltage regulator control testing.

METER Command. The **METER** command shows the ac current and voltages (magnitude and phase angle) presented to the voltage regulator control in primary values (secondary value magnitudes also available). In addition, the command shows power system frequency. Compare these quantities against other devices of known accuracy. The **METER** command is available at the serial ports and front-panel display. See *Section 9: Communications* and *Section 10: Front-Panel Operations*.

HISTORY Command and CEV Command. The voltage regulator control generates a 30-cycle event report in response to abnormal tap-changer operations (see *Routing of Abnormal Tap-Changer Outputs in Factory-Default Settings* on page 5.14). Each report contains current and voltage information, voltage regulator control element states, and input/output contact information. Even motor raise and lower (and hold, for Cooper) currents can be observed. If you question the voltage regulator control response or your test method, use the event report for more information. The **HIS** and **CEV** commands are available at the serial ports. See *Section 11: Analyzing Events*.

SER Command. The voltage regulator control provides a Sequential Events Recorder (SER) event report that time-tags changes in voltage regulator control element and abnormal tap-changer operations (see *Routing of Abnormal Tap-Changer Outputs in Factory-Default Settings* on page 5.14). The SER provides a convenient means to verify the pickup/dropout of any element in the voltage regulator control. The **SER** command is available at the serial ports. See *Section 11: Analyzing Events*.

TARGET Command. Use the **TARGET** command to view the state of voltage regulator control inputs, voltage regulator control outputs, and voltage regulator control elements individually during a test. The **TARGET** command is available at the serial ports and the front panel. See *Section 9: Communications* and *Section 10: Front-Panel Operations*.

PULSE Command. Use the **PULSE** command to test the contact output circuits. The **PULSE** command is available at the serial ports and the front panel. See *Section 9: Communications* and *Section 10: Front-Panel Operations*.

RAISE/LOWER Commands. Use the **RAISE** and **LOWER** commands to verify proper operation of the voltage regulator tap mechanism. With factory-default settings, Control Configuration must be in Remote for these commands to operate.

Test Methods

Test the pickup and dropout of voltage regulator control elements using one of three methods: target command indication, output contact closure, or sequential events recorder (SER).

Testing Via TARGET Commands

Display the state of voltage regulator control elements, inputs, and outputs using the front-panel or serial port **TAR** commands. Use this method to verify the pickup settings of elements.

Testing With the Front-Panel TARGET Command

You can use the front-panel display and navigation pushbuttons to check Device Word bit elements. See *Section 10: Front-Panel Operations* for more information on using the voltage regulator control front panel.

Display the `MAIN` menu. If the voltage regulator control LCD is in the Rotating Display, press the **ENT** pushbutton to display the `MAIN` menu as shown in *Figure 12.1*.

```
MAIN
Meter
Events
Tap Counters
Targets
Control
Set/Show
Status
Quit
```

Figure 12.1 Main Menu

Select the `Targets` menu item from the `Main` menu and then use the cursor keys to navigate to the Device Word row that contains the element you wish to view as shown by the Targets menu in *Figure 12.2*. You may view the entire row at once or you can select the row by pressing the **ENT** pushbutton to view more detailed information about each Device Word bit in the row selected as shown by the Targets Display in the figure.

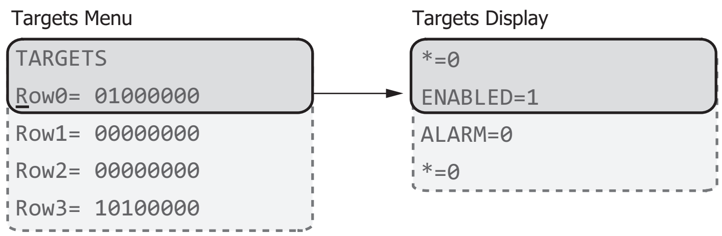


Figure 12.2 Targets Menu and Targets Display

See *Table E.1* for the correspondence between the Device Word elements and the **TAR** command.

Testing With the Serial Port TARGET Command

For example, to view the HBNDFWD element status from the serial port, issue the **TAR HBNDFWD** command. The voltage regulator control will display the state of all elements in the Device Word row containing the HBNDFWD element.

Review **TAR** command descriptions in *Section 9: Communications* and *Section 10: Front-Panel Operations* for further details on displaying element status via the **TAR** commands.

Testing Via Output Contacts

You can set the voltage regulator control to operate an output contact for testing a single element. Use the **SET L** command (SELOGIC control equations) to set an output contact (e.g., OUT101–OUT104) to the element under test. The available elements are the Device Word bits referenced in *Table E.1*.

For example, to test the HBNDFWD element via output contact OUT104, make the following setting:

```
OUT104 := HBNDFWD
```

Do not forget to reenter the correct voltage regulator control settings when you are finished testing and ready to place the voltage regulator control in service.

Testing Via Sequential Events Recorder

You can set the voltage regulator control to generate an entry in the Sequential Events Recorder (SER) for testing voltage regulator control elements. Use the **SET R** command to include the element(s) under test in any of the SER trigger list entries 01–96 (see *Section 11: Analyzing Events*.)

To test the HBNDFWD element with the SER, make the following setting at the end of the factory-default SER trigger list:

```
33:
?       HBNDFWD
```

Element HBNDFWD asserts when regulated voltage is above the high-band edge. The assertion and deassertion of this element is time-stamped in the SER report.

Do not forget to reenter the correct voltage regulator control settings when you are ready to place the voltage regulator control in service.

Self-Tests

The SEL-2431 continuously runs many self-tests to detect out-of-tolerance conditions. These tests run at the same time as voltage regulator control logic but do not degrade SEL-2431 performance.

Status Warning and Status Failure

The voltage regulator control reports out-of-tolerance conditions as a status warning or a status failure. For conditions that do not compromise voltage regulator control functionality, yet are beyond expected limits, the voltage regulator control issues a status warning and continues to operate. A severe out-of-tolerance condition causes the voltage regulator control to declare a status failure and enter a control-disabled state. During a control-disabled state, the voltage regulator control suspends control element processing and de-energizes all control outputs. When disabled, the **ENABLED** front-panel LED is not illuminated.

The voltage regulator control signals a status warning by pulsing the HALARM Device Word bit (hardware alarm) to logical 1 for five seconds. For a Status Failure, the voltage regulator control latches the HALARM Device Word bit at logical 1. To provide remote status indication, connect the Form B contact of OUT101 to your control system remote alarm input. With factory settings, output contact OUT101 comes programmed as an alarm (logic setting OUT101 := NOT ALARM; Front Panel setting ALARM := HALARM OR. . .).

If you repeatedly receive status warnings, check the voltage regulator control 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 *Technical Support* on page 12.10).

The voltage regulator control generates an automatic status report at the serial ports for a self-test status failure if you set Port setting AUTO := Y. The voltage regulator control issues a status message with a format identical to the **STATUS** command output.

Use the serial port **STATUS** and **CSTATUS** commands, the Quickset **HMI Status** button, and the front-panel `Status` menu to display status warnings and status failures. See *Section 9: Communications* for more information on automatic status notifications and on viewing voltage regulator control status.

Firmware Version Number

At the top of each status report the voltage regulator control displays the present firmware version number that identifies the software program that controls voltage regulator control functions. The firmware version is the four-place designator immediately following the voltage regulator control model number (the first characters in the firmware identification string). The first character in the four-place firmware version number is “R” (representing “Release”). 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

Use the serial port **STATUS** command or select the `Status` menu item from the `Main` menu on the front-panel HMI to view the self-test status report. An example status report is shown in *STATUS Command (Voltage Regulator Control Self-Test Status)* on page 9.29. Use *Table 12.1* to interpret the self-test results and measurements.

Table 12.1 Status Report Results (Sheet 1 of 2)

Self-Test	Condition	Limits	Control Disabled	HALARM Device Word Bit	Description
PS1.5V	Warning	1.455 V 1.545 V	No	Pulsed	Measures the 1.5 V power supply.
PS1.5V	Failure	1.425 V 1.575 V	Yes	Latched	
PS3.3V	Warning	3.16 V 3.43 V	No	Pulsed	Measures the 3.3 V power supply.
PS3.3V	Failure	3.07 V 3.53 V	Yes	Latched	
PS5V	Warning	4.80 V 5.20 V	No	Pulsed	Measures the 5 V power supply.
PS5V	Failure	4.65 V 5.40 V	Yes	Latched	
PS5VA	Warning	4.80 V 5.20 V	No	Pulsed	Measures the 5 V power supply (for analog circuits).
PS5VA	Failure	4.65 V 5.40 V	Yes	Latched	
PSN5V	Warning	–5.60 V –4.40 V	No	Pulsed	Measures the –5 V power supply.
PSN5V	Failure	–5.70 V –4.30 V	Yes	Latched	
PSN5VA	Warning	–5.60 V –4.40 V	No	Pulsed	Measures the –5 V power supply (for analog circuits).
PSN5VA	Failure	–5.70 V –4.30 V	Yes	Latched	
PS12V	Warning	11.28 V 16.40 V	No	Pulsed	Measures the 12 V power supply.
PS12V	Failure	10.92 V 17.00 V	Yes	Latched	
HMI	Warning		No	Pulsed	Checks communication with HMI board.
RAM	Failure		Yes	Latched	Performs a read/write test on system RAM.
NON_VOL	Failure	checksum	Yes	Latched	Performs a checksum test on the nonvolatile copy of the voltage regulator control settings.
CLOCK	Warning		No	Pulsed	Checks for real-time clock communications.
CARD1	Warning		No	Pulsed	Checks for correct communications card in Comm. Port 1 slot (per part number).
CARD2	Warning		No	Pulsed	Checks for correct communications card in Comm. Port 2 slot (per part number).

Table 12.1 Status Report Results (Sheet 2 of 2)

Self-Test	Condition	Limits	Control Disabled	HALARM Device Word Bit	Description
Master Offset (MOF)	Warning	> 30 mV	No	Pulsed	Measures the dc offset at the A/D.
Channel Offsets ILLOW, ILHIGH, IMH, IMR, IML, V_{S1}, V_{S2}	Warning	> 30 mV	No	Pulsed	Measures the dc offset at each of the input channels.

Voltage Regulator Control Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the voltage regulator control. After you finish the inspection, proceed to the *Troubleshooting Procedure*. For the following steps, refer to *Figure C.1, Figure C.2,* and *Figure C.3* in the *SEL-2431 Voltage Regulator Control Field Reference Guide*.

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

Step 2. Check to see that the power is on. Do not turn the voltage regulator control off.

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

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

Step 5. Inspect the serial communications ports cabling to be sure that a communications device is connected to at least one communications port.

Troubleshooting Procedure

Troubleshooting procedures for common problems are listed in *Table 12.2*. The table lists each symptom, possible causes, and corresponding diagnoses/solutions. Related SEL-2431 commands are listed in bold capitals. See *Section 9: Communications* for details on SEL-2431 commands and *Section 8: Settings* for details on voltage regulator control settings. See the referenced sections in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for details on the following:

- ➤ SEL-2431 mounting, grounding, and wiring (*Section 2: Installation*)
- ➤ Fusing and front panel (*Section 3: Front-Panel Interface*)
- ➤ General voltage regulator construction and interface (*Appendix B: Voltage Connections, Internal Voltage Regulator Wiring, and Voltage Polarity Reversal*)
- ➤ General SEL-2431 internal wiring/functions and extra I/O (*Appendix C: Internal SEL-2431 Wiring and Extra I/O Connections*)

Table 12.2 Troubleshooting Procedures (Sheet 1 of 3)

Symptom/Possible Cause	Diagnosis/Solution
Dark Front Panel	
Power is off.	Check the status of the front-panel **CONTROL POWER** switch.
Input power is not present.	Verify that power is present at the **VOLTAGES** connector. If there is no power, verify that all wire harness connections are correct according to the *SEL-2431 Voltage Regulator Control Field Reference Guide*.

Table 12.2 Troubleshooting Procedures (Sheet 2 of 3)

Symptom/Possible Cause	Diagnosis/Solution
Blown power supply fuse.	Replace the **CONTROL** fuse.
Poor contrast adjustment.	Press and hold **ESC** for two seconds. Press **Right Arrow** and **Left Arrow** pushbuttons to adjust contrast.
Status Failure Notice on Front Panel	
Self-test failure.	Contact the SEL factory or your Technical Service Center. The OUT101 Form B contact will be closed (comes as an alarm with factory settings).
Alarm Output OUT101 Asserts and ENABLED LED Extinguishes	
Power is off.	Check the status of the front-panel **CONTROL POWER** switch.
Blown power supply fuse.	Replace the **CONTROL** fuse.
Power supply failure.	LCD displays `STATUS FAILURE`. Contact the SEL factory or your Technical Service Center.
Other self-test failure.	Contact the SEL factory or your Technical Service Center.
Alarm Output OUT101 Asserts and ALARM LED Illuminates	
Tap-changer abnormality.	See *Routing of Abnormal Tap-Changer Outputs in Factory-Default Settings* on page 5.14.
Self-test failure.	Contact the SEL factory or your Technical Service Center.
System Does Not Respond to Commands	
No communication.	Confirm cable connections and types. If OK, type **<Ctrl+X>**, then **<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 voltage regulator control port settings. Use the front panel to check port settings (see *Set/Show Menu* on page 10.29.)
Incorrect communications cables.	Use SEL communications cables or cables you build according to SEL specifications (see *Port Connector and Communications Cables* on page 9.6).
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 Interfaces* on page 9.2 and *Communications Protocol* on page 9.9).
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 *EIA-485 Serial Port* on page 9.4).
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Voltage Changes	
Voltage regulator control is set improperly.	Review the voltage regulator control settings (see *Section 8: Settings*).
Improper test settings.	Restore operating settings.
Connection wiring error.	Confirm the correct wiring harness is being used.
Input voltages and current phasing errors.	Use voltage regulator control metering. Use the **TRI** event trigger command and examine the generated event report.
Blown motor fuse.	Replace the **MOTOR** fuse.
Blown second voltage fuse.	Replace the in-line fuse for Terminal 3 of the **VOLTAGE** connector.

Table 12.2 Troubleshooting Procedures (Sheet 3 of 3)

Symptom/Possible Cause	Diagnosis/Solution
Output Contact Remains Closed Following an Operation	
Voltage regulator control outputs have burned closed.	Remove voltage regulator control power. Remove the control output connection. Check continuity; Form A contacts will be open and Form B contacts will be closed. Contact the SEL factory or your Technical Service Center if continuity checks fail.
Check the voltage regulator control self-test status.	Take preventive action as directed by voltage regulator control Status Warning and Status Failure information.
Power Supply Voltage Status Warning	
Power supply voltage(s) are out-of-tolerance.	Log the Status Warning. If repeated warnings occur, take preventive action.
Power Supply Voltage Status Failure	
Power supply voltage(s) are out-of-tolerance.	LCD displays `STATUS FAILURE`. Contact the SEL factory or your Technical Service Center.
Channel Offset Status Warning	
A/D converter drift.	Log the Status Warning. If repeated warnings occur, contact the SEL factory or your Technical Service Center.
Master offset drift.	Log the Status Warning. If repeated warnings occur, contact the SEL factory or your Technical Service Center.
Meter Command Does Not Respond as Expected	
Current magnitude is incorrect.	Global setting CTPRIM not set correctly.
Voltage magnitudes are incorrect.	Global settings PT1PRIM, PT1SEC, PT2PRIM, PT2SEC, BASE_PRI, or BASE_SEC not set correctly.
Voltage magnitude is low.	Check return wiring for VS2; ensure it has solid return path.
Current or voltage angles or power magnitudes are incorrect.	Voltage regulator control analog inputs not connected correctly. Global setting CTPOL, PT1POL, PT2POL, CONFIG, DELTA, D_LAG, D_LEAD, or ISHIFT not set correctly.
Multimeter on **VOLTMETER** terminals disagrees with metering screens.	Voltage base difference. Harmonics (ignored by the SEL-2431, included by the true RMS multimeters). Low-impedance voltmeters may not measure the voltage at the voltmeter terminals accurately because these terminals are impedance-protected.

Technical Support

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

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APPENDIX A

Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Voltage Regulator Control

To find the firmware version number in your SEL-2431 Voltage Regulator Control, view the status report through use of the serial port **STATUS** command or the front-panel `Status` menu.

The firmware revision number is after the R and the date code is after the D. For example, the following is firmware revision number 100, release date June 1, 2007.

FID=SEL-2431-R100-V0-Z001001-D20070601

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.

Starting with revisions published after March 1, 2022, changes that address security vulnerabilities are marked with “[Cybersecurity]”. Other improvements to cybersecurity functionality that should be evaluated for potential cybersecurity importance are marked with “[Cybersecurity Enhancement]”.

Table A.1 Firmware Revision History (Sheet 1 of 5)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2431-R121-V1-Z013003-D20240229	Includes all the functions of SEL-2431-R121-V0-Z013003-D20230606 with the following additions: ➤ Improved the tap tracking algorithm for Cooper Quik-Drive QD3 voltage regulators when entering or leaving neutral. ➤ Added tap tracking support for Romagnole voltage regulators. ➤ Revised the firmware for replacement of the complex programmable logic device (CPLD).	20240229
SEL-2431-R121-V0-Z013003-D20230606	➤ Added new Flexible Distributed Generation operation mode (available via group setting OPMODE := FLEXDG). ➤ Added new group settings BIASMODE, FLEX_50, TAPDELTL, and TAPDELTH (last three settings exclusively for new Flexible Distributed Generation operation mode). ➤ Enhanced group setting ELDC so that it has a wider setting range when the new Flexible Distributed Generation operation mode is operational. ➤ Added new Device Word bits DVLOW and OP_FLEX for the new Flexible Distributed Generation operation mode. ➤ Enhanced existing control operating modes Cogeneration (OPMODE := COGEN) and Bidirectional (OPMODE := BIDIR) so that they can operate with setting BIASMODE (new Flexible Distributed Generation operation mode operates with setting BIASMODE, too).	20230606

Table A.1 Firmware Revision History (Sheet 2 of 5)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added new global settings ZREGMAG, ZREGANG, and VADJUST. ➤ Added FASTOP to Port E settings to support fast operate over Telnet functionality.	
SEL-2431-R120-V2-Z012003-D20240229	Includes all the functions of SEL-2431-R120-V1-Z012003-D20220922 with the following additions: ➤ Revised the firmware for replacement of the complex programmable logic device (CPLD).	20240229
SEL-2431-R120-V1-Z012003-D20220922	Includes all the functions of SEL-2431-R120-V0-Z012003-D20201113 with the following additions: ➤ Resolved an issue where DNP3 Counter values reported in a static object variation were not being returned in Class (Static) or Class 1230 (Integrity) poll. ➤ Added Event Type to the HIS command response. ➤ Resolved an issue where the CAS command response did not include sufficient CEV header information for communication with an SEL RTAC. ➤ Resolved an issue that caused DNP sessions to restart when changing settings group.	20220922
SEL-2431-R120-V0-Z012003-D20201113	➤ Added a feature to allow an anonymous TCP connection from DNP masters when DNPIP*x* is set to 0.0.0.0. ➤ Increased the number of DNP3 sessions from three to six. ➤ Improved diagnostics so that the relay will recover following a diagnostic reset. ➤ Set fixed-length pulse for **DRAG HAND RESET** pushbutton.	20201113
SEL-2431-R119-V3-Z011003-D20240229	Includes all the functions of SEL-2431-R119-V2-Z011003-D20220922 with the following additions: ➤ Revised the firmware for replacement of the complex programmable logic device (CPLD).	20240229
SEL-2431-R119-V2-Z011003-D20220922	Includes all the functions of SEL-2431-R119-V1-Z011003-D20190308 with the following additions: ➤ Resolved an issue where DNP3 Counter values reported in a static object variation were not being returned in Class (Static) or Class 1230 (Integrity) poll. ➤ Added Event Type to the **HIS** command response. ➤ Resolved an issue where the **CAS** command response did not include sufficient CEV header information for communication with an SEL RTAC. ➤ Resolved an issue that caused DNP sessions to restart when changing settings group.	20220922
SEL-2431-R119-V1-Z011003-D20190308	Includes all the functions of SEL-2431-R119-V0-Z011003-D20180622 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause the SEL-2431 to safely restart.	20190308
SEL-2431-R119-V0-Z011003-D20180622	➤ Added a Future Ethernet Compatible MOT option for Port 2. This gives the user the ability to order and install Ethernet communications cards for Port 2 in the field if the SEL-2431 unit was ordered as Future Ethernet Compatible. ➤ Resolved an issue that caused INHIBSV to incorrectly deassert in DNP with a settings change even though the INHIBSV Device Word bit remained asserted.	20180622

Table A.1 Firmware Revision History (Sheet 3 of 5)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2431-R118-V3-Z010003-D20240229	Includes all the functions of SEL-2431-R118-V2-Z010003-D20220922 with the following additions: ➤ Revised the firmware for replacement of the complex programmable logic device (CPLD).	20240229
SEL-2431-R118-V2-Z010003-D20220922	Includes all the functions of SEL-2431-R118-V1-Z010003-D20190308 with the following additions: ➤ Resolved an issue where DNP3 Counter values reported in a static object variation were not being returned in Class (Static) or Class 1230 (Integrity) poll. ➤ Added Event Type to the **HIS** command response. ➤ Resolved an issue where the **CAS** command response did not include sufficient CEV header information for communication with an SEL RTAC. ➤ Resolved an issue that caused DNP sessions to restart when changing settings group.	20220922
SEL-2431-R118-V1-Z010003-D20190308	Includes all the functions of SEL-2431-R118-V0-Z010003-D20161223 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause the SEL-2431 to safely restart.	20190308
SEL-2431-R118-V0-Z010003-D20161223	➤ Updated handling of nonvolatile memory to prevent diagnostic failures.	20161223
SEL-2431-R117-V1-Z010003-D20190308	Includes all the functions of SEL-2431-R117-V0-Z010003-D20150416 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause the SEL-2431 to safely restart.	20190308
SEL-2431-R117-V0-Z010003-D20150416	➤ Resolved an issue that caused devices with a four-wire EIA-485 communications card to stop communicating on the EIA-485 port and scrolling messages on the front-panel LCD. ➤ Added Meter, Demand, Energy, Harmonic, and Maximum/Minimum reports to the USB Read Reports operation. ➤ Removed the Static Load Estimation report (SLE.TXT) from the USB Read Reports and USB Automatic Backup operations.	20150416
SEL-2431-R116-V1-Z010003-D20190308	Includes all the functions of SEL-2431-R116-V0-Z010003-D20140930 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause the SEL-2431 to safely restart.	20190308
SEL-2431-R116-V0-Z010003-D20140930	➤ Improved the tap tracking algorithm for Cooper Quik-Drive™ QD3 regulators. Previously, the SEL-2431 occasionally lost track of tap position when connected to some Cooper Quik-Drive QD3 regulators. ➤ Modified the SEL-2431 to display a tap position of `Unknown`, rather than `Neutral`, on local interfaces when the SEL-2431 tap position value is 0 but the regulator neutral position switch is not asserted. The behavior of the NO_NEUT alarm and values transmitted to the communications interfaces and stored in reports were unchanged.	20140930
SEL-2431-R115-V1-Z010003-D20190308	Includes all the functions of SEL-2431-R115-V0-Z010003-D20140508 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause the SEL-2431 to safely restart.	20190308
SEL-2431-R115-V0-Z010003-D20140508	➤ Modified the firmware scaling of the Seconds to Select/Operate Time-Out (STIMEO) setting on Port E. ➤ Corrected handling of unrecognized Ethertype frames that can cause Ethernet to stop responding.	20140508

Table A.1 Firmware Revision History (Sheet 4 of 5)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Improved error handling during USB file sends that contain invalid files. ➤ Prevented the **NEUTRAL POSITION** light from turning on when the SEL-2431 internal diagnostics turn the **ENABLED** light off.	
SEL-2431-R114-V1-Z010003-D20190308	Includes all the functions of SEL-2431-R114-V0-Z010003-D20121213 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause the SEL-2431 to safely restart.	20190308
SEL-2431-R114-V0-Z010003-D20121213	➤ Improved timeliness of USB interface response. ➤ Corrected stale data issue in synchrophasor implementation.	20121213
SEL-2431-R113-V1-Z010003-D20190308	Includes all the functions of SEL-2431-R113-V0-Z010003-D20121108 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause the SEL-2431 to safely restart.	20190308
SEL-2431-R113-V0-Z010003-D20121108	➤ Added support for dual Ethernet communications cards. ➤ Added support for Type A USB. ➤ Added Line Drop Compensation Limit calculations. ➤ Modified format of Load Sense Technology reports. ➤ Added support for digitally signed firmware files.	20121213
SEL-2431-R112-V0-Z009003-D20120201	➤ Added support for new 2-Wire EIA-485 Communications Card. ➤ Increased baud rate on EIA-232, 4-Wire EIA-485 and ST Fiber to 57600 baud. ➤ Increased baud rate on V-pin Fiber to 38400 baud.	20120201
SEL-2431-R111-V0-Z008003-D20110614	➤ Added DNPBOOP setting to support customers with a dependence on the original binary output behavior and modified binary output behavior for consistency with other SEL devices. **Note:** Setting-mapped binary outputs with firmware version R110 do not behave as stated in published literature.	20110614
SEL-2431-R110-V0-Z007003-D20110208	➤ Added IEEE C37.118 Synchrophasors. ➤ Added Load Sense Technology. ➤ Added compatibility for Siemens Type A Voltage Regulators with only a source side PT. ➤ Added Analog Quantity to report volt meter terminal voltage. ➤ Added NO_NEUT back to default SER trigger list. ➤ Improved ability to keep track of GE voltage regulator tap position. ➤ Increased number of available display points to 32. ➤ Widened the available center band voltage setting range. ➤ Removed SER entry for Level 1 Access (ACC) granted. ➤ Added RST_TAP SELOGIC equation to reset the tap counter information. ➤ Added SEAL_PB Global setting to allow manual operations to complete automatically. ➤ Added TAP_DHR Global setting to prevent older regulators from resetting the Tap Position when DHR asserts. ➤ Added MWHOUT, MWHIN, MVARHOUT, and MVARHIN to signal profile quantities. ➤ Modified max/min, peak demand, and energy metering quantities to be written to nonvolatile memory every four hours.	20110208

Table A.1 Firmware Revision History (Sheet 5 of 5)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Allowed either even or odd parity in IRIG-B data streams. ➤ Modified DNP Analog Input and Counters to allow a dead band of 0. ➤ Added DNP Object 0. ➤ Modified DNP Object 12 Control Operations. ➤ Added OPCNTY, OPCNTM, OPCNTD, and OPCNT to DNP Analog Inputs and DNP Counter quantities. ➤ Added VMIN and VMAX settings as Analog Inputs and Analog Outputs for DNP.	
SEL-2431-R109-V0-Z006002-D20100112	➤ Made tap raise/lower pulse duration settable. ➤ Allowed tap position to be determined by feedback or raise/lower pulse duration.	20100112
SEL-2431-R108-V0-Z005002-D20090512	➤ Corrected DNP fiber-optic loop logic to suppress echo of invalid DNP messages.	20090512
SEL-2431-R107-V0-Z005002-D20081219	➤ Expanded front-panel contrast setting range. ➤ Enhanced DNP fiber-optic loop logic.	20081219
SEL-2431-R105-V0-Z003002-D20080910	➤ Added CTPOL, PT2POL, and ISHIFT Global settings to account for CT and PT2 polarity reversals and to allow phase shift of load current IL. Added SHIFT option to CONFIG Global setting. ➤ Removed NO_NEUT from default SER trigger list.	20080910
SEL-2431-R104-V0-Z002002-D20080421	➤ Added **PARTNUMBER** command to allow setting of the SEL-2431 part number for field-installed accessories. ➤ Improved use of Analog Quantities in Display Points and SELOGIC. ➤ Lowered TD2 group setting lower limit. ➤ Allow reset of tap counters from the front panel. ➤ Improved the reset of PULSE mode voltage reduction logic. ➤ Modified **AUTO INHIBIT** LED logic to illuminate for all inhibit or manual conditions. ➤ Added Analog Quantity PF_LEG legacy power factor for use in DNP. ➤ Added Analog Quantity TAP_POS tap position to the Fast Meter message. ➤ Added INHIBIT Device Word bit to default SER trigger list settings. ➤ Corrected logic so that if voltage is out-of-band and SELOGIC Group setting BLOCKSV is asserted (= logical 1; no tapping) during TD2 timing, subsequent tapping and timing on TD2 will resume when BLOCKSV is deasserted (= logical 0; tapping allowed) and voltage is still out-of-band. Previously, tapping and timing on TD2 was not resuming.	20080421
SEL-2431-R102-V0-Z001001-D20071018	➤ Modified TAP_OFF logic. For Global setting TAPCHNGR := HOWARD, the TAP_OFF Device Word bit output operates the exact opposite of how it operates for Global setting TAPCHNGR := SIEMENS.	20071018
SEL-2431-R101-V0-Z001001-D20070920	➤ Modified –5 V and –5 VA power supply diagnostic warn and failure thresholds.	20070920
SEL-2431-R100-V0-Z001001-D20070601	➤ Initial version.	20070601

Instruction Manual

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

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

Table A.2 Instruction Manual Revision History (Sheet 1 of 8)

Date Code	Summary of Revisions
20240909	Section 1 ➤ Updated *Features*, *Models and Options, Applications*, and *Specification*. Section 5 ➤ Updated *Digital Outputs*. Section 8 ➤ Updated *Make Global Settings (SET G) First*. ➤ Updated *Tap Changer Type (TAPCHNGR)*. ➤ Updated *Table 8.6: Voltage Regulator Types*. Section 9 ➤ Updated *Table 9.1: SEL-2431 Communications Port Interfaces*. Appendix I ➤ Updated *Physical Access Controls*.
20240229	Section 1 ➤ Corrected Radiated RFI entry in *Specifications*. Section 4 ➤ Added *Figure 4.7: Tap Delta Voltage Operation Classification per Resultant Tap Delta Voltage DLT_VLS*. Section 8 ➤ Added clarifying subheads in *Per Unit Regulator Impedance Magnitude (ZREGMAG) and Regulator Impedance Angle (ZREGANG) and Per Unit Voltage Adjustment (VADJUST)*. Appendix A ➤ Updated for firmware versions R121-V1, R120-V2, R119-V3, and R118-V3.
20230606	Section 4 ➤ Updated *Figure 4.2: Active Power Flow Regions for the Different Operating Modes*. ➤ Added *BIASMODE Setting* and *Control and LDC Settings Per Operating Mode*. ➤ Added *Flexible Distributed Generation Voltage Regulation Mode (OPMODE = FLEXDG)*. Section 7 ➤ Updated *Table 7.3: Operating Mode and Regulation Status Messages in METER Command*. Section 8 ➤ Added settings explanation for new global settings ZREGMAG, ZREGANG, and VADJUST. Section 9 ➤ Added *Ethernet Protocols: Fast Operate over Telnet*.

Table A.2 Instruction Manual Revision History (Sheet 2 of 8)

Date Code	Summary of Revisions
	Settings Sheets ➤ Added new global settings ZREGMAG, ZREGANG, and VADJUST to *Advanced Regulator Settings*. ➤ Updated range of group setting OPMODE with new option FLEXDG (Flexible Distributed Generation operation mode) in *Configuration Settings*. ➤ Added new group settings BIASMODE, FLEX_50, TAPDELTL, and TAPDELTH to Configuration Settings (last three settings exclusively for new Flexible Distributed Generation operation mode). ➤ Revised settings rule at front of Reverse Controller Settings to allow for OPMODE := FLEXDG. ➤ Updated range of group setting ELDC for OPMODE := FLEXDG in *Line-Drop Compensation Settings*. ➤ Added settings rules in *Line-Drop Compensation Settings* to detail various settings availability. ➤ Added settings rules in *Overcurrent Settings* to detail 50FWDP and 50REVP settings availability. ➤ Added new Port E setting FASTOP for fast operate over Telnet functionality. Appendix C ➤ Added row *A5E0 Fast Operate Remote Bit Control* to *Table C.3: Binary Message List*. ➤ Added *Table C.12: A5E0 Fast Operate Remote Bit Control* and explanations. Appendix D ➤ Updated *Figure D.5: Sample Response to SHO DNP Command* with Binary Input map values DVLOW and OP_FLEX. ➤ Updated *Table D.11: DNP3 Default Data Map* with Binary Input map values DVLOW and OP_FLEX. Appendix E ➤ Updated *Table E.1: Device Word Bit Mapping* and *Table E.2:Alphabetic List of Device Word Bits* with Device Word bits DVLOW and OP_FLEX.
20220922	Section 11 ➤ Updated *Figure 11.1: Example Event History*. ➤ Updated *Table 11.5: Event History Data*. Section 12 ➤ Updated *Testing Philosophy*. Appendix A ➤ Updated for firmware version R120-V1, R119-V2, and R118-V2. Appendix D ➤ Updated *Event Data*.
20220809	Section 1 ➤ Updated *Extensive Voltage Regulator Compatibility (Interface Ordering Option)* to include the ITB regulator. Section 5 ➤ Updated *Digital Outputs* to include the ITB regulator. ➤ Updated *Table 8.6: Voltage Regulator Types* to include the ITB regulator. Section 8 ➤ Updated *Tap Changer Type (TAPCHNGR)* to include the ITB regulator. Appendix I ➤ Added Appendix.
20220617	Section 9 ➤ Updated *IRIG-B*. ➤ Updated *Figure 9.2 Fiber-Optic Communications Card IRIG-B Jumper Location*. ➤ Updated *Table 9.7: Serial Fiber-Optic Communications Card Parameters*.
20201113	Settings Sheets ➤ Updated *Port E DNP3 Protocol*.

Table A.2 Instruction Manual Revision History (Sheet 3 of 8)

Date Code	Summary of Revisions
	Section 9 ➤ Updated for *Table 9.9: Protocol Session Limits*. Appendix A ➤ Updated for firmware version R120. Appendix D ➤ Updated *Table D.4: TCP/UDP Selection Guidelines*. ➤ Updated *Table D.7: Port DNP3 Protocol Settings*.
20200604	Section 6 ➤ Added a note about pressing and holding the **DRAG HAND RESET** pushbutton. Section 12 ➤ Updated *Technical Support*. Appendix B ➤ Updated *Technical Support*.
20190308	Appendix A ➤ Updated for firmware versions R113-V1, R114-V1, R115-V1, R116-V1, R117-V1, R118-V1, and 119-V1.
20180622	Section 9 ➤ Updated *Communications Interfaces*. ➤ Updated footnote d in *Table 9.1: SEL-2431 Communications Port Interfaces*. Appendix A ➤ Updated for firmware version R119.
20161223	Section 1 ➤ Updated *Specifications*. Section 7 ➤ Updated to reflect that **TAP P** command cannot set tap position to neutral. Appendix A ➤ Updated for firmware version R118.
20160921	Section 1 ➤ Added reference to Toshiba voltage regulator. Section 5 ➤ Added references to Toshiba voltage regulator. Section 8 ➤ Added references to Toshiba voltage regulator.
20150416	Preface ➤ Updated *Safety Information*. Section 1 ➤ Updated *Specifications*. Section 3 ➤ Updated *Figure 3.5: Application of VLDCFWMN When VCMP* $\geq V_L$. Section 9 ➤ Updated *Table 9.1: SEL-2431 Communications Port Interfaces*. Section 10 ➤ Updated *Type A USB Port*.

Table A.2 Instruction Manual Revision History (Sheet 4 of 8)

Date Code	Summary of Revisions
	Appendix A ➤ Updated for firmware version R117.
20140930	Appendix A ➤ Updated for firmware version R116.
20140508	Section 1 ➤ Updated *Specifications*. Section 7 ➤ Removed *Load Sense Technology*. Settings Sheets ➤ Removed *Load Estimation* settings. Section 9 ➤ Updated *IRIG-B in Communications Interfaces*. Section 10 ➤ Removed Load Sense Technology from *Table 10.2: Data Rate of Automatic Backup Feature*. ➤ Added note to *Display and Front-Panel Pushbuttons*. Section 11 ➤ Removed *Analyzing Load Sense Technology Events*. Section 12 ➤ Added entry for low voltage magnitude in *Table 12.2: Troubleshooting Procedures*. Appendix A ➤ Updated for firmware version R115.
20121213	Section 1 ➤ Updated *Specifications*. Section 3 ➤ Added Line Drop Compensation Limits description. Section 8 ➤ Added new settings associated with Ethernet. Section 10 ➤ Added *Type A USB Port* section. Appendix A ➤ Updated for firmware version R113 and R114. Appendix F ➤ Added DLT_ analog quantities related to line drop compensation limits.
20120201	Section 1 ➤ Increased baud rate on all ports. Settings Sheets ➤ Clarified TAPDUR and TPFDBK settings descriptions. Section 9 ➤ Added 2-Wire EIA-485 card description and differentiation from 4-Wire EIA-485 card. ➤ Added **CAL** command and **PAS C** command information. Appendix A ➤ Updated for firmware version R112.

Table A.2 Instruction Manual Revision History (Sheet 5 of 8)

Date Code	Summary of Revisions
	Appendix D ➤ Added Analog Output quantities in DNP map. Command Summary ➤ Added **CAL** command and **PAS C** command definitions.
20110614	Setting Sheets ➤ Added DNPBOOP setting. Appendix A ➤ Updated for firmware version R111. Appendix D ➤ Added DNPBOOP setting information to *Binary Controls*. ➤ Corrected *Table D.11: Example Object 12 Trip/Close or Code Selection Operation*.
20110208	Section 1 ➤ Modified *Specifications* to include Synchronization and Synchrophasor Accuracies. Section 6 ➤ Added description of RST_TAP Global setting to SELOGIC *Reset Equation*. Section 7 ➤ Modified time interval in which Peak Demand, Energy Metering, and Max/Min data are written to nonvolatile memory. ➤ Added *Load Sense Technology* subsection. Section 8 ➤ Modified number of available display points. ➤ Added NO_NEUT back to default front panel ALARM and report settings. ➤ Moved Global settings NEUTOVR, TPFDBK, and TAPDUR, to *Advanced Regulator Nameplate Data*. ➤ Added Global settings SEAL_PB, GE_WIND, and TAP_DHR to *Advanced Regulator Nameplate Data*. ➤ Modified description of *Automatic Daylight-Saving Time Settings*. Setting Sheets ➤ Added *Advanced Regulator Nameplate Data* subsection to Global settings. ➤ Added Global setting RST_TAP to the *Data Reset* SELOGIC *Equations*. ➤ Expanded range for F_CNBND and R_CNBND. ➤ Modified number of display points. Section 9 ➤ Modified maximum data rate for ST and V-Pin Fiber-Optic Communication Cards. ➤ Added description of **CONTROL O** command. ➤ Added description of **METER PM** command. Section 11 ➤ Added *Analyzing Load Sense Technology Events* subsection. Appendix A ➤ Updated for firmware version R110. Appendix B ➤ Modified the maximum allowable baud rate for a firmware transfer. Appendix C ➤ Modified the Fast Meter (FM) map in *Table C.17: Communications Processor METER Region Map*.

Table A.2 Instruction Manual Revision History (Sheet 6 of 8)

Date Code	Summary of Revisions
	Appendix D ➤ Added DNP Object 0 to *Table D.8: SEL-2431 DNP Object List*. ➤ Modified DNP Object 12 Control Operations in *Table D.11: Example Object 12 Trip/Close or Code Selection Operation*. Appendix E ➤ Modified *Table E.1: Device Word Bit Mapping and Table E.2: Alphabetical List of Device Word Bits* to include new Device Word Bits. Appendix F ➤ Modified *Table F.1: Analog Quantities* to include new Analog Quantities. Appendix H ➤ Added *Appendix H: Synchrophasors*.
20100112	Section 1 ➤ Added control of load tap changer information to *Applications*. Section 5 ➤ Updated *Other Tapchanger Outputs* to show RSEFAIL, RSELIM, LWRFAIL, and LWRLIM Device Word bits are now dependent on Global setting TAPDUR (tap duration). ➤ Added note to *Routing of Abnormal Tapchanger Outputs in Factory-Default Settings*. ➤ Removed reference to Device Word bit NO_NEUT in *Routing of Abnormal Tapchanger Outputs in Factory-Default Settings*. Section 6 ➤ Corrected *Example 6.1* for time-of-day operations. Section 8 ➤ Added *Tap Pulse Duration (TAPDUR)*. ➤ Added *Tap Position Based on Feedback (TPFDBK)*. Settings Sheets ➤ Added TAPDUR and TPFDBK Global settings to *Regulator Nameplate Data*. Section 10 ➤ Added note to *Front Panel Settings VTJ_MODE and VTJ_L for VOLTMETER Test Terminals* regarding accuracy when using non-high impedance voltmeters. ➤ Updated *Figure 10.16: Global Settings Submenu* with TAPDUR and TPFDBK Global settings. Appendix A ➤ Updated for firmware version R109. ➤ Updated R105 firmware revision summary. Appendix D ➤ Clarified information in *Control Point Operation*.
20090512	Appendix A ➤ Updated for firmware version R108.
20081219	Section 8 ➤ Modified DNPECHO port setting to include LOOP1ST and LOOPLAST options. ➤ Added MINDLY, MAXDLY, PREDLY, and PSTDLY port settings for fiber-optic communications ports. Settings Sheets ➤ Expanded LCD Contrast setting range. Section 10 ➤ Modified DNPECHO port setting to include LOOP1ST and LOOPLAST options.

Table A.2 Instruction Manual Revision History (Sheet 7 of 8)

Date Code	Summary of Revisions
	Section 12 ➤ Updated *Table 12.2: Troubleshooting Procedures*. **Appendix A** ➤ Updated for firmware version R107. **Appendix D** ➤ Added instructions for using new DNPECHO port setting options, as well as MINDLY, MAXDLY, and PREDLY port settings in a multiple DNP fiber-optic loop architecture.
20080910	**Section 3** ➤ Added text to multiply line drop compensation settings by 1.73 ($\sqrt{3}$) when regulators are connected in delta. **Section 7** ➤ Added note that IL, V_S, and V_L phase angles can be adjusted. **Section 8** ➤ Added CTPOL, PT2POL, and ISHIFT Global settings. ➤ Added SHIFT option to CONFIG Global setting. ➤ Removed NO_NEUT from front panel ALARM and report default settings. **Section 9** ➤ Added footnote to *Table 9.5: Fiber-Optic Communications Card Parameters* stating that IRIG-B time code can only be used on communications Port 1. **Section 12** ➤ Updated *Table 12.5: Troubleshooting Procedures*. **Appendix A** ➤ Updated for firmware version R105. **Appendix D** ➤ Clarified that ST fiber-optic communications cards can retransmit IRIG-B. **Appendix F** ➤ Added footnote to *Table F.1: Analog Quantities describing Day of Week (DOW)*.
20080421	**Section 1** ➤ Added specifications for 12 Vdc Auxiliary Source and 120 Vac Whetting Source. **Section 4** ➤ Added description of mode inhibit logic. ➤ Improvements made to PULSE mode of voltage reduction. **Section 5** ➤ Corrected description of OPSWHCN Device Word bit. ➤ Added *Inhibiting/Blocking then Resuming Tap Operation*. **Section 6** ➤ Optoisolated inputs IN201–IN204 are now standard rather than an ordering option. ➤ Output contacts OUT102–OUT104 are now standard rather than an ordering option. **Section 7** ➤ Corrected PL > 0 label in *Table 7.5: Energy Metering Quantities*. ➤ Added legacy power factor to *Meter Power Direction*. **Setting Sheets** ➤ Modified lower setting limit of TD2. ➤ Modified setting rules for voltage reduction settings VREDFP2, VREDFP3, VREDRP2, and VREDRP3.

Table A.2 Instruction Manual Revision History (Sheet 8 of 8)

Date Code	Summary of Revisions
	Section 9 ➤ Added text stating that communications cards can be ordered with the SEL-2431 or ordered later and installed into the SEL-2431. ➤ Changed access level of **TAP P *x*** command from Access Level 2 to Access Level 1. ➤ Added **PARTNUMBER** command. Section 10 ➤ Modified **AUTO INHIBIT** LED definition. ➤ Added complete menu structure diagram for front panel. ➤ Added reset of tap counters from front panel. Appendix A ➤ Updated for firmware version R104. Appendix C ➤ Added TAP_POS to Fast Meter configuration block A5C1. Appendix E ➤ Device Word Bits DSTP, IN201, IN202, IN203, IN204, IRIGOK, LPSEC, LPSECP, OUT102, OUT103, OUT104, TIRIG, TQUAL1, TQUAL2, TQUAL3, TQUAL4, TSLOCK and TSOK are no longer hidden. Appendix F ➤ Allow more analog quantities to be used as Display Points.
20071018	Section 5 ➤ Revised TAP_OFF logic discussion in *Other Tapchanger Outputs*. Settings Sheets ➤ For Global settings PT1POL, PT1PRIM, PT1SEC, PT2PRIM, and PT2SEC, added reference information on how these settings relate to particular voltages on the interface terminals shown in figures in *Appendix B* in the *SEL-2431 Field Reference Guide*. Section 9 ➤ Made IRIG-B clarifications (how it is realized with different communications Port 1 types). ➤ Corrected *Table 9.2: EIA-232 Serial Port Pin Functions* (only addresses EIA-232, not EIA-485). ➤ Separated Ports 1 and 2 in *Table 9.3: EIA-485 Serial Port Pin Functions for EIA-485*. Section 11 ➤ Added *Oscillography Channel VS Detail*. Appendix A ➤ Updated for firmware version R102. Appendix E ➤ Clarified Device Word bit TAP_DIF definition.
20070920	General ➤ Removed references to the second voltage input ordering option throughout manual. Section 12 ➤ Updated PSN5V and PSN5VA Warning and Failure Limits in *Table 12.1: Status Report Results*. Appendix A ➤ Updated for firmware version R101.
20070601	➤ Initial version.

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APPENDIX B

Firmware Upgrade Instructions

Overview

SEL occasionally offers firmware upgrades to improve the performance of your voltage regulator control. Because the SEL-2431 Voltage Regulator Control stores firmware in Flash memory, changing physical components is not necessary. Upgrade the voltage regulator control firmware in one of two ways: either through the front-panel USB port (if equipped), or via the front-panel serial port.

Upgrade Instructions Using the Type A USB Port

If the SEL-2431 is equipped with a Type A USB port, you can use these instructions.

Required Equipment

Gather the following equipment before starting this firmware upgrade:

USB flash drive with a digitally signed firmware file (e.g., r1132431.zds) copied using QuickSet, as outlined in *Section 2: PC Software*

Upgrade Procedure

Step 1. If the voltage regulator control is in service, follow your company's policy to remove the voltage regulator control from service.

Step 2. Insert the USB flash drive into the Type A USB port.

Step 3. Using the HMI, navigate to the **Read Settings** menu and read the settings from the SEL-2431 to the USB flash drive. See *Section 3: Front-Panel Interface* in the *SEL-2431 Voltage Regulator Control Field Reference Guide* for more information.

Step 4. Using the HMI, navigate to the **Send FW** menu and select the firmware file to use.

Step 5. Respond to the prompts to confirm you do wish to send the firmware file. The SEL-2431 will validate that the firmware file has been created by Schweitzer Engineering Laboratories, load the firmware file, and restart the device.

Step 6. Remove the USB flash drive.

Step 7. When the device restarts, it will display the pass or fail status of the firmware upgrade.

Step 8. Confirm that the device serial number is correct (not all "0"). On the HMI, navigate to **Status > Device Status > Serial Number**.

Step 9. If you notice any problems, contact the SEL factory or your Technical Service Center.

Upgrade Instructions Using the Front Serial Port

Before starting a firmware upgrade, determine if the SEL-2431 requires an .s19 file, or a .zds file (the .zds file is compressed and digitally signed by Schweitzer Engineering Laboratories for security purposes).

- If the SEL-2431 has a Type A USB port on the front panel, it requires a .zds file.

NOTE: The **ID** command shows the Firmware ID (FID) and boot firmware ID (BFID).

- If the SEL-2431 does not have a Type A USB port, then examine the response to the **ID** command at the ASCII prompt. Specifically, look at the number in bold:

  BFID=SLBT-2431-**R102**-V0-Z001001-D20120611","0967"

  If the value following the R is 102 or greater, then it requires a .zds file. Otherwise, the SEL-2431 requires an .s19 file.

Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer (PC)
- Terminal emulation software that supports Xmodem/CRC or 1k Xmodem/CRC protocol
- Serial communications cable (SEL cable SEL-C234A or equivalent, or a null-modem cable)
- Disk containing the correct type of firmware upgrade (e.g., r1012431.s19 or r1022431.zds) file

Upgrade Procedure

The instructions below assume you have a working knowledge of your personal computer terminal emulation software. In particular, you must be able to modify your serial communications parameters (data rate, data bits, parity, etc.), select transfer protocol (Xmodem/CRC or 1k Xmodem/CRC), and transfer files (e.g., send and receive binary files).

Step 1. If the voltage regulator control is in service, follow your company's policy to remove the voltage regulator control from service.

Step 2. Connect the PC to the front-panel serial port and enter Access Level 2.

Step 3. Save the current voltage regulator control settings.

PC software (described in *Section 2: PC Software*) can be used to save and restore settings easily. Otherwise, use the following steps.

a. Issue the following commands at the ASCII prompt:

SHO, **SHO L**, **SHO G**, **SHO P**, **SHO F**, **SHO R**, etc.

b. Record all the settings for possible re-entry after the firmware upgrade.

Step 4. Start upgrade of firmware.

a. Issue the **L_D** command to the voltage regulator control.

b. Type **Y <Enter>** at the following prompt:

```
Disable relay to receive firmware (Y/N)?
```

c. Type **Y <Enter>** at the following prompt:

`Are you sure (Y,N)?`

The voltage regulator control will send the `!>` prompt.

NOTE: If you have difficulty at 57600 bps, choose a slower data transfer rate (e.g. 38400 bps or 19200 bps). Be sure to match the voltage regulator control and PC data rates.

Step 5. Change the data rate, if desired.

a. Type **BAU 57600 <Enter>**.

This will change the data rate of the communications port to 57600.

b. Change the data rate of the PC to 57600 to match the voltage regulator control.

Step 6. Begin the transfer of new firmware to the voltage regulator control by issuing the **REC** command.

Step 7. Type **Y** to erase the existing firmware or press **<Enter>** to abort.

Step 8. Press any key (e.g., **<Enter>**) when the voltage regulator control sends a prompt.

Step 9. Start the file transfer.

a. Select the send file option in your communications software.

b. Use the Xmodem or 1k Xmodem protocol and send the file that contains the new firmware (e.g., r1012431.s19).

The file transfer takes approximately 20 minutes at 57600 bps and with 1k Xmodem transfer protocol. After the transfer is complete, the voltage regulator control will reboot and return to Access Level 0.

Figure B.1 shows the entire process.

```
=>>L_D <Enter>
Disable relay to receive firmware (Y/N) ? Y <Enter>
Are you sure (Y,N) ? Y <Enter>
Device Disabled
!>BAU 57600 <Enter>
!>REC <Enter>
Caution! This command erases the firmware.
If you erase the firmware then new firmware
must be loaded before returning the IED to service.
Are you sure you want to erase the existing firmware (Y/N)? Y <Enter>
Erasing firmware.
Erase successful.
Press any key to begin transfer and then start transfer at the terminal. <Enter>
Upload completed successfully. Attempting a restart.
```

Figure B.1 Firmware File Transfer Process

Step 10. The voltage regulator control illuminates the **ENABLED** front-panel LED if the voltage regulator control settings were retained through the download.

If the **ENABLED** LED is illuminated, proceed to *Step 11*.

If the **ENABLED** LED is not illuminated or the front-panel displays `STATUS FAIL`, `EEPROM FAILURE`, or `Non_Vol Failure`, use the following procedure to restore the factory-default settings:

a. Set the communications software settings to 9600 bps, 8 data bits, and 1 stop bit.

b. Enter Access Level 2 by issuing the **2AC** command.

c. Issue the **R_S** command to restore the factory-default settings.

The voltage regulator control will then reboot with the factory-default settings.

d. Enter Access Level 2.

e. If the firmware upgrade did not include a settings version change (Z number did not change), then restore voltage regulator control settings back to the settings saved in *Step 3*.

If the firmware upgrade did include a settings version change (Z number has changed), then use QuickSet's **Saved Settings Conversion Utility** to convert the settings saved in *Step 3* before restoring voltage regulator control settings.

Step 11. Change the data rate of the PC to match that of the voltage regulator control prior to *Step 5*, and enter Access Level 2.

Step 12. Issue the **STATUS** command; verify all voltage regulator control self-test results are OK and that the serial number is correct (not all "0"). If you notice any problems, contact the SEL factory or your Technical Service Center.

Step 13. Issue the **METER** command; verify that the current and voltage signals are correct.

Step 14. Autoconfigure the SEL-2032/SEL-2030/SEL-2020 port if you have a Communications Processor connected.

This step reestablishes automatic data collection between the SEL-2032, SEL-2030, SEL-2020 Communications Processor and the SEL voltage regulator control. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

The voltage regulator control is now ready for your commissioning procedure.

Technical Support

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

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APPENDIX C

SEL Communications Processors

SEL Communications Protocols

The SEL-2431 Voltage Regulator Control supports SEL protocols and command sets shown in *Table C.1*.

Table C.1 Supported Serial Command Sets

Command Set	Description
SEL ASCII	Use this protocol to send ASCII commands and receive ASCII responses that are human readable with an appropriate terminal emulation program.
SEL Compressed ASCII	Use this protocol the send ASCII commands and receive Compressed ASCII responses that are comma-delimited for use with spreadsheet and database programs or for use by intelligent electronic devices (IEDs).
SEL Fast Meter	Use this protocol to send binary commands and receive binary meter and target responses.
SEL Fast Operate	Use this protocol to receive binary control commands.

SEL ASCII Commands

We originally designed SEL ASCII commands for communication between the voltage regulator control and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the voltage regulator control, collect data, and issue commands.

SEL Compressed ASCII Commands

The voltage regulator control supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the voltage regulator control can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The voltage regulator control calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII or Compressed ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports because the compressed reports reduce blanks, tabs, and other white space between data fields to a single comma.

Table C.2 lists the Compressed ASCII commands and the contents of the command responses.

Table C.2 Compressed ASCII Commands

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CEVENT	Event report	1
CHISTORY	List of events	1
CLD	Load Profile (same as **CPROFILE** command)	1
CMETER	Metering data, including fundamental, thermal, energy, max/min, rms, analog inputs, and math variables	1
CPROFILE	Profile data	1
CSTATUS	Device status	1
DNAME	ASCII names of digital I/O reported in Fast Meter	0
ID	Device identification	0

Interleaved ASCII and Binary Messages

SEL devices have two separate data streams that share the same physical serial port. Human data communications with the device consist of ASCII character commands and reports that you view through use of a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the SEL-2431 communicates with an SEL communications processor. These SEL communications processors perform autoconfiguration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the SEL communications processor uses the binary data stream for Fast Meter and Fast Operate messages to populate a local database and to perform SCADA operations. At the same time, you can use the binary data stream to connect transparently to the SEL-2431 and use the ASCII data stream for commands and responses.

SEL Application Guide AG95-10, *Configuration and Fast Meter Messages*, is a comprehensive description of the SEL binary messages. Below is a description of the messages provided in the SEL-2431 Voltage Regulator Control.

Message Lists

Table C.3 Binary Message List

Request to Device (hex)	Response From Device
A5C0	Device Definition Block
A5C1	Fast Meter Configuration Block
A5D1	Fast Meter Data Block
A5C2	Demand Fast Meter Configuration Block
A5D2	Demand Fast Meter Data Message
A5C3	Peak Demand Fast Meter Configuration Block
A5D3	Peak Demand Fast Meter Data Message
A5B9	Fast Meter Status Acknowledge
A5CE	Fast Operate Configuration Block
A5E0	Fast Operate Remote Bit Control

Table C.4 ASCII Configuration Message List

Request to Device (hex)	Response From Device
ID	ASCII Firmware ID String and Terminal ID Setting (TID)
DNA	ASCII Names of Device Word bits
BNA	ASCII Names of bits in the A5B9 Status Byte

Message Definitions

A5C0 Device Definition Block

In response to the A5C0 request, the SEL-2431 sends the block shown in *Table C.5*.

Table C.5 A5C0 Device Definition Block

Data	Description
A5C0	Command
17	Length
02	Support two protocols, SEL and DNP
03	Support three Fast Meter messages
00	Support no status flag commands
A5C1	Fast Meter configuration commands
A5D1	Fast Meter command
A5C2	Demand Fast Meter configuration command
A5D2	Demand Fast Meter command
A5C3	Peak Demand Fast Meter configuration command
A5D3	Peak Demand Fast Meter command
0005	DNP3 protocol, No Fast Operate
checksum	1-byte checksum of preceding bytes

A5C1 Fast Meter Configuration Block

In response to the A5C1 request, the SEL-2431 sends the block shown in *Table C.6*.

Table C.6 A5C1 Fast Meter Configuration Block (Sheet 1 of 3)

Data	Description
A5C1	Fast Meter command
BB	Length
01	One status flag byte
00	Scale factors in Fast Meter message
00	No scale factors
11	# of analog input channels
01	# of samples per channel
34	# of digital banks (number of visible rows as defined by the Device Word—in hex)
00	No calculation blocks
0004	Analog channel offset
0048	Time stamp offset
0050	Digital offset
494C00000000	Analog channel name (IL)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494C41000000	Analog channel name (ILA)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
565300000000	Analog channel name (VS)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
565341000000	Analog channel name (VSA)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564C00000000	Analog channel name (VL)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564C41000000	Analog channel name (VLA)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
56434D500000	Analog channel name (VCMP)

Table C.6 A5C1 Fast Meter Configuration Block (Sheet 2 of 3)

Data	Description
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
544150504F53	Analog channel name (TAPPOS)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
565353454300	Analog channel name (VSSEC)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564C53454300	Analog channel name (VLSEC)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
56434D505343	Analog channel name (VCMPSC)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
504C00000000	Analog channel name (PL)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
514C00000000	Analog channel name (QL)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
534C00000000	Analog channel name (SL)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
504600000000	Analog channel name (PF)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50464C440000	Analog channel name (PFLD)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
465245510000	Analog channel name (FREQ)
01	Analog channel type

Table C.6 A5C1 Fast Meter Configuration Block (Sheet 3 of 3)

Data	Description
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
checksum	1-byte checksum of all preceding bytes

A5D1 Fast Meter Data Block

In response to the A5D1 request, the SEL-2431 sends the block shown in *Table C.7*.

Table C.7 A5D1 Fast Meter Data Block

Data	Description
A5D1	Command
133 bytes (0x85)	Length
1 byte	1 Status Byte
68 bytes	Magnitudes of IL, ILA, VS, VSA, VL, VLA, VCMP, TAPPOS, VSSEC, VLSEC, VCMPSC, PL, QL, SL, PF, PFLD, FREQ in 4-byte IEEE FPS
8 bytes	Time stamp
52 bytes	52 Digital banks: TAR0–TAR51
checksum	1-byte checksum of all preceding bytes

A5C2 Demand Fast Meter Configuration Message

In response to the A5C2 or A5C3 request, the device sends the block shown in *Table C.8* and *Table C.9*.

Table C.8 A5C2 Demand Fast Meter Configuration Message (Sheet 1 of 2)

Data	Description
A5C2	Command; Demand (A5C2)
75	Length
01	# of status flag byte
00	Scale factors in meter message
00	# of scale factors
0A	# of analog input channels
01	# of samples per channel
00	# of digital banks
00	# calculation blocks
0004	Analog channel offset
002C	Time stamp offset
FFFF	Digital offset
494C4644454D	Analog channel name (ILFDEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494C5244454D	Analog channel name (ILRDEM)

Table C.8 A5C2 Demand Fast Meter Configuration Message (Sheet 2 of 2)

Data	Description
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
504644454D00	Analog channel name (PFDEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
505244454D00	Analog channel name (PRDEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51464F44454D	Analog channel name (QFODEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51464944454D	Analog channel name (QFIDEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51524F44454D	Analog channel name (QRODEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51524944454D	Analog channel name (QRIDEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
534644454D00	Analog channel name (SFDEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
535244454D00	Analog channel name (SRDEM)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
00	Reserved
checksum	1-byte checksum of preceding bytes

Table C.9 A5C3 Demand Fast Meter Configuration Message (Sheet 1 of 2)

Data	Description
A5C3	Command; Peak Demand (A5C3)
75	Length
01	# of status flag byte
00	Scale factors in meter message
00	# of scale factors
OA	# of analog input channels
01	# of samples per channel
00	# of digital banks
00	# calculation blocks
0004	Analog channel offset
002C	Time stamp offset
FFFF	Digital offset
494C46504B00	Analog channel name (ILFPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494C52504B00	Analog channel name (ILRPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
5046504B0000	Analog channel name (PFPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
5052504B0000	Analog channel name (PRPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51464F504B00	Analog channel name (QFOPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
514649504B00	Analog channel name (QFIPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51524F504B00	Analog channel name (QROPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
515249504B00	Analog channel name (QRIPK)

Table C.9 A5C3 Demand Fast Meter Configuration Message (Sheet 2 of 2)

Data	Description
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
5346504B0000	Analog channel name (SFPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
5352504B0000	Analog channel name (SRPK)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
00	Reserved
checksum	1-byte checksum of preceding bytes

A5D2/A5D3 Demand/Peak Demand Fast Meter Message

In response to the A5D2 request, the device sends the block shown in *Table C.10*.

Table C.10 A5D2/A5D3 Demand/Peak Demand Fast Meter Message

Data	Description
A5D2	Command
35	Length
1 byte	1 Status Byte
176 bytes	Demand: ILFDEM, ILRDEM, PFDEM, PRDEM, QFO-DEM, QFIDEM, QRODEM, QRIDEM, SFDEM, SRDEM or Peak Demand: ILFPK, ILRPK, PFPK, PRPK, QFOPK, QFOPK, QROPK, QRIPK, SFPK, SRPK in 4-byte IEEE FPS
8 bytes	Time Stamp
1 byte	Reserved

A5B9 Fast Meter Status Acknowledge Message

In response to the A5B9 request, the device clears the Fast Meter (message A5D1) Status Byte. The SEL-2431 Status Byte contains one active bit, STSET (bit 4) The bit is set on power up and on setting changes. If the STSET bit is set, the external device should request the A5C1, A5C2, and A5C3 messages. The external device can then determine if the scale factors or configuration parameters have been modified.

A5CE Fast Operate Configuration Block

In response to the A5CE request, the device sends the block shown in *Table C.11*.

Table C.11 A5CE Fast Operate Configuration Block (Sheet 1 of 2)

Data	Description
A5CE	Command
39	Length
00	Support no circuit breakers
0010	Support 16 remote bit set/clear commands
0100	Allow remote bit pulse command
00	Operate code, clear remote bit RB01
20	Operate code, set remote bit RB01
40	Operate code, pulse remote bit RB01
01	Operate code, clear remote bit RB02
21	Operate code, set remote bit RB02
41	Operate code, pulse remote bit RB02
02	Operate code, clear remote bit RB03
22	Operate code, set remote bit RB03
42	Operate code, pulse remote bit RB03
03	Operate code, clear remote bit RB04
23	Operate code, set remote bit RB04
43	Operate code, pulse remote bit RB04
04	Operate code, clear remote bit RB05
24	Operate code, set remote bit RB05
44	Operate code, pulse remote bit RB05
05	Operate code, clear remote bit RB06
25	Operate code, set remote bit RB06
45	Operate code, pulse remote bit RB06
06	Operate code, clear remote bit RB07
26	Operate code, set remote bit RB07
46	Operate code, pulse remote bit RB07
07	Operate code, clear remote bit RB08
27	Operate code, set remote bit RB08
47	Operate code, pulse remote bit RB08
08	Operate code, clear remote bit RB09
28	Operate code, set remote bit RB09
48	Operate code, pulse remote bit RB09
09	Operate code, clear remote bit RB10
29	Operate code, set remote bit RB10
49	Operate code, pulse remote bit RB10
0A	Operate code, clear remote bit RB11
2A	Operate code, set remote bit RB11
4A	Operate code, pulse remote bit RB11

Table C.11 A5CE Fast Operate Configuration Block (Sheet 2 of 2)

Data	Description
0B	Operate code, clear remote bit RB12
2B	Operate code, set remote bit RB12
4B	Operate code, pulse remote bit RB12
0C	Operate code, clear remote bit RB13
2C	Operate code, set remote bit RB13
4C	Operate code, pulse remote bit RB013
0D	Operate code, clear remote bit RB14
2D	Operate code, set remote bit RB14
4D	Operate code, pulse remote bit RB14
0E	Operate code, clear remote bit RB15
2E	Operate code, set remote bit RB15
4E	Operate code, pulse remote bit RB15
0F	Operate code, clear remote bit RB16
2F	Operate code, set remote bit RB16
4F	Operate code, pulse remote bit RB16
00	Reserved
checksum	1-byte checksum of all preceding bytes

A5E0 Fast Operate Remote Bit Control

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

Table C.12 A5E0 Fast Operate Remote Bit Control

Data	Description
A5E0	Command
06	Length
1 byte	Operate code: 00-0F clear remote bit RB01–RB16 20-2F set remote bit RB01–RB16 40-4F pulse remote bit RB01–RB16 for one processing interval
1 byte	Operate validation: 4 • Operate code + 1
checksum	1-byte checksum of preceding bytes

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

- The Operate code is valid.
- The Operate validation = 4 • Operate code + 1.
- The message checksum is valid.
- The FASTOP port setting is set to Y.
- The relay is enabled.

Remote bit set and clear operations are latched by the relay. Remote bit pulse operations assert the remote bit for one processing interval (one cycle).

It is common practice to route remote bits to output contacts to provide remote control of the relay outputs. If you wish to pulse an output contact closed for a specific duration, SEL recommends using the remote bit pulse command and SELOGIC control equations to provide secure and accurate contact control. The remote device sends the remote bit pulse command; the relay controls the timing of the output contact assertion. You can use any remote bit (RB01–RB16) and any SELOGIC control equation timer (SV01–SV08) to control any of the output contacts. For example, to pulse output contact OUT104 for 30 cycles with Remote Bit RB04 and SELOGIC control equation timer SV04, issue the following relay settings:

Via the **SET L** command:

ESV := **4** enable 4 SELOGIC control equations

SV04PU := **0** SV04 pickup time = 0

SV04DO := **30** SV04 dropout time is 30 cycles

SV4 := **RB04** SV04 input is RB04

OUT104 := **SV04T** route SV04 timer output to OUT104

To pulse the contact, send the **A5E006430DDB** command to the relay.

ID Message

In response to the **ID** command, the device sends the firmware IF (FID), boot firmware ID (BFID), firmware checksum (CID), device DEVID setting, Modbus device code—for use by the SEL-2032, SEL-2030, and SEL-2020 Communications Processors, device part number (PARTNO), and configuration string (CONFIG)—for use by other IEDs or software. A sample response is shown below; responses will differ depending on device model, setting, and firmware.

```
<STX>"FID=SEL-2431-R100-V0-Z001001-D20070502","yyyy"
"BFID=SLBT-2431-R100-V0-Z001001-D20070129","yyyy"
"CID=9C2C","yyyy"
"DEVID=SEL-2431","yyyy"
"DEVCODE=68","yyyy"
"PARTNO=24310X11X1131XXXXXXX","yyyy"
"CONFIG=10000000","yyyy"<ETX>
```

where: <STX> is the STX character (02)
<ETX> is the ETX character (03)
yyyy is the 4-byte ASCII hex representation of the checksum for each line

The ID message is available from Access Level 0 and higher.

DNA Message

In response to the **DNA** command, the device sends names of the Device Word bits transmitted in the A5D1 message. The first name is associated with the MSB, the last name with the LSB. These names are listed in the Device Word bits table in *Table E.1*. The **DNA** command is available from Access Level 1 and higher.

A sample DNA message for the SEL-2431 follows.

```
<STX>"*","ENABLED","ALARM","*","VRIPROG","INHIBSV","REVERSE","TAPNEUT","yyyy"
"*","VMAXLMT","HBND","IN_BND","LBND","VMINLMT","*","*","yyyy"
"PB01LED","PB02LED","PB03LED","PB04LED","PB05LED","PB06LED","PB07LED","*","yyyy"
"REMOTE","LOCAL","AUTO","MANUAL","MRAISE","MLOWER","*","*","yyyy"
"PB01","PB02","PB03","PB04","PB05","PB06","PB07","*","yyyy"
"PB01PUL","PB02PUL","PB03PUL","PB04PUL","PB05PUL","PB06PUL","PB07PUL","*","yyyy"
"LOCALSW","AUTOSW","RAISESW","LOWERSW","*","*","*","*","yyyy"
"MODEINH","ENFWD","ENREV","INHIBIT","*","*","RC","LC","yyyy"
"OPNOCUR","TAPDONE","MAXTAP","MINTAP","TOOHIGH","TOOLOW","XTAP16R","XTAP16L","yyyy"
"TAP_OFF","NO_NEUT","TAP_DIF","*","*","*","*","*","yyyy"
"RB01","RB02","RB03","RB04","RB05","RB06","RB07","RB08","yyyy"
"RB09","RB10","RB11","RB12","RB13","RB14","RB15","RB16","yyyy"
"LB01","LB02","LB03","LB04","LB05","LB06","LB07","LB08","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"SV01","SV02","SV03","SV04","SV05","SV06","SV07","SV08","yyyy"
"SV01T","SV02T","SV03T","SV04T","SV05T","SV06T","SV07T","SV08T","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"LT01","LT02","LT03","LT04","LT05","LT06","LT07","LT08","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"SC01QU","SC02QU","SC03QU","SC04QU","SC05QU","SC06QU","SC07QU","SC08QU","yyyy"
"SC01QD","SC02QD","SC03QD","SC04QD","SC05QD","SC06QD","SC07QD","SC08QD","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"SG1","SG2","SG3","SG4","*","*","*","*","yyyy"
"*","ER","SPEN","BLOCKSV","RBKBLSV","*","*","*","yyyy"
"MHOLD","MET_FWD","*","*","*","*","*","*","yyyy"
"TSOK","TIRIG","IRIGOK","*","*","*","SALARM","HALARM","yyyy"
"OP_LFWD","OP_LREV","OP_IREV","OP_BDIR","OP_COGN","*","COGNREV","*","yyyy"
"IN_BNDF","HBNDFWD","LBNDFWD","*","IN_BNDR","HBNDREV","LBNDREV","*","yyyy"
"VMAXF","VMAXR","*","*","VMINF","VMINR","*","*","yyyy"
"RBKFH","RBKFWDH","RBKFL","RBKFWDL","RBKRH","RBKREVH","RBKRL","RBKREVL","yyyy"
"DLYHBF","DLYLBF","DLYHBR","DLYLBR","*","*","*","*","yyyy"
"TAPHBF","TAPLBF","TAPHBR","TAPLBR","*","*","TAPLWR2","TAPRSE2","yyyy"
"50L1","50L2","50L3","50L4","50L5","50L6","50L7","*","yyyy"
"50FLT","50FWD","50REV","*","*","*","*","*","yyyy"
"FORWARD","NO_TORK","*","*","*","*","*","*","yyyy"
"VRED1SV","VRED2SV","VRED3SV","VRRSTSV","OVRIDSV","*","*","*","yyyy"
"RAISESV","LOWERSV","*","*","MANULSV","AUTOSV","REMOTSV","LOCALSV","yyyy"
"NORAIS","NOLOWR","RSEFAIL","RSELIM","LWRFAIL","LWRLIM","*","*","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"*","*","*","*","*","*","*","*","yyyy"
"OP1","OP2","OP3","OP4","*","*","*","*","yyyy"
"OUT101","OUT102","OUT103","OUT104","RAISE","LOWER","DHR","VTJVOLT","yyyy"
"*","LAMPTST","*","*","*","*","*","*","yyyy"
"IN101","IN102","*","*","*","*","*","*","yyyy"
"IN201","IN202","IN203","IN204","*","*","*","OPSWHCN","yyyy"
"DST","DSTP","LPSEC","LPSECP","TQUAL4","TQUAL3","TQUAL2","TQUAL1","yyyy"
"EFCNBD1","EFCNBD2","EFCNBD3","*","ERCNBD1","ERCNBD2","ERCNBD3","*","yyyy"
<ETX>
```

where: <STX> is the STX character (02)
<ETX> is the ETX character (03)
the last field in each line (yyyy) is the 4-byte ASCII hex representation of the checksum for the line
"*" indicates an unused bit location

BNA Message

In response to the **BNA** command, the device sends names of the bits transmitted in the Status Byte in the A5D1 message. The first name is the MSB, the last name is the LSB. The BNA message is:

```
<STX>"*","*","*","*","*","PWRUP","STSET","*","yyyy"<ETX>
```

where: "yyyy" is the 4-byte ASCII representation of the checksum
"*" indicates an unused bit location

The **BNA** command is available from Access Level 1 and higher.

SEL Communications Processor

SEL offers SEL communications processors, powerful tools for system integration and automation. The SEL-2030 series and the SEL-2020 communications processors are similar, except that the SEL-2030 series has two slots for network protocol cards. These devices provide a single point of contact for integration networks with a star topology, as shown in *Figure C.1*.

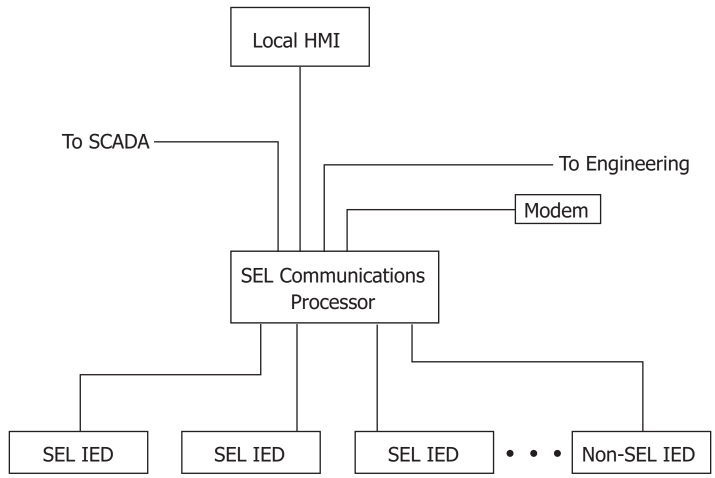

Figure C.1 SEL Communications Processor Star Integration Network

In the star topology network in *Figure C.1* the SEL communications processor offers the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Distribution of IRIG-B time-synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Automated dial-out on alarms

The SEL communications processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure C.2*.

In this multitiered system, the lower-tier SEL communications processors forward data to the upper-tier SEL communications processor that serves as the central point of access to substation data and substation IEDs.

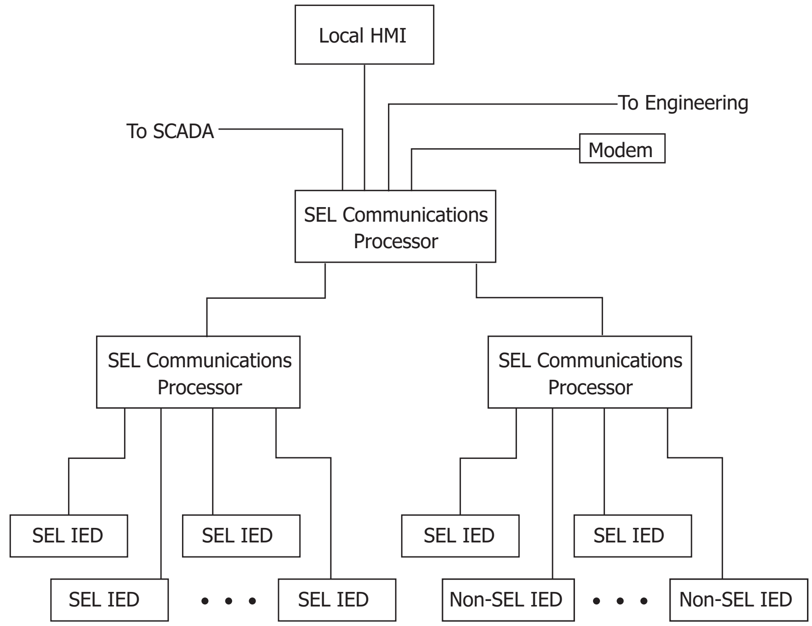

Figure C.2 Multitiered SEL Communications Processor Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. SEL communications processors provide an integration solution with a reliability comparable to that of SEL devices. In terms of MTBF (mean time between failures), SEL communications processors are 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure SEL communications processors with a system of communication-specific keywords and data movement commands rather than programming in a general-purpose computer language such as C. SEL communications processors offer the protocol interfaces listed in *Table C.13*.

Table C.13 SEL Communications Processors Protocol Interface

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters
Modbus RTU Protocol	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays and controls
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus[a]	Modbus Plus peers with global data and Modbus Plus masters
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol and peers

[a] Requires SEL-2711 Modbus Plus protocol card.
[b] Requires SEL-2701 Ethernet Processor.

SEL Communications Processor and Device Architecture

You can apply SEL communications processors and SEL devices in a limitless variety of applications that integrate, automate, and improve station operation. Most system integration architectures utilizing SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-2431 and an SEL communications processor is shown in *Figure C.1*. In this architecture, the SEL communications processor collects data from the SEL-2431 and other station IEDs. The SEL communications processor acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses an SEL communications processor to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting any SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface, so you can install, test, and even upgrade the system in the future without disturbing voltage regulator controls, protective relays, and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

SEL communications processors equipped with an SEL-2701 Ethernet Processor can provide a UCA2 interface to SEL-2431 voltage regulator controls and other serial IEDs. The SEL-2431 data appear in models in a virtual device domain. The combination of the SEL-2701 with an SEL communications processor offers a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 with an SEL communications processor, see the SEL-*2701 Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software can use either a serial port connection or an Ethernet network connection from an engineering workstation to the devices in the field.

Enhancing Multidrop Networks

You can also use an SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure C.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI (Human Machine Interface) multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI.

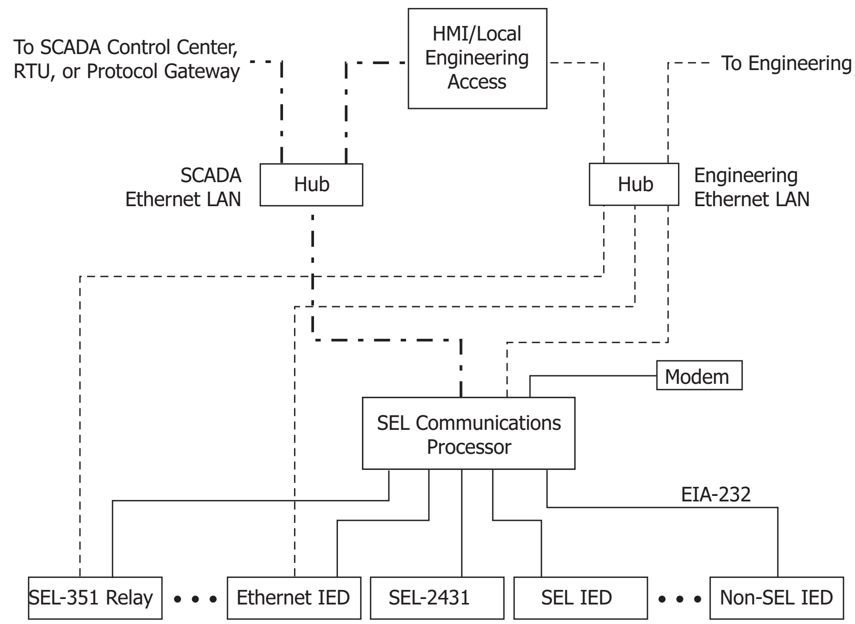

Figure C.3 Enhancing Multidrop Networks With SEL Communications Processors

In this example, the SEL communications processor provides the following enhancements when compared to a system that employs only the multidrop network:

- Ethernet access for IEDs with serial ports
- Backup engineering access through the dial-in modem
- IRIG-B time signal distribution to all station IEDs
- Integration of IEDs without Ethernet
- Single point of access for real-time data for SCADA, HMI, and other uses
- Significant cost savings by use of existing IEDs with serial ports

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-2431. The physical configuration used in this example is shown in *Figure C.4*.

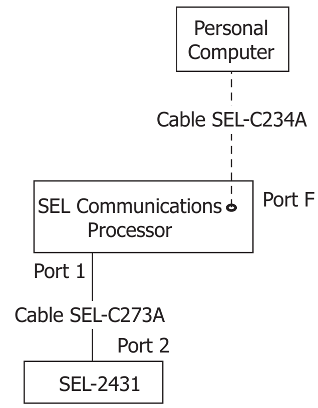

Figure C.4 Example of SEL Voltage Regulator Control and SEL Communications Processor Configuration

Table C.14 shows the PORT 1 settings for the SEL communications processor.

Table C.14 SEL Communications Processor Port 1 Settings

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	*Control 1*	Name of connected voltage regulator control[a]
BAUD	19200	Channel speed of 19200 bps[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit
PARITY	N	No parity
RTS_CTS	N	Hardware flow control enabled
TIMEOUT	30	Idle time out that terminates transparent connections of 30 seconds

[a] Automatically collected by the SEL communications processor during autoconfiguration.

Data Collection

The SEL communications processor is configured to collect data from the SEL-2431, using the list in *Table C.15*.

Table C.15 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Control metering data
D2	Binary	TARGET	Control Word bit data
D3–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

Table C.16 shows the automessage (**SET A**) settings for the SEL communications processor.

Table C.16 SEL Communications Processor Port 1 Automatic Messaging Settings

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	ACC\nOTTER\n	Automatically log-in at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker control
REC_SER	N	Automatic sequential event recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	2	Two automessages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Control Word bit data
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table C.17 shows the map of regions in the SEL communications processor for data collected from the SEL-2431. Use the **MAP *n*** command to view these data.

Table C.17 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Control metering data
D2	Binary	TARGET	Control Word bit data
D3–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

Voltage Regulator Control Metering Data

Table C.18 shows the list of meter data available in the SEL communications processor and the location and data type for the memory areas within D1 (Data Region 1). The type field indicates the data type and size. The *int* type is a 16-bit integer. The *float* type is a 32-bit IEEE floating-point number. Use the **VIA *n*:D1** command to view these data.

Table C.18 Communications Processor METER Region Map (Sheet 1 of 2)

Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME(ms)	2002h	int[2]
MONTH	2004h	char
DATE	2005h	char
YEAR	2006h	char
HOUR	2007h	char
MIN	2008h	char
SECONDS	2009h	char
MSEC	200Ah	int
IL	200Bh	float
ILA	200Dh	float
VS	200Fh	float
VSA	2011h	float
VL	2013h	float
VLA	2015h	float
VCMP	2017h	float
TAPPOS	2019h	float
VSSEC	201Bh	float
VLSEC	201Dh	float
VCMPSC	201Fh	float
PL	2021h	float
QL	2023h	float
SL	2025h	float

Table C.18 Communications Processor METER Region Map (Sheet 2 of 2)

Item	Starting Address	Type
PF	2027f	float
PFLD	2029h	float
FREQ	202Bh	float

Control Word Bits Information

Table C.19 lists the Control Word bit data available in the SEL communications processor TARGET region.

Table C.19 Communications Processor TARGET Region

Address	Control Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
2804h	*	*	*	STSET	*	*	*	*
2805h	See *Table E.1*, Row 0							
2806h	See *Table E.1*, Row 1							
2807h	See *Table E.1*, Row 2							
2808h	See *Table E.1*, Row 3							
2809h	See *Table E.1*, Row 4							
280Ah	See *Table E.1*, Row 5							
280Bh	See *Table E.1*, Row 6							
280Ch	See *Table E.1*, Row 7							
280Dh	See *Table E.1*, Row 8							
280Eh	See *Table E.1*, Row 9							
280Fh	See *Table E.1*, Row 10							
2810h	See *Table E.1*, Row 11							
2811h	See *Table E.1*, Row 12							
•	•							
•	•							
•	•							
2858h	See *Table E.1*, Row 83							

Control Points

The SEL communications processor can automatically pass control messages, called Fast Operate messages, to the SEL-2431. You must enable Fast Operate messages by using the FASTOP setting in the SEL-2431 port settings for the port connected to the SEL communications processor. You must also enable Fast Operate messages in the SEL communications processor by setting the automessage setting SEND_OPER equal to Y.

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the voltage regulator control for changes to remote bits RB01–RB16 on the corresponding SEL communications processor port. In this example, if you set RB01 on **PORT 1** in the SEL communications processor, it automatically sets RB01 in the SEL-2431.

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APPENDIX D

DNP3 Communications

Overview

The SEL-2431 Voltage Regulator Control provides a Distributed Network Protocol Version 3.0 (DNP3) Slave Level 2 interface for direct serial and LAN/WAN network connections to the device.

This section covers the following topics:

- ➤ Introduction to DNP3
- ➤ DNP3 in the SEL-2431
- ➤ DNP3 Documentation, Object Tables, and Data Maps

Introduction to DNP3

A Supervisory Control and Data Acquisition (SCADA) manufacturer developed the first versions of DNP from the lower layers of IEC 60870-5. Originally designed for use in telecontrol applications, Version 3.0 of the protocol has also become popular for local substation data collection. DNP3 is one of the protocols included in the IEEE Recommended Practice for Data Communication between Remote Terminal Units (RTUs) and Intelligent Electronic Devices (IEDs) in a Substation.

The DNP Users Group maintains and publishes DNP3 standards. See the DNP Users Group website, www.dnp.org, for more information on standards, implementers, and tools for working with DNP3.

DNP3 Specifications

DNP3 is a feature-rich protocol with many ways to accomplish tasks, defined in a series of specifications known as the Basic 4. A companion specification called the Subset Definitions simplifies DNP3 implementation by providing three standard interoperable implementation levels. The levels are listed in *Table D.1*.

Table D.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communication requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communication requirements	Large RTUs, SCADA masters
4	Enhanced: additional data types and functionality for more complex requirements	Large RTUs, SCADA masters

Each level is a proper superset of the previous lower-numbered level. A higher-level device can act as a master to a lower-level device, but can only use the data types and functions implemented in the lower level device. For example, a typical SCADA master is a Level 3 device and can use Level 2 (or lower) functions to poll a Level 2 (or lower) device for Level 2 (or lower) data. Similarly, a lower-level device can poll a higher-level device, but the lower level device can only access the features and data available to its level.

In addition to the Basic 4 and the Subset Definitions, the protocol is further refined by conformance requirements, optional features, and a series of technical bulletins. The technical bulletins supplement the specifications with discussion and examples of specific features of DNP3.

Data Handling

Objects

DNP3 uses a system of data references called objects, defined by the Basic 4 standard object library. Each subset level specification requires a minimum implementation of object types and recommends several optional object types. DNP3 object types, commonly referred to as objects, are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for special operations, including collections of data, time synchronization, or even all data within the DNP3 device.

If there can be more than one instance of a type of object, then each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, and Index 15.

Each object also includes multiple versions called variations. For example, Object 1 (binary inputs) has three variations: 0, 1, and 2. You can use variation 0 to request all variations, variation 1 to specify binary input values only, and variation 2 to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and defines what data or control points correspond with each index.

A master initiates all DNP3 message exchanges except unsolicited data. DNP3 terminology describes all points from the perspective of the master. Binary points for control that move from the master to the remote are called Binary Outputs, while binary status points within the remote are called Binary Inputs.

Function Codes

Each DNP3 message includes a function code. Each object has a limited set of function codes that a master may use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table D.2*.

Table D.2 Selected DNP3 Function Codes (Sheet 1 of 2)

Function Code	Function	Description
1	Read	Request data from the remote
2	Write	Send data to the remote
3	Select	First part of a select-before-operate operation

Table D.2 Selected DNP3 Function Codes (Sheet 2 of 2)

Function Code	Function	Description
4	Operate	Second part of a select-before-operate operation
5	Direct operate	One-step operation with reply
6	Direct operate, no reply	One-step operation with no reply

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range and the range specifies the indices of the objects of interest. DNP3 masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP3 remote.

For example, the qualifier code 01 specifies that the request for points will include a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four hexadecimal byte range field, 00h 04h 00h 10h, which specifies points in the range 4 to 16.

Access Methods

DNP3 has many features that help obtain maximum possible message efficiency. DNP3 masters send requests with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of static (unchanging) data values. These features optimize use of bandwidth and maximize performance over a connection of any speed.

DNP3 event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are time-stamped records that show when observed measurements changed. For binary points, the remote device (DNP3 slave) logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the remote device logs changes that exceed a deadband. DNP3 remote devices collect event data in a buffer that either the master can request or the device can send to the master without a request message. Data sent from the remote to the master without a polling request are called unsolicited data.

DNP3 data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value data (static data). Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With remotes that contain great amounts of data or in large systems, the three event classes provide a framework for prioritizing different types of data. For example, you can poll once a minute for Class 1 data, once an hour for Class 2 data, and once a day for Class 3 data.

DNP3 also supports static polling: simple polling of the present value of data points within the remote. By combining event data, unsolicited polling, and static polling, you can operate your system in one of the four access methods shown in *Table D.3*.

The access methods listed in *Table D.3* are listed in order of increasing communication efficiency. With various tradeoffs, each method is less demanding of communication bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communication bandwidth than polled report-by-exception because that method does not require polling messages from the master. In order to properly evaluate which access method provides optimum performance for your application, you must also consider overall system size and the volume of data communication expected.

Table D.3 DNP3 Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data
Unsolicited report-by-exception	Remote devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data
Quiescent	Master never polls and relies on unsolicited reports only

Binary Control Operations

DNP3 masters use Object 12, control relay output block, to perform DNP3 binary control operations. The control relay output block has both a trip/close selection and a code selection. The trip/close selection allows a single DNP3 index to operate two related control points such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP3 master implementations.

The control relay output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP3 remotes have only a limited subset of the possible combinations of the code field. Sometimes, DNP3 remotes assign special operation characteristics to the latch and pulse selections. *Table D.12* describes control point operation for the SEL-2431.

DNP3 Serial Network Issues

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (Open Systems Interconnect) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the Data Link Layer, includes several functions for error checking and media access control.

A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP3 device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP3 conversation. You should consider whether you require this link integrity function in your application at the expense of overall system speed and performance.

The DNP3 technical bulletin (*DNP Confirmation and Retry Guidelines 9804-002*) on confirmation processes recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single (serial) network medium, you must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your serial network as a star topology of point-to point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before transmitting. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your serial network allows for spontaneous data transmission including unsolicited event data transmissions, you also must use application confirmation to provide a retry mechanism for messages lost as a result of data collisions.

DNP3 LAN/WAN Overview

The main process for carrying DNP3 over an Ethernet Network (LAN/WAN) involves encapsulating the DNP3 data link layer data frames within the transport layer frames of the Internet Protocol (IP) suite. This allows the IP stack to deliver the DNP3 data link layer frames to the destination in place of the original DNP3 physical layer.

The DNP User Group Technical Committee has recommended the following guidelines for carrying DNP3 over a network:

NOTE: Link layer confirmations are explicitly disabled for DNP3 LAN/WAN. The IP suite provides a reliable delivery mechanism, which is backed up at the application layer by confirmations when required.

- DNP3 shall use the IP suite to transport messages over a LAN/WAN
- Ethernet is the recommended physical link, although others may be used
- TCP must be used for WANs
- TCP is strongly recommended for LANs
- User Datagram Protocol (UDP) may be used for highly reliable single segment LANs
- UDP is necessary if broadcast messages are required
- The DNP3 protocol stack shall be retained in full
- Link layer confirmations shall be disabled

The Technical Committee has registered a standard port number, 20000, for DNP3 with the Internet Assigned Numbers Authority (IANA). This port is used for either TCP or UDP.

TCP/UDP Selection

The Committee recommends the selection of TCP or UDP protocol as per the guidelines in *Table D.4*.

Table D.4 TCP/UDP Selection Guidelines

Use in the case of...	TCP	UDP
Most situations	X	
Non-broadcast or multicast	X	
Mesh Topology WAN	X	
Anonymous DNP	X	
Broadcast		X
Multicast		X
High-reliability single-segment LAN		X
Pay-per-byte, non-mesh WAN, for example, Cellular Digital Packet Data (CDPD)		X
Low priority data, for example, data monitor or configuration information		X

DNP3 in the SEL-2431

The SEL-2431 is a DNP3 Level 2 remote (slave) device.

Data Access

Table D.5 lists DNP3 data access methods along with corresponding SEL-2431 settings. You must select a data access method and configure each DNP3 master for polling as specified.

NOTE: Because unsolicited messaging is problematic in most circumstances, SEL recommends using the polled report-by-exception access method to maximize performance and minimize risk of configuration problems.

Table D.5 DNP3 Access Methods

Access Method	Master Polling	SEL-2431 Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA to 0; UNSOL to No
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLASSC, ECLASSA to the desired event class; UNSOL to No
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently; mainly relies on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class; set UNSOL to Yes and PUNSOL to Yes or No
Quiescent	Class 0, 1, 2, 3 never; relies completely on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class; set UNSOL and PUNSOL to Yes

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table D.5*, you must make a selection for the PUNSOL setting. This setting enables or disables unsolicited data reporting at power up. If your DNP3 master can send a message to enable unsolicited reporting on the SEL-2431, you should set PUNSOL to No.

While automatic unsolicited data transmission on power up is convenient, this can cause problems if your DNP3 master is not prepared to start receiving data immediately on power up. If the master does not acknowledge the unsolicited data with an Application Confirm, the device will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several devices simultaneously begin sending data and waiting for acknowledgment messages.

The SEL-2431 allows you to set the conditions for transmitting unsolicited event data on a class-by-class basis. It also allows you to assign points to event classes on a point-by-point basis (see *Configurable Data Mapping*). You can prioritize data transmission with these event class features. For example, you might place high-priority points in event Class 1 and set it with low thresholds (NUMEVE and AGEEVE settings) so that changes to these points will be sent to the master quickly. You may then place low priority data in event Class 2 with higher thresholds.

If the SEL-2431 does not receive an Application Confirm in response to unsolicited data, it will wait for ETIMEO seconds and then repeat the unsolicited message. In order to prevent clogging of the network with unsolicited data retries, the SEL-2431 uses the URETRY and UTIMEO settings to increase retry time when the number of retries set in URETRY is exceeded. After URETRY has been exceeded, the SEL-2431 pauses UTIMEO seconds and then transmits the unsolicited data again. *Figure D.1* provides an example with URETRY = 2.

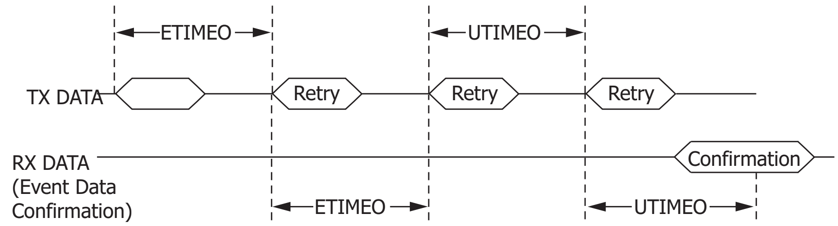

Figure D.1 Application Confirmation Timing With URETRY = 2

Collision Avoidance

If your application uses unsolicited reporting on a serial network, you must select a half-duplex medium or a medium that includes carrier detection to avoid data collisions. Two-Wire EIA-485 networks are half-duplex. Four-Wire EIA-485 networks do not provide carrier detection, while EIA-232 systems can support carrier detection.

The SEL-2431 uses Application Confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The SEL-2431 pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. For example, if you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the SEL-2431 will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission (see *Figure D.2*).

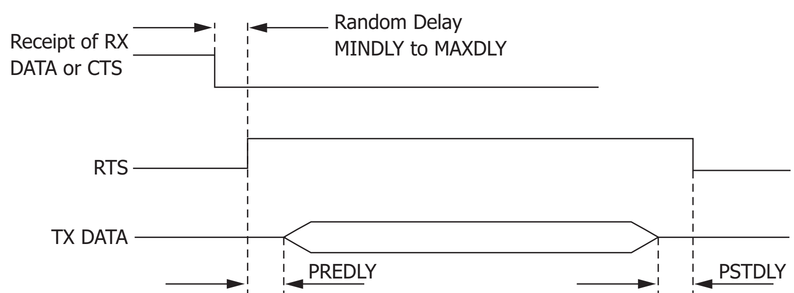

Figure D.2 Message Transmission Timing

Transmission Control

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your DNP3 network, you may need to adjust data transmission properties. Use the PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission (see *Figure D.2*). For example, an EIA-485 transceiver typically requires 10 to 20 ms to change from receive to transmit. If you set the pre-delay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Use of the MINDLY or PREDLY setting may also be required for DNP master compatibility, as some masters may expect a minimum delay between the transmission of the request and the receipt of a response from the SEL-2431.

Event Data

DNP3 event data objects contain change-of-state and time-stamp information that the SEL-2431 collects and stores in a buffer. Points assigned in the Binary Input Map that are also assigned in the Sequential Events Recorder (SER) settings carry the time stamp of actual occurrence. Binary input points not assigned in the SER settings will carry a time stamp based on the DNP map scan time. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. The DNP map is scanned approximately once per second to generate events. You can configure the SEL-2431 to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB, ECLASSC, and ECLASSA, you can set the event class for binary, counter, analog and virtual terminal. Select DNP3 event class 1, 2, or, 3 as a simple priority system for collecting event data. You can disable event reporting by making the setting 0. The SEL-2431 does not treat data of different classes differently with respect to message scanning, but it does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. You must confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-2431.

For event data collection, you must also consider and enter appropriate settings for deadband and scaling operation on analog points shown in *Table D.7*. You can either:

- set and use default deadband and scaling according to data type, or
- use a custom data map to select deadbands on a point-by-point basis.

See *Configurable Data Mapping* on page D.14 for a discussion of how to set scaling and dead-band operation on a point-by-point basis. Deadbands for analog inputs can be modified at run-time by writing to object 34.

The settings ANADBA, ANADBV, and ANADBM control default dead-band operation for each type of analog data. Because DNP3 Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

With no scaling, the value of 12.632 would be sent as 13. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

You can set the default analog value scaling with the DECPLA, DECPLV, and DECPLM settings. Application of event reporting deadbands occurs after scaling. For example, if you set DECPLA to 2 and ANADBA to 10, a measured current of 10.14 A would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a change in magnitude of ± 0.1 A) for the device to report a new event value.

The SEL-2431 uses the NUMEVE and AGEEVE settings to decide when to send unsolicited data to the master. The device sends an unsolicited report when the total number of events accumulated in the event buffer reaches NUMEVE. The device also sends an unsolicited report if the age of the oldest event in the master buffer exceeds AGEEVE. The SEL-2431 has the buffer capacities listed in *Table D.6*.

Table D.6 SEL-2431 Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	100
Counters	32

Binary Controls

The SEL-2431 provides more than one way to control individual points. The SEL-2431 maps incoming control points either to remote bits or to internal command bits that cause setting adjustments. *Table D.12* lists control points and control methods available in the SEL-2431.

A DNP3 technical bulletin (*Control Relay Output Block Minimum Implementation 9701-002*) recommends that you use one point per Object 12, control block output relay. You can use this method to perform Pulse, Latch On, and Latch Off operations on a single control point. Trip/Close and Latch On/Latch Off can also be used on selected remote bit pairs, but pulse operations are not available.

If your master does not support the single-point-per-index messages or single operation database points, you can use the trip/close operation or use the code field in the DNP3 message to specify operation of the points shown in *Control Point Operation* on page D.31.

When setting DNPBOOP = DEFAULT, DNP Object 12 operation is consistent with the preferred interoperable control commands for Binary Outputs recommendations of the DNP3 Specification Volume 1 *DNP3 Introduction Version 2.02 15 December 2007* and with newer SEL products. When setting DNPBOOP = LEGACY, DNP Object 12 operation is consistent with earlier versions of SEL-2431 firmware and with older SEL products. Set DNPBOOP to LEGACY when your existing SCADA system is configured for SEL-2431 firmware prior to R110. Set DNPBOOP to DEFAULT for new installations, as this yields behavior consistent with other new SEL products and DNP3 interoperability guidelines. Refer to *Table D.12* for the details of binary output operation and the differences relative to the two DNPBOOP configurations.

Time Synchronization

The accuracy of DNP3 time synchronization is insufficient for most control and oscillography needs. DNP3 time synchronization provides backup time synchronization in the event the device loses primary synchronization through the IRIG-B input. You can enable time synchronization with the TIMERQ setting and then use Object 50, Variation 1, and Object 52, Variation 2, to set the time via the DNP3 master.

By default, the SEL-2431 accepts and ignores time set requests (TIMERQ*n* = I for “ignore”). (This mode allows the SEL-2431 to use a high accuracy, IRIG time source, but still interoperate with DNP3 masters that send time-synchronization messages.) It can be set to request time synchronization periodically by setting the TIMERQ setting to the desired period. It can also be set to not request, but accept time synchronization (TIMERQ*n* = M for “master”).

No Modem Support

The SEL-2431 DNP implementation does not include modem support for serial ports.

Fiber-Optic Ring Support

The SEL-2431 supports DNP over fiber-optic ring, where two or more slave devices are connected to the master device TX and RX fiber-optic connectors (see *Figure D.3*). To enable this feature, set DNPECHO := Y in the port settings. The SEL-2431 will then retransmit any received packets, even packets that are addressed to it. To avoid endless traffic, the master must not be configured to echo packets.

When DNPECHO := N, the SEL-2431 will perform standard DNP communications by discarding all received data after it has been processed.

NOTE: The ST fiber-optic communications cards can be configured to retransmit IRIG-B time codes (see *IRIG-B* on page 9.5).

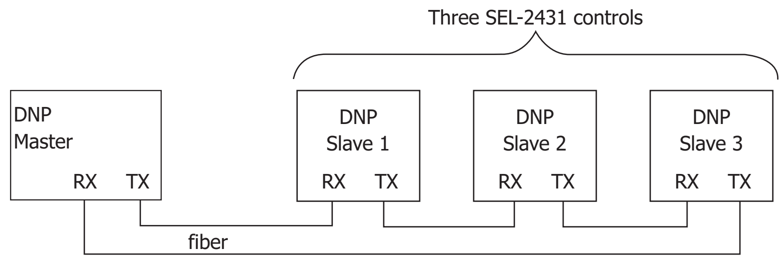

Figure D.3 Fiber-Optic Ring Connection Example

EIA-485 and Fiber-Optic Ring Networks

Many communications systems are a combination of EIA-485 and fiber-optic rings. An example of three fiber-optic rings connected to an 4-Wire EIA-485 network by EIA-485 to fiber-optic transceivers is shown below in *Figure D.4*.

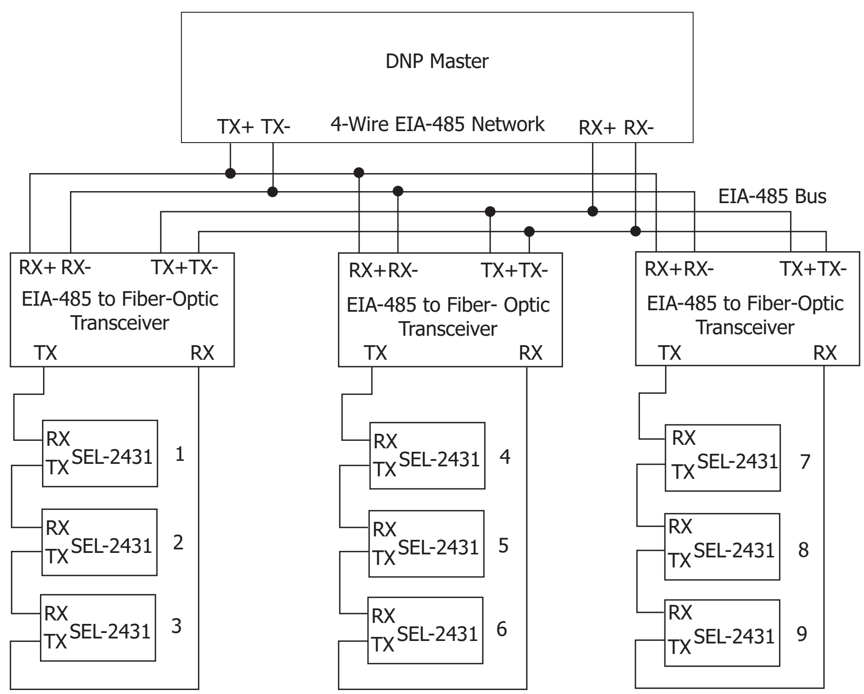

Figure D.4 Example 4-Wire EIA-485 and Fiber-Optic Ring Network

For the communications system topology shown in *Figure D.4*, the design goal is to lessen the traffic on the EIA-485 bus to minimize data collisions at the DNP master. The SEL-2431 includes logic to filter out unwanted echoed messages on the fiber-optic ring.

If the SEL-2431 is the first device on a fiber-optic ring, set port setting DNPECHO := LOOP1ST. The first SEL-2431 in the loop (ring) will only send responses and will only echo messages received from the master.

If the SEL-2431 is the last device on a fiber-optic ring, set port setting DNPECHO := LOOPLAST. The last SEL-2431 in the loop will only send responses and will only echo messages received from devices other than the master.

If the SEL-2431 is neither the first nor the last device in a fiber-optic ring, set port setting DNPECHO := Y, so that all echoed messages received are also transmitted to the next device in the loop.

Filtering echoed messages in the first and last device in a fiber-optic loop decreases the amount of traffic that gets back to the EIA-485 network at the master, thus helping to avoid data collisions.

You may also use the port settings MINDLY and MAXDLY to help prevent data collisions (see *Collision Avoidance* on page D.7). Further, you may wish to add a fixed delay to the data transmission from devices in each respective loop. Use port setting PREDLY for this purpose (see *Transmission Control* on page D.7).

Compatible EIA-485-to-fiber-optic transceivers include the B&B Electronics FOSTCDR-INV (which SEL has tested).

DNP3 Settings

The DNP3 port configuration settings available on the SEL-2431 are shown in *Table D.7*. You can enable DNP3 on Ethernet Port E (if equipped) and on any of the serial Ports 1 or 2 (if equipped), up to a maximum of three concurrent DNP3 sessions. Each session defines the characteristics of the connected DNP3 Master, to which you assign one of the two available custom maps.

Table D.7 Port DNP3 Protocol Settings (Sheet 1 of 3)

Name	Description	Range	Default
DNPADR	Device DNP3 address	0–65519	0
REPADR	DNP3 address of the Master to send messages to	0–65519	1
DNPECHO[a]	Enable the Echoing of the Received Messages	Y, LOOP1ST, LOOPLAST, N	N
Serial Port Settings			
DNPMAP	DNP3 Session Custom Map	1–2	1
DVARAI	Analog Input Default Variation	0–6	4
ECLASSB	Class for binary event data, 0 disables	0–3	1
ECLASSC	Class for counter event data, 0 disables	0–3	0
ECLASSA	Class for analog event data, 0 disables	0–3	2
DECPLA	Decimal places scaling for Current data	0–3	1
DECPLV	Decimal places scaling for Voltage data	0–3	1
DECPLM	Decimal places scaling for Miscellaneous data	0–3	1
ANADBA	Analog reporting deadband for current; hidden if ECLASSA set to 0	0–32767	100
ANADBV	Analog reporting deadband for voltages; hidden if ECLASSA set to 0	0–32767	100
ANADBM	Analog reporting deadband for miscellaneous analogs; hidden if ECLASSA and ECLASSC set to 0	0–32767	100
TIMERQ	Time-set request interval, minutes (M = Disables time sync requests, but still accepts and applies time syncs from Master; I = Ignores (does not apply) time syncs from Master)	I, M, 1–32767	I

Table D.7 Port DNP3 Protocol Settings (Sheet 2 of 3)

Name	Description	Range	Default
STIMEO	Select/operate time-out, seconds	0.0–30.0	1.0
DRETRY	Data link retries	0–15	0
DTIMEO	Data link time-out, seconds; hidden if DRETRY set to 0	0.0–5.0	1
ETIMEO	Event message confirm time-out, seconds	1–50	5
UNSOL	Enable unsolicited reporting; hidden and set to N if ECLASSB1, ECLASSC1, and ECLASSA1 set to 0	Y, N	N
PUNSOL	Enable unsolicited reporting at power up; hidden and set to N if UNSOL set to N	Y, N	N
NUMEVE[b]	Number of events to transmit on	1–200	10
AGEEVE[b]	Oldest event to transmit on, seconds	0.0–99999.0	2.0
URETRY[b]	Unsolicited messages maximum retry attempts at ETIMEO interval	2–10	3
UTIMEO[b]	Unsolicited messages offline time-out, seconds	1–5000	60
MINDLY	Minimum delay from DCD to TX, seconds	0.00–1.00	0.05
MAXDLY	Maximum delay from DCD to TX, seconds	0.00–1.00	0.10
PREDLY	Settle time from RTS on to TX; Off disables PSTDLY	OFF, 0.00–30.00	0.00
PSTDLY	Settle time from TX to RTS off; hidden if PREDLY set to Off	0.00–30.00	0.00
Ethernet Session 1 Settings			
DNPIP1	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR1	Transport protocol	UDP, TCP	TCP
DNPUDP1	UDP response port	REQ, 1–65534	20000
REPADR1	DNP3 address of the Master to send messages to	0–65519	1
DNPMAP1	DNP3 Session Custom Map	1–2	1
DVARAI1	Analog Input Default Variation	1–6	4
ECLASSB1	Class for binary event data, 0 disables	0–3	1
ECLASSC1	Class for counter event data, 0 disables	0–3	0
ECLASSA1	Class for analog event data, 0 disables	0–3	2
DECPLA1	Decimal places scaling for Current data	0–3	1
DECPLV1	Decimal places scaling for Voltage data	0–3	1
DECPLM1	Decimal places scaling for Miscellaneous data	0–3	1
ANADBA1	Analog reporting deadband for current; hidden if ECLASSA1 set to 0	0–32767	100
ANADBV1	Analog reporting deadband for voltages; hidden if ECLASSA1 set to 0	0–32767	100
ANADBM1	Analog reporting deadband for miscellaneous analogs; hidden if ECLASSA and ECLASSC set to 0	0–32767	100
TIMERQ1	Time-set request interval, minutes (M = Disables time sync requests, but still accepts and applies time syncs from Master; I = Ignores (does not apply) time syncs from Master)	I, M, 1–32767	I
STIMEO1	Select/operate time-out, seconds	0.0–30.0	1.0
DNPINA1	Send Data Link Heartbeat, seconds; hidden if DNPTR1 set to UDP	0.0–7200	120
ETIMEO1	Event message confirm time-out, seconds	1–50	5
UNSOL1	Enable unsolicited reporting; hidden and set to N if ECLASSB1, ECLASSC1, and ECLASSA1 set to 0	Y, N	N
PUNSOL1[b]	Enable unsolicited reporting at power up; hidden and set to N if UNSOL1 set to N	Y, N	N
NUMEVE1[b]	Number of events to transmit on	1–200	10
AGEEVE1[b]	Oldest event to transmit on, seconds	0.0–99999.0	2.0

Table D.7 Port DNP3 Protocol Settings (Sheet 3 of 3)

Name	Description	Range	Default
URETRY1[b]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO1[b]	Unsolicited messages offline time-out, seconds	1–5000	60
Ethernet Session 2 Settings			
DNPIP2	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR2	Transport protocol	UDP, TCP	TCP
. . .			
URETRY2[b]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO2[b]	Unsolicited messages offline time-out, seconds	1–5000	60
Ethernet Session 3 Settings			
DNPIP3	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR3	Transport protocol	UDP, TCP	TCP
. . .			
URETRY3[b]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO3[b]	Unsolicited messages offline time-out, seconds	1–5000	60
Ethernet Session 4 Settings			
DNPIP4	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR4	Transport protocol	UDP, TCP	TCP
. . .			
URETRY4[b]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO4[b]	Unsolicited messages offline time-out, seconds	1–5000	60
Ethernet Session 5 Settings			
DNPIP5	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR5	Transport protocol	UDP, TCP	TCP
. . .			
URETRY5[b]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO5[b]	Unsolicited messages offline time-out, seconds	1–5000	60
Ethernet Session 6 Settings[c]			
DNPIP6	IP address (zzz.yyy.xxx.www)	15 characters	“”
DNPTR6	Transport protocol	UDP, TCP	TCP
. . .			
URETRY6[b]	Unsolicited messages maximum retry attempts	2–10	3
UTIMEO6[b]	Unsolicited messages offline time-out, seconds	1–5000	60

[a] Available only on fiber-optic serial ports.
[b] Hidden if UNSOL set to N.
[c] The number of sessions is the combination of serial and Ethernet DNP sessions. If there is a serial session, the maximum number of Ethernet sessions is five.

Anonymous DNP Master Connection

The SEL-2431 allows you to configure one DNP3 session to accept an anonymous DNP3 master connection through use of the Port E setting DNPIP*n* = 0.0.0.0. For this session, the SEL-2431 accepts a DNP3 connection request from any DNP3 master whose address is not configured as DNPIP*n* in another session.

Be advised that once an anonymously connected DNP3 master disconnects from the session in which DNPIP*n* = 0.0.0.0, that session is again available and any DNP3 master that requests a connection (whose address is not explicitly set as a DNPIP*n* setting elsewhere) will connect to the anonymous session.

DNP3 events and class polls are associated with the session, not with a particular DNP3 master. If a DNP3 master disconnects from the anonymous session and a different DNP3 master then connects, the SEL-2431 will not re-send previously acknowledged DNP3 events.

If multiple sessions are required, the anonymous DNP session must be the highest session number.

Configurable Data Mapping

One of the most powerful features of the SEL-2431 implementation is the ability to remap DNP3 data and, for analog values, specify per-point scaling and deadbands. Remapping is the process of selecting data from the reference map and organizing it into a data subset optimized for your application. The SEL-2431 uses object and point labels, rather than point indices, to streamline the remapping process. This enables you to quickly create a custom map without having to search for each point index in a large reference map.

You may use any of the two available DNP3 maps simultaneously with as many as two unique DNP3 masters. Each map is initially populated with default data points, as described in *Default Data Map* on page D.29. You may remap the points in a default map to create a custom map with as many as:

➤ 100 Binary Inputs
➤ 32 Binary Outputs
➤ 100 Analog Inputs
➤ 32 Analog Outputs
➤ 32 Counters

You can use the **SHOW DNP *x* <Enter>** command to view the DNP3 data map settings, where *x* is the DNP3 map number from 1 to 2. See *Figure D.5* for an example display of Map 1, with factory-default settings.

```
=>>SHO DNP 1 <Enter>
DNP Map 1

Binary Input Map
0: ENABLED
1: ALARM
2: VRIPROG
3: INHIBSV
4: REVERSE
5: TAPNEUT
6: VMAXLMT
7: HBND
8: IN_BND
9: LBND
10: VMINLMT
11: REMOTE
12: LOCAL
13: AUTO
14: MANUAL
15: ENFWD
16: ENREV
17: MAXTAP
18: MINTAP
19: TAP_OFF
20: NO_NEUT
21: BLOCKSV
22: RBKBLSV
23: SALARM
24: HALARM
25: OP_LFWD
26: OP_LREV
27: OP_IREV
28: OP_BDIR
29: OP_COGN
30: COGNREV
31: RBKFH
32: RBKFL
33: RBKRH
34: RBKRL
35: NORAIS
36: NOLOWR
37: EFCNBD1
38: EFCNBD2
39: EFCNBD3
40: ERCNBD1
41: ERCNBD2
42: ERCNBD3
43: DVLOW
44: OP_FLEX
Binary Output Map
0: RB01
1: RB02
2: RB03
3: RB04
4: RB05
5: RB06
6: RB07
7: RB08
8: RB09
9: RB10
10: RB11
11: RB12
12: RB13
13: RB14
14: RB15
15: RB16
Analog Input Map
0: PRCNTVR
1: ACTGRP
2: IL
3: VS
4: VSSEC
5: VL
6: VLSEC
7: VCMP
8: VCMPSEC
9: PL
```

Figure D.5 Sample Response to SHO DNP Command

```
10: QL
11: SL
12: PF
13: PFLD
14: PFQ
15: TAP_POS
16: FREQ
17: MWHOUT
18: MWHIN
19: MVARHOUT

20: MVARHIN
21: ILFDEM
22: PFDEM
23: QFODEM
24: QFIDEM
25: SFDEM
26: ILRDEM
27: PRDEM
28: QRODEM
29: QRIDEM

30: SRDEM
31: ILTHD
32: VLTHD
33: OPCNTT

Analog Output MapSEL-2431 Voltage Regulator Control

Counter Map
0: OPCNTT

=>>
```

Figure D.5 Sample Response to SHO DNP Command (Continued)

You can use the command **SET DNP *x***, where *x* is the map number, to edit or create custom DNP3 data maps. You can also use QuickSet, which is recommended for this purpose.

You can customize the DNP3 analog input map with per-point scaling and dead-band settings. Per-point customization is not required, but class scaling (DECPLA, DECPLV, and DECPLM) and dead-band (ANADBA, ANADBV, and ANADBM) settings are applied to indices that do not have per-point entries. Unlike per-point scaling, class-level scaling is specified by an integer in the range 0–3 (inclusive), which indicates the number of decimal place shifts. In other words, you should select 0 to multiply by 1, 1 for 10, 2 for 100, or 3 for 1000.

NOTE: Per-point scaling will override the default scaling factors. They are applied in conjunction with the default.

Scaling factors allow you to overcome the limitations imposed by the integer nature of Objects 30 and 32. For example, the SEL-2431 truncates a value of 11.4 A to 11 A by default. You may use scaling to include decimal point values by multiplying by a power of 10. If you use 10 as a scaling factor, 11.4 A will be transmitted as 114. You must divide the value by 10 in the master to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. For example, if you have a value that can reach 157834, you cannot send it using DNP3 16-bit analog object variations. You could use a scaling factor of 0.1 so that the maximum value reported is 15783. You can then multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is rounded off in the scaling process, but you can transmit the scaled value using standard DNP3 Objects 30 and 32.

If it is important to maintain tight data coherency (that is, all data read of a certain type was sampled or calculated at the same time), then you should group those data together within your custom map. For example, if you want all the voltages to be coherent, you should group points VL and VS together in the custom map. If points are not grouped together, they might not come from the same data sample.

Analog Input Example

The following example shows the details of analog input map creation using the serial port commands. The binary input, binary output, and counter map entry details are not shown in the example. To enter custom DNP map points, use the following format:

- ➤ for BI, AO, and Counters, specify point label
- ➤ for BO, specify point label [:paired point label]
- ➤ for AI, specify point label [:][scale factor][:][deadband]

  To use default sealing, use double colons "::" followed by deadband.

The serial port **SET D 2** and **MAP 1** commands are used in these examples. Alternately, you can use QuickSet to simplify custom data map creation.

Consider a case where you want to set the AI points in a map as shown in *Table D.8*. The setting example that follows assumes the analog scaling and deadband values shown for serial port 1 in *Figure D.6*.

```
=>SHO P 1 <Enter>
Port 1

Protocol Selection
PROTO    := DNP

Communications Settings
SPEED    := 9600         T_OUT    := 15

DNP Protocol Settings
DNPADR   := 0            REPADR   := 1            DNPECHO  := N
DNPMAP   := 2            DVARAI   := 4            ECLASSB  := 1
ECLASSC  := 0            ECLASSA  := 2            DECPLA   := 1
DECPLV   := 3            DECPLM   := 2            ANADBA   := 50
ANADBV   := 1000         ANADBM   := 100          TIMERQ   := I
STIMEO   := 1.0          DRETRY   := 0            ETIMEO   := 5
UNSOL    := N

=>
```

Figure D.6 Sample SHO P 1 Command With Example Settings

NOTE: By default, angles are scaled to 1/100 of a degree. This is not controlled by a setting, so scaling of angles must be done on a per-point basis.

Table D.8 Sample Custom DNP3 AI Map (Sheet 1 of 2)

Name	Object	Custom Map Index	Description
IL[a], ILA[b]	30	1, 2	IL magnitude and angle
VL[c], VLA[b]	30	3, 4	VL primary magnitude and angle
VS[c], VSA[b]	30	5, 6	VS primary magnitude and angle
VCMPSEC[d]	30	7	V compensated secondary magnitude
PL[e]	30	8	Real power in kW
QL[e]	30	9	Reactive power in kVAr

Table D.8 Sample Custom DNP3 AI Map (Sheet 2 of 2)

Name	Object	Custom Map Index	Description
TAP_POS[f]	30	10	Tap position
ACTGRP[g]	30	11	Active settings group

[a] Assume the largest expected current is 300 A, scale the analog value by the factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of more than 5 A.

[b] Angles are scaled to 1/100 of a degree. Report change events on a change of more than 2 degrees.

[c] For a nominal voltage of 19.9 kV, scale the analog value by a factor of 1000 to provide a resolution of 1 V and a maximum value of 32.767 kV. Report change events on a change of more than 1 kV.

[d] For a nominal voltage of 125 V, scale the analog value by a factor of 100 to provide a resolution of 0.01 V and a maximum value of 327.67 V. Report change events on a change of more than 3 V.

[e] For a maximum load of 7000 kW (or 7000 kVAr), scale the power by a factor of 4 to provide a resolution of 0.25 kW, and a maximum value of 8191.75 kW. Report change events on a change of more than 100 kW.

[f] TAP_POS is an integer and does not need to be scaled. Report change events on a change of more than 8 tap positions.

[g] ACTGRP is an integer and does not need to be scaled. Do not use for change event reporting.

To set these points as part of custom map 2, you can use the command **SET DNP 2 <Enter>** command as shown in *Figure D.7*.

```
=>>SET DNP 2 <Enter>
DNP Map 2

Binary Input Map

0: ENABLED
? <Enter>
1: ALARM
? <Enter>
2:
? <Enter>


Binary Output Map

0: RB01
? <Enter>
1: BO_F_TD1
? <Enter>
2:
? <Enter>

Analog Input Map

0: PRCNTVR
? DELETE 50 <Enter>
0:
? IL <Enter>
1:
? ILA::200 <Enter>
2:
? VL <Enter>
3:
? VLA::200 <Enter>

4:
? VS <Enter>
5:
? VSA::200 <Enter>
6:
? VCMPSEC:100:300 <Enter>
7:
? PL:4:400 <Enter>
8:
? QL:4:400 <Enter>
9:
? TAP_POS:1:8 <Enter>
10:
```

Figure D.7 Sample Custom DNP3 AI Map Settings

```
? ACTGRP <Enter>
11:
? END <Enter>

DNP Map 2

Binary Input Map
0: ENABLED
1: ALARM

Binary Output Map
0: RB01
1: BO_F_TD1

Analog Input Map
0: IL
1: ILA::200
2: VL
3: VLA::200
4: VS
5: VSA::200
6: VCMPSEC::300
7: PL:4:400
8: QL:4:400
9: TAP_POS:1:8
10: ACTGRP

Analog Output Map

Counter Map
0: OPCNTT

Save Changes (Y,N)? Y <Enter>
Settings Saved
```

Figure D.7 Sample Custom DNP3 AI Map Settings (Continued)

The **MAP *n*** command may be used to view the active map for a given serial port. *Figure D.8* shows the **MAP** command for port 1, with the analog settings as entered in *Figure D.5*. The scale factor and dead-band values reported are either representing the port setting class scaling values as shown in *Figure D.6*, or the per-point override values, entered with colon ":" symbols in *Figure D.7*.

```
=>MAP 1 <Enter>

SEL-2431                              Date: 05/10/2007   Time: 19:15:21
Voltage Reg

Map                 2
Device DNP Address  0
Master DNP Address  1

Binary Inputs
--------------------------------------------------------------------------------
  INDEX  POINT LABEL  EVENT CLASS  SER TIMESTAMP
  0      ENABLED      1
  1      ALARM        1            Yes

Binary Outputs
--------------------------------------------------------------------------------
  INDEX  POINT LABEL
  0      RB01
  1      BO_F_TD1

Counters
--------------------------------------------------------------------------------
  INDEX  POINT LABEL  EVENT CLASS  DEADBAND
  0      OPCNTT       0            1

Analog Inputs
--------------------------------------------------------------------------------
  INDEX  POINT LABEL  EVENT CLASS  SCALE FACTOR  DEADBAND
  0      IL           2                 10.0000  50
  1      ILA          2                  1.0000  200
  2      VL           2               1000.0000  1000
  3      VLA          2                  1.0000  200
  4      VS           2               1000.0000  1000
  5      VSA          2                  1.0000  200
  6      VCMPSEC      2                100.0000  300
  7      PL           2                  4.0000  400
  8      QL           2                  4.0000  400
  9      TAP_POS      2                  1.0000  8
  10     ACTGRP       2                  1.0000  100

Analog Outputs
--------------------------------------------------------------------------------


=>
```

Figure D.8 Sample Response to MAP 1 Command

You can also use QuickSet to enter the above AI map settings as shown in the screen capture in *Figure D.9*. You can enter scaling and dead-band settings in the dialog box accessed by double-clicking the respective row in the “Mapped Elements” pane on the right side of *Figure D.9*.

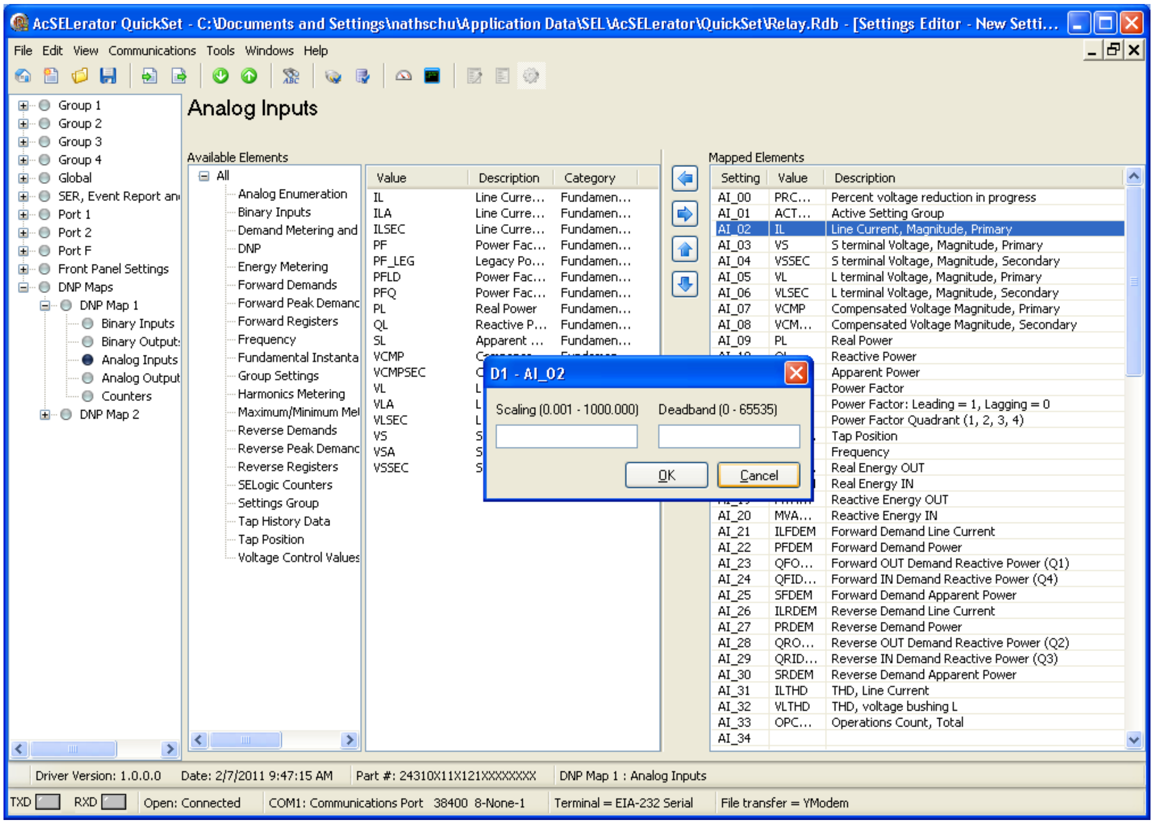

Figure D.9 Analog Input Map Entry in QuickSet

Binary Outputs and Inputs

You may populate the custom Binary Output map with any of the 16 remote bits (RB01–RB16), or settings adjustment binary outputs, as shown in *Table D.10*.

You can define remote bit pairs in BO maps by including a colon (:) between the bit labels.

The settings adjustment binary outputs provide means for a DNP Master to increment or decrement certain settings in the active settings group. The DNP Binary Output name is the same as the affected group-setting name, with a prefix of "BO_". The DNP setting increment is listed in *Table D.10* for each setting.

For example, BO_F_TD1 affects Group setting F_TD1 (Forward Time Delay 1 for First Tap). If BO_F_TD1 is included in the binary output map, each time the DNP master executes an increment on the point (as shown in the bottom row of *Table D.12*), the active Group setting F_TD1 is increased by 5 s.

The SEL-2431 will complete the settings change in the normal fashion, with a brief disabled period. If several changes are requested in a row, the control may disable and enable several times. Avoid continual use of the DNP settings adjustment, because the SEL-2431 may continually perform settings changes, and the voltage regulation algorithms will be effectively disabled.

Setting adjustment binary outputs cannot be used in pairs.

The binary input (BI) maps are modified in a similar manner, but pairs are not allowed.

DNP3 Documentation

Object List

Table D.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-2431. The list of supported objects conforms to the format laid out in the DNP specifications and includes both supported and unsupported objects. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table D.9 SEL-2431 DNP Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
0	211	Device Attributes—User-specific sets of attributes	1	0	129	0,17
0	212	Device Attributes—Master data set prototypes	1	0	129	0,17
0	213	Device Attributes—Outstation data set prototypes	1	0	129	0,17
0	214	Device Attributes—Master data sets	1	0	129	0,17
0	215	Device Attributes—Outstation data sets	1	0	129	0,17
0	216	Device Attributes—Max binary outputs per request	1	0	129	0,17
0	219	Device Attributes—Support for analog output events	1	0	129	0,17
0	220	Device Attributes—Max analog output index	1	0	129	0,17
0	221	Device Attributes—Number of analog outputs	1	0	129	0,17
0	222	Device Attributes—Support for binary output events	1	0	129	0,17
0	223	Device Attributes—Max binary output index	1	0	129	0,17
0	224	Device Attributes—Number of binary outputs	1	0	129	0,17
0	225	Device Attributes—Support for frozen counter events	1	0	129	0,17
0	226	Device Attributes—Support for frozen counters	1	0	129	0,17
0	227	Device Attributes—Support for counter events	1	0	129	0,17
0	228	Device Attributes—Max counter index	1	0	129	0,17
0	229	Device Attributes—Number of counters	1	0	129	0,17
0	230	Device Attributes—Support for frozen analog inputs	1	0	129	0,17
0	231	Device Attributes—Support for analog input events	1	0	129	0,17
0	232	Device Attributes—Max analog input index	1	0	129	0,17
0	233	Device Attributes—Number of analog inputs	1	0	129	0,17
0	234	Device Attributes—Support for double-bit events	1	0	129	0,17
0	235	Device Attributes—Max double-bit binary index	1	0	129	0,17
0	236	Device Attributes—Number of double-bit binaries	1	0	129	0,17
0	237	Device Attributes—Support for binary input events	1	0	129	0,17
0	238	Device Attributes—Max binary input index	1	0	129	0,17
0	239	Device Attributes—Number of binary inputs	1	0	129	0,17
0	240	Device Attributes—Max transmit fragment size	1	0	129	0,17
0	241	Device Attributes—Max receive fragment size	1	0	129	0,17
0	242	Device Attributes—Software version	1	0	129	0,17

Table D.9 SEL-2431 DNP Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
0	243	Device Attributes—Hardware version	1	0	129	0,17
0	245	Device Attributes—User-assigned location name	1	0	129	0,17
0	246	Device Attributes—User-assigned ID code/number	1	0	129	0,17
0	247	Device Attributes—User-assigned device name	1	0	129	0,17
0	248	Device Attributes—Serial number	1	0	129	0,17
0	249	Device Attributes—DNP subset and conformance	1	0	129	0,17
0	250	Device Attributes—Product name and model	1	0	129	0,17
0	252	Device Attributes—Manufacturer's name (“SEL”)	1	0	129	0,17
0	254	Device Attributes—All attributes	1	0,6	129	0,17
0	255	Device Attributes—List of attribute variations	1	0,6	129	0,17
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
1	1	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary Input Change—All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	2	16-Bit Binary Counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				

Table D.9 SEL-2431 DNP Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
21	0	Frozen Counter—All Variations	1		129	
21	1	32-Bit Frozen Counter	1		129	
21	2	16-Bit Frozen Counter	1		129	
21	3	32-Bit Frozen Delta Counter	1		129	
21	4	16-Bit Frozen Delta Counter	1		129	
21	5	32-Bit Frozen Counter With Time of Freeze	1		129	
21	6	16-Bit Frozen Counter With Time of Freeze	1		129	
21	7	32-Bit Frozen Delta Counter With Time of Freeze	1		129	
21	8	16-Bit Frozen Delta Counter With Time of Freeze	1		129	
21	9	32-Bit Frozen Counter Without Flag	1		129	
21	10	16-Bit Frozen Counter Without Flag	1		129	
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Delta Counter Change Event With Time				
23	8	16-Bit Delta Counter Change Event With Time				
30	0	Analog Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28

Table D.9 SEL-2431 DNP Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
30	5	Short Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6	Long Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
31	7	Short Floating Point Frozen Analog Input				
31	8	Long Floating Point Frozen Analog Input				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	5	Short Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32	6	Long Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32	7	Short Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	8	Long Floating Point Analog Change Event With Time	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
33	5	Short Floating Point Frozen Analog Event				
33	6	Long Floating Point Frozen Analog Event				
33	7	Short Floating Point Frozen Analog Event With Time				
33	8	Long Floating Point Frozen Analog Event With Time				
34	0	Analog Deadband—All Variations				
34	1[e]	16-Bit Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2	32-Bit Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Floating Point Analog Input Reporting Deadband Object	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog Output Status—All Variations	1	0, 1, 6, 7, 8	129	
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28

Table D.9 SEL-2431 DNP Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
40	3	Short Floating Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	4	Long Floating Point Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2[e]	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	3	Short Floating Point Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date—All Variations				
50	1	Time and Date	1, 2	7, 8 index=0	129	07, quantity=1
50	2	Time and Date With Interval				
50	3	Time and Date Last Recorded	2	7, 8		
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO			129	07, quantity=1
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine			129	7, quantity=1
60	0	All Classes of Data	1, 20, 21	6, 7, 8		
60	1	Class 0 Data	1, 20, 21	6, 7, 8		
60	2	Class 1 Data	1	6, 7, 8		
60	3	Class 2 Data	1, 20, 21	6, 7, 8		
60	4	Class 3 Data	1, 20, 21	6, 7, 8		
70	1	File Identifier				
70	2	Authentication Object				
70	3	File Command Object				
70	4	File Command Status Object				
70	5	File Transport Object				
70	6	File Transport Status Object				
70	7	File Descriptor Object				
80	1	Internal Indications	2	0, 1 index=4,7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				

Table D.9 SEL-2431 DNP Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
100	3	Extended Floating Point				
101	1	Small Packed Binary-Coded Decimal				
101	2	Medium Packed Binary-Coded Decimal				
101	3	Large Packed Binary-Coded Decimal				
110	all	Octet String				
111	all	Octet String Event				
112	All	Virtual Terminal Output Block	2	6	129	
113	All	Virtual Terminal Event Data	1	6	129, 130	17, 28
N/A		No object required for the following function codes: 13 cold start, 14 warm start, 23 delay measurement	13, 14, 23			

[a] Supported in requests from master.
[b] May generate in response to master.
[c] Decimal.
[d] Hexadecimal.
[e] Default variation.

Device Profile

The DNP3 Device Profile document, available on the supplied CD or as a download from the SEL website, contains standard device profile information for the SEL-2431. This information is also available in XML format. Please refer to this document for complete information on DNP3 protocol support in the SEL-2431.

Reference Data Map

Table D.10 shows the SEL-2431 reference data map. The reference map shows the data available to a DNP3 master. You can use the default map or the custom DNP3 mapping functions of the SEL-2431 to retrieve only the points required by your application.

NOTE: Dead-band changes via Object 34 are not stored in nonvolatile memory. Make sure to reissue the Object 34 deadbands after a warm (**STA C**) or cold start (power cycle).

The SEL-2431 scales analog values by the indicated settings or fixed scaling indicated in the description. Analog deadbands for event reporting use the indicated settings, or ANADBM if you have not specified a setting.

Table D.10 DNP3 Reference Data Map (Sheet 1 of 3)

Object	Labels	Description
Binary Inputs		
01, 02	STSET	Device Settings Changed
	ENABLED–OP_FLEX	Device Word Elements (see *Table E.1*)
	0	Logical 0
	1	Logical 1
Binary Outputs		
10, 12	RB*xx*	Remote Bits (*xx* = 01–16)

Table D.10 DNP3 Reference Data Map (Sheet 2 of 3)

Object	Labels	Description
Settings Adjustment Binary Outputs[a]		
10, 12	BO_F_CNBND	Forward center band settings adjust (0.1 V steps)
	BO_F_BNBWD	Forward bandwidth settings adjust (0.1 V steps)
	BO_F_TD1	Forward time delay adjust (5 sec steps)
	BO_R_CNBND	Reverse center band settings adjust (0.1 V steps)
	BO_R_BNBWD	Reverse bandwidth settings adjust (0.1 V steps)
	BO_R_TD1	Reverse time delay adjust (5 sec steps)
	BO_VLDCFWR	Forward Resistive LDC setting adjust (1 V steps)
	BO_VLDCFWX	Forward Reactive LDC setting adjust (1 V steps)
	BO_VLDCRVR	Reverse Resistive LDC setting adjust (1 V steps)
	BO_VLDCRVX	Reverse Reactive LDC setting adjust (1 V steps)
	BO_VREDFP1	Voltage Reduction Forward pickup 1 adjust (0.5% steps)
	BO_VREDFP2	Voltage Reduction Forward pickup 2 adjust (0.5% steps)
	BO_VREDFP3	Voltage Reduction Forward pickup 3 adjust (0.5% steps)
	BO_VREDRP1	Voltage Reduction Reverse pickup 1 adjust (0.5% steps)
	BO_VREDRP2	Voltage Reduction Reverse pickup 2 adjust (0.5% steps)
	BO_VREDRP3	Voltage Reduction Reverse pickup 3 adjust (0.5% steps)
Counters		
20, 22	SC*xx*	SELOGIC Counter Values (*xx* = 01–08)
	OPCNTT	Total Operations Counter
Analog Inputs		
30, 32, 34	IL–OPCNTT	Analog Quantities from *Table F.1* with an "x" in the DNP column
	0	numeric 0
	1	numeric 1
Analog Outputs		
40, 41	F_BNDWD	Forward band width
	F_CNBND	Forward center band
	F_TD1	Forward time delay 1 for first tap
	NOOP	Analog output writes to points with this label mapped shall report no error and modify no internal values
	R_BNDWD	Reverse band width
	R_CNBND	Reverse center band
	R_TD1	Reverse time delay 1 for first tap
	VLDCFWR	Forward resistive LDC voltage
	VLDCFWX	Forward reactive LDC voltage
	VLDCRVR	Reverse resistive LDC voltage
	VLDCRVX	Reverse reactive LDC voltage
	VMAX	Voltage control, maximum volts
	VMIN	Voltage control, minimum volts
	VREDFP1	Forward VR 1 Percent
	VREDFP2	Forward VR 2 Percent

Table D.10 DNP3 Reference Data Map (Sheet 3 of 3)

Object	Labels	Description
	VREDFP3	Forward VR 3 Percent
	VREDRP1	Reverse VR 1 Percent
	VREDRP2	Reverse VR 2 Percent
	VREDRP3	Reverse VR 3 Percent

[a] See *Binary Outputs and Inputs*.

Default Data Map

The default data map is an automatically generated subset of the reference map. *Table D.11* shows the SEL-2431 default data map. If the default maps are not appropriate, you can also use the custom DNP mapping commands **SET D** and **SHOW D** to create the map required for your application.

Table D.11 DNP3 Default Data Map (Sheet 1 of 3)

Object	Default Index	Point Label
01, 02	0	ENABLED
	1	ALARM
	2	VRIPROG
	3	INHIBSV
	4	REVERSE
	5	TAPNEUT
	6	VMAXLMT
	7	HBND
	8	IN_BND
	9	LBND
	10	VMINLMT
	11	REMOTE
	12	LOCAL
	13	AUTO
	14	MANUAL
	15	ENFWD
	16	ENREV
	17	MAXTAP
	18	MINTAP
	19	TAP_OFF
	20	NO_NEUT
	21	BLOCKSV
	22	RBKBLSV
	23	SALARM
	24	HALARM
	25	OP_LFWD
	26	OP_LREV

Table D.11 DNP3 Default Data Map (Sheet 2 of 3)

Object	Default Index	Point Label
	27	OP_IREV
	28	OP_BDIR
	29	OP_COGN
	30	COGNREV
	31	RBKFH
	32	RBKFL
	33	RBKRH
	34	RBKRL
	35	NORAIS
	36	NOLOWR
	37	EFCNBD1
	38	EFCNBD2
	39	EFCNBD3
	40	ERCNBD1
	41	ERCNBD2
	42	ERCNBD3
	43	DVLOW
	44	OP_FLEX
10, 12	0–15	RB01–16 Remote Bits
20, 22	0	OPCNTT (Total Operation Counter)
30, 32, 34	0	PRCNTVR
	1	ACTGRP
	2	IL
	3	VS
	4	VSSEC
	5	VL
	6	VLSEC
	7	VCMP
	8	VCMPSEC
	9	PL
	10	QL
	11	SL
	12	PF
	13	PFLD
	14	PFQ
	15	TAP_POS
	16	FREQ
	17	MWHOUT
	18	MWHIN
	19	MVARHOUT
	20	MVARHIN

Table D.11 DNP3 Default Data Map (Sheet 3 of 3)

Object	Default Index	Point Label
	21	ILFDEM
	22	PFDEM
	23	QFODEM
	24	QFIDEM
	25	SFDEM
	26	ILRDEM
	27	PRDEM
	28	QRODEM
	29	QRIDEM
	30	SRDEM
	31	ILTHD
	32	VLTHD
	33	OPCNTT
40, 41	0–31	NA

Binary Inputs

The SEL-2431 default Binary Input map contains a useful subset of available Device Word bits.

Analog Inputs

NOTE: Dead-band changes via Object 34 are stored in nonvolatile memory. Make sure to reissue the Object 34 deadbands after a warm (HIS C) or cold start (power cycle).

The SEL-2431 default Analog Input map contains a subset of metering and tap-related data.

Binary Outputs

The default binary output data map is populated with the RB01–RB16 point labels.

Control Point Operation

The SEL-2431 can perform special control operations and functions according to the code portion of the Object 12 control relay output block command. The examples in *Table D.12* demonstrate how you may invoke this functionality in both paired, nonpaired (single-point), and setting-mapped controls. Please refer to the proper binary output operations based on the DNPBOOP setting.

Table D.12 Example Object 12 Trip/Close or Code Selection Operation

Control Points	Trip/Close		Code Selection Operation			
	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
DNPBOOP = LEGACY						
RB*nn*[a]	**SET RB*nn***[a, b]	**CLEAR RB*nn***[a, b]	SET RB*nn*[a]	CLEAR RB*nn*[a]	**SET RB*nn***[a, b]	CLEAR RB*nn*[a]
RB*xx*:RB*yy*[c]	PULSE RB*yy*[c]	PULSE RB*xx*[c]	PULSE RB*yy*[c]	PULSE RB*xx*[c]	PULSE RB*yy*[c]	PULSE RB*xx*[c]
BO_R_CNBND	INCREMENT	DECREMENT	INCREMENT	DECREMENT	INCREMENT	DECREMENT
DNPBOOP = DEFAULT						
RB*nn*[a]	**PULSE RB*nn***[a, b]	**PULSE RB*nn***[a, b]	SET RB*nn*[a]	CLEAR RB*nn*[a]	**PULSE RB*nn***[a, b]	CLEAR RB*nn*[a]
RB*xx*:RB*yy*	PULSE RB*yy*[c]	PULSE RB*xx*[c]	PULSE RB*yy*[c]	PULSE RB*xx*[c]	PULSE RB*yy*[c]	PULSE RB*xx*[c]
BO_R_CNBND	INCREMENT	DECREMENT	INCREMENT	DECREMENT	INCREMENT	DECREMENT

[a] nn is the Remote Bit number, from 01 to 16.
[b] Items in bold indicate differences in Binary Output behavior when DNPBOOP changes.
[c] xx and yy are the Remote Bit pair numbers of 01 to 16. For example, a valid Remote Bit pair is RB01:RB02.

You can modify the default Binary output map to accommodate any combination of single-point or paired controls. To define any two Remote Bit points as a paired control for Trip/Close or Code Selection operations, simply specify any two Remote Bits to control as a pair separated by a colon, e.g., RB01:RB02. For single-point controls, supply only one Remote Bit name, e.g., RB04. You may also specify a single-point control in the paired format by submitting the same Remote Bit as both elements in the pair, e.g., RB05:RB05.

NOTE: All pulse operations send a pulse with a duration of one control-processing interval.

Because the SEL-2431 allows only one control bit to be pulsed at a time, ensure that consecutive controls are sent in consecutive messages.

APPENDIX E

Device Word Bits

Device Word bits show the status of functions within the voltage regulator control. The bits are available via communications protocol and the front panel.

Any Device Word bit can be used in SELOGIC control equations (see *Section 6: Logic Functions*) and the Sequential Events Recorder (SER) trigger list settings (see *Section 11: Analyzing Events*).

Use *Table E.1* for an overview of what bits are available and their row number. You can display the bits with either the row number (**TAR *row_number***) or the bit name (**TAR *bit_name***).

Table E.2 provides an alphanumeric listing of the Device Word bits that include a description of each bit.

Table E.1 Device Word Bit Mapping (Sheet 1 of 2)

Row	Device Word Bits[a]							
0	*	ENABLED	ALARM	*	VRIPROG	INHIBSV	REVERSE	TAPNEUT
1	*	VMAXLMT	HBND	IN_BND	LBND	VMINLMT	*	*
2	PB01LED	PB02LED	PB03LED	PB04LED	PB05LED	PB06LED	PB07LED	*
3	REMOTE	LOCAL	AUTO	MANUAL	MRAISE	MLOWER	*	*
4	PB01	PB02	PB03	PB04	PB05	PB06	PB07	*
5	PB01PUL	PB02PUL	PB03PUL	PB04PUL	PB05PUL	PB06PUL	PB07PUL	*
6	LOCALSW	AUTOSW	RAISESW	LOWERSW	*	*	*	*
7	MODEINH	ENFWD	ENREV	INHIBIT	DVLOW	*	RC	LC
8	OPNOCUR	TAPDONE	MAXTAP	MINTAP	TOOHIGH	TOOLOW	XTAP16R	XTAP16L
9	TAP_OFF	NO_NEUT	TAP_DIF	*	*	*	*	*
10	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
11	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
12	LB01	LB02	LB03	LB04	LB05	LB06	LB07	LB08
13	*	*	*	*	*	*	*	*
14	SV01	SV02	SV03	SV04	SV05	SV06	SV07	SV08
15	SV01T	SV02T	SV03T	SV04T	SV05T	SV06T	SV07T	SV08T
16	*	*	*	*	*	*	*	*
17	*	*	*	*	*	*	*	*
18	LT01	LT02	LT03	LT04	LT05	LT06	LT07	LT08
19	*	*	*	*	*	*	*	*
20	SC01QU	SC02QU	SC03QU	SC04QU	SC05QU	SC06QU	SC07QU	SC08QU
21	SC01QD	SC02QD	SC03QD	SC04QD	SC05QD	SC06QD	SC07QD	SC08QD
22	*	*	*	*	*	*	*	*
23	*	*	*	*	*	*	*	*

Table E.1 Device Word Bit Mapping (Sheet 2 of 2)

Row	Device Word Bits[a]							
24	SG1	SG2	SG3	SG4	*	*	*	*
25	*	ER	SPEN	BLOCKSV	RBKBLSV	*	*	*
26	MHOLD	MET_FWD	*	PMTRIG	TREA4	TREA3	TREA2	TREA1
27	TSOK	TIRIG	IRIGOK	PMDOK	FREQ_EN	*	SALARM	HALARM
28	OP_LFWD	OP_LREV	OP_IREV	OP_BDIR	OP_COGN	OP_FLEX	COGNREV	*
29	IN_BNDF	HBNDFWD	LBNDFWD	*	IN_BNDR	HBNDREV	LBNDREV	*
30	VMAXF	VMAXR	*	*	VMINF	VMINR	*	*
31	RBKFH	RBKFWDH	RBKFL	RBKFWDL	RBKRH	RBKREVH	RBKRL	RBKREVL
32	DLYHBF	DLYLBF	DLYHBR	DLYLBR	*	*	*	*
33	TAPHBF	TAPLBF	TAPHBR	TAPLBR	*	*	TAPLWR2	TAPRSE2
34	50L1	50L2	50L3	50L4	50L5	50L6	50L7	*
35	50FLT	50FWD	50REV	*	*	*	*	*
36	FORWARD	NO_TORK	*	*	*	*	*	*
37	VRED1SV	VRED2SV	VRED3SV	VRRSTSV	OVRIDSV	*	*	*
38	RAISESV	LOWERSV	*	*	MANULSV	AUTOSV	REMOTSV	LOCALSV
39	NORAIS	NOLOWR	RSEFAIL	RSELIM	LWRFAIL	LWRLIM	*	*
40	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*
42	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*
45	OP1	OP2	OP3	OP4	*	*	*	*
46	OUT101	OUT102	OUT103	OUT104	RAISE	LOWER	DHR	VTJVOLT
47	TSLOCK	LAMPTST	*	*	*	*	*	*
48	IN101	IN102	*	*	*	*	*	*
49	IN201	IN202	IN203	IN204	*	*	*	OPSWHCN
50	DST	DSTP	LPSEC	LPSECP	TQUAL4	TQUAL3	TQUAL2	TQUAL1
51	EFCNBD1	EFCNBD2	EFCNBD3	*	ERCNBD1	ERCNBD2	ERCNBD3	*

[a] An asterisk (*) denotes "reserved for future use."

Table E.2 Alphabetic List of Device Word Bits (Sheet 1 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
50FLT	Asserts when current IL exceeds the 50FLTP setting	35
50FWD	Asserts when current IL exceeds the 50FWDP setting	35
50L1	Asserts when current IL exceeds the 50L1 setting	34
50L2	Asserts when current IL exceeds the 50L2 setting	34
50L3	Asserts when current IL exceeds the 50L3 setting	34
50L4	Asserts when current IL exceeds the 50L4 setting	34
50L5	Asserts when current IL exceeds the 50L5 setting	34
50L6	Asserts when current IL exceeds the 50L6 setting	34

Table E.2 Alphabetic List of Device Word Bits (Sheet 2 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
50L7	Asserts when current IL exceeds the 50L7 setting	34
50REV	Asserts when current IL exceeds the 50REVP setting	35
ALARM	ON indicates a user-programmable alarm is asserted	0
AUTO	Control Configuration—Auto Position	3
AUTOSV	Place control in AUTO mode (SELOGIC equation)	38
AUTOSW	Asserts when the front-panel **AUTO/MANUAL** pushbutton is pressed	6
BLOCKSV	Block tap operations (SELOGIC equation)	25
COGNREV	Asserts when, in the Cogen Mode, the controller operates in the forward direction with the reverse LDC settings	28
DHR	Drag hand reset switch	46
DLYHBF	Asserts when the F_DLYRST dropout timer (high band, forward power flow) is timing	32
DLYHBR	Asserts when the R_DLYRST dropout timer (high band, reverse power flow) is timing	32
DLYLBF	Asserts when the F_DLYRST dropout timer (low band, forward power flow) is timing	32
DLYLBR	Asserts when the R_DLYRST dropout timer (low band, reverse power flow) is timing	32
DST	Asserts during daylight-saving time	50
DSTP	Asserts up to a minute before daylight-saving time change	50
DVLOW	Asserts (= logical 1) for a qualified low tap delta voltage transition (and subsequent operating in Bidirectional Reverse submode) and deasserts (= logical 0) for a qualified high (normal) tap delta voltage transition (and subsequent operating in Cogeneration submode) for OPMODE = FLEXDG (see *Figure 4.8*)	7
EFCNBD1	Level 1 voltage reduction in forward direction active	51
EFCNBD2	Level 2 voltage reduction in forward direction active	51
EFCNBD3	Level 3 voltage reduction in forward direction active	51
ENABLED	Indicate supply voltage absent, reset dead-man time-out, control disabled, firmware download, and self-test failure	0
ENFWD	Asserts when forward control is enabled	7
ENREV	Asserts when reverse control is enabled	7
ER	Trigger event report (SELOGIC equation)	25
ERCNBD1	Level 1 voltage reduction in reverse direction active	51
ERCNBD2	Level 2 voltage reduction in reverse direction active	51
ERCNBD3	Level 3 voltage reduction in reverse direction active	51
FORWARD	Asserts when the power direction is in the forward direction	36
FREQ_EN	Frequency measurement source valid	27
HALARM	Signals hardware warning or failure conditions	27
HBND	ON indicates load center voltage above high band edge	1
HBNDFWD	Asserts when the system voltage exceeds the high-band edge (forward direction)	29
HBNDREV	Asserts when the system voltage exceeds the high-band edge (reverse direction)	29

Table E.2 Alphabetic List of Device Word Bits (Sheet 3 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
IN_BND	ON indicates load center voltage within band edges	1
IN_BNDF	Asserts when the system voltage is in-band (forward direction)	29
IN_BNDR	Asserts when the system voltage is in-band (reverse direction)	29
IN101	Programmable contact input	48
IN102	Programmable contact input	48
IN201	Optional programmable contact input	49
IN202	Optional programmable contact input	49
IN203	Optional programmable contact input	49
IN204	Optional programmable contact input	49
INHIBIT	Asserts when any inhibit condition asserts	7
INHIBSV	Inhibit conditions (SELOGIC equation)	0
IRIGOK	TSOK or TIRIG	27
LAMPTST	Asserts when **LAMP TEST** front-panel pushbutton is pressed	47
LB01	Local Bit	12
LB02	Local Bit	12
LB03	Local Bit	12
LB04	Local Bit	12
LB05	Local Bit	12
LB06	Local Bit	12
LB07	Local Bit	12
LB08	Local Bit	12
LBND	ON indicates load center voltage below low band edge	1
LBNDFWD	Asserts when the system voltage exceeds the low band edge (forward direction)	29
LBNDREV	Asserts when the system voltage exceeds the low band edge (reverse direction)	29
LC	Asserts when the **LOWER** command is issued	7
LOCAL	Control Configuration—Local position	3
LOCALSV	Place control in LOCAL mode (SELOGIC equation)	38
LOCALSW	Asserts when the front-panel **REMOTE/LOCAL** is pressed	6
LOWER	To lower output	46
LOWERSV	Lower command (SELOGIC equation)	38
LOWERSW	Follows front-panel **LOWER** pushbutton (hidden if raise/lower toggle switch ordered)	6
LPSEC	Leap Second Polarity—Add if deasserted, delete if asserted	50
LPSECP	Asserts up to a minute prior to leap second insertion.	50
LT01	Latch bit variable	18
LT02	Latch bit variable	18
LT03	Latch bit variable	18
LT04	Latch bit variable	18
LT05	Latch bit variable	18

Table E.2 Alphabetic List of Device Word Bits (Sheet 4 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
LT06	Latch bit variable	18
LT07	Latch bit variable	18
LT08	Latch bit variable	18
LWRFAIL	Lower failure—Asserts for one control processing interval if no tap change detected after waiting TAPDUR seconds	39
LWRLIM	Lower limit condition—Asserts for one control processing interval if no lower current detected for TAPDUR seconds	39
MANUAL	Control Configuration—Manual position	3
MANULSV	Place control in MANUAL mode (SELOGIC equation)	38
MAXTAP	TAP_POS > TAPMAX – 1	8
MET_FWD	Meter demands in forward direction when asserted Meter demands in reverse direction when deasserted	26
MHOLD	Asserts when motor current is drawn from the holding circuit	26
MINTAP	TAP_POS < TAPMIN + 1	8
MLOWER	Indicates when lower motor is active	3
MODEINH	Asserts when any of the normal operational modes are inhibited	7
MRAISE	Indicates when raise motor is active	3
NO_NEUT	Tap = 0, but neutral position indicator not asserted	9
NO_TORK	Asserts when both FORWARD and REVERSE are deasserted	36
NOLOWR	No operations allowed in the lower direction (counterclockwise indicator movement)	39
NORAIS	No operations allowed in the raise direction (clockwise indicator movement)	39
OP_BDIR	Asserts when setting OPMODE = BIDIR	28
OP_COGN	Asserts when setting OPMODE = COGEN	28
OP_FLEX	Asserts when OPMODE = FLEXDG	28
OP_IREV	Asserts when setting OPMODE = IDLEREV	28
OP_LFWD	Asserts when setting OPMODE = LOCKFWD	28
OP_LREV	Asserts when setting OPMODE = LOCKREV	28
OP1	Asserts for approximately one minute when the time of day matches the OP1TOD setting	45
OP2	Asserts for approximately one minute when the time of day matches the OP2TOD setting	45
OP3	Asserts for approximately one minute when the time of day matches the OP3TOD setting	45
OP4	Asserts for approximately one minute when the time of day matches the OP4TOD setting	45
OPNOCUR	Operation counter switch operates, but no motor raise or lower current detected (Siemens/Howard and GE modes only)	8
OPSWHCN	OPSWHCN—Debounce operation counter AC input	49
OUT101	Standard programmable contact output—defaults as an alarm	46
OUT102	Optional programmable contact output	46
OUT103	Optional programmable contact output	46

Table E.2 Alphabetic List of Device Word Bits (Sheet 5 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
OUT104	Optional programmable contact output	46
OVRIDSV	VR remote override (SELOGIC equation)	37
PB01	Asserts when Pushbutton 1 is pressed	4
PB01LED	Follows the Front Panel setting SELogic equation of the same name	2
PB01PUL	Asserts for one control processing interval when Pushbutton 1 is pressed	5
PB02	Asserts when Pushbutton 2 is pressed	4
PB02LED	Follows the Front Panel setting SELogic equation of the same name	2
PB02PUL	Asserts for one control processing interval when Pushbutton 2 is pressed	5
PB03	Asserts when Pushbutton 3 is pressed	4
PB03LED	Follows the Front Panel setting SELogic equation of the same name	2
PB03PUL	Asserts for one control processing interval when Pushbutton 3 is pressed	5
PB04	Asserts when Pushbutton 4 is pressed	4
PB04LED	Follows the Front Panel setting SELogic equation of the same name	2
PB04PUL	Asserts for one control processing interval when Pushbutton 4 is pressed	5
PB05	Asserts when Pushbutton 5 is pressed	4
PB05LED	Follows the Front Panel setting SELogic equation of the same name	2
PB05PUL	Asserts for one control processing interval when Pushbutton 5 is pressed	5
PB06	Asserts when Pushbutton 6 is pressed	4
PB06LED	Follows the Front Panel setting SELogic equation of the same name	2
PB06PUL	Asserts for one control processing interval when Pushbutton 6 is pressed	5
PB07	Asserts when Pushbutton 7 is pressed	4
PB07LED	Follows the Front Panel setting SELogic equation of the same name	2
PB07PUL	Asserts for one control processing interval when Pushbutton 7 is pressed	5
PMDOK	Phasor measurement data okay	27
PMTRIG	Assertion influences status field of C37.118 PMU frame	26
RAISE	To Raise output	46
RAISESV	Raise command (SELOGIC equation)	38
RAISESW	Follows front-panel **RAISE** pushbutton (hidden if raise/lower switch ordered)	6
RB01	Remote bit	10
RB02	Remote bit	10
RB03	Remote bit	10
RB04	Remote bit	10
RB05	Remote bit	10
RB06	Remote bit	10

Table E.2 Alphabetic List of Device Word Bits (Sheet 6 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
RB07	Remote bit	10
RB08	Remote bit	10
RB09	Remote bit	11
RB10	Remote bit	11
RB11	Remote bit	11
RB12	Remote bit	11
RB13	Remote bit	11
RB14	Remote bit	11
RB15	Remote bit	11
RB16	Remote bit	11
RBKBLSV	Runback Block (SELOGIC equation)	25
RBKFH	Runback forward high asserted—before timer	31
RBKFL	Runback forward low asserted—before timer	31
RBKFWDH	Runback forward high asserted—with time delay	31
RBKFWDL	Runback forward low asserted—with time delay	31
RBKREVH	Runback reverse high asserted—with time delay	31
RBKREVL	Runback reverse low asserted—with time delay	31
RBKRH	Runback reverse high asserted—before timer	31
RBKRL	Runback reverse low asserted—before timer	31
RC	Asserts when the **RAISE** command is issued	7
REMOTE	Control configuration—Remote position	3
REMOTSV	Place control in REMOTE mode (SELOGIC equation)	38
REVERSE	Indicates reverse power flow detected	0
RSEFAIL	Raise failure—Asserts for one control processing interval if no tap change detected after waiting TAPDUR seconds	39
RSELIM	Raise limit condition—Asserts for one control processing interval if no raise current detected for TAPDUR seconds	39
SALARM	Pulses for software-programmed conditions	27
SC01QD	SELOGIC counter (asserted when counter = 0)	21
SC01QU	SELOGIC counter (asserted when counter = preset value)	20
SC02QD	SELOGIC counter (asserted when counter = 0)	21
SC02QU	SELOGIC counter (asserted when counter = preset value)	20
SC03QD	SELOGIC counter (asserted when counter = 0)	21
SC03QU	SELOGIC counter (asserted when counter = preset value)	20
SC04QD	SELOGIC counter (asserted when counter = 0)	21
SC04QU	SELOGIC counter (asserted when counter = preset value)	20
SC05QD	SELOGIC counter (asserted when counter = 0)	21
SC05QU	SELOGIC counter (asserted when counter = preset value)	20
SC06QD	SELOGIC counter (asserted when counter = 0)	21
SC06QU	SELOGIC counter (asserted when counter = preset value)	20

Table E.2 Alphabetic List of Device Word Bits (Sheet 7 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
SC07QD	SELOGIC counter (asserted when counter = 0)	21
SC07QU	SELOGIC counter (asserted when counter = preset value)	20
SC08QD	SELOGIC counter (asserted when counter = 0)	21
SC08QU	SELOGIC counter (asserted when counter = preset value)	20
SG1	Setting Group 1 active	24
SG2	Setting Group 2 active	24
SG3	Setting Group 3 active	24
SG4	Setting Group 4 active	24
SPEN	Enables signal profiling when asserted (SELogic equation)	25
SV01	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV01T	SELOGIC timer, timed out when asserted	15
SV02	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV02T	SELOGIC timer, timed out when asserted	15
SV03	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV03T	SELOGIC timer, timed out when asserted	15
SV04	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV04T	SELOGIC timer, timed out when asserted	15
SV05	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV05T	SELOGIC timer, timed out when asserted	15
SV06	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV06T	SELOGIC timer, timed out when asserted	15
SV07	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV07T	SELOGIC timer, timed out when asserted	15
SV08	SELOGIC variable. Associated timer (below) is picked up when variable is asserted.	14
SV08T	SELOGIC timer, timed out when asserted	15
TAP_DIF	Neutral position indicator newly asserting, but internal tap position does not indicate it having arrived from Tap = –1 (for a raise) or from Tap = +1 (for a lower)	9
TAP_OFF	Tap is off count (count is even when it should be odd; count is odd when it should be even; Siemens/Howard tap changers only)	9
TAPDONE	Tap change complete	8
TAPHBF	Asserts when the F_TD1 definite timer (high band, forward power flow) is timed out	33
TAPHBR	Asserts when the R_TD1 definite timer (high band, reverse power flow) is timed out	33
TAPLBF	Asserts when the F_TD1 definite timer (low band, forward power flow) is timed out	33

Table E.2 Alphabetic List of Device Word Bits (Sheet 8 of 8)

Name	Definition	Device Word Bit Row (*Table E.1*)
TAPLBR	Asserts when the R_TD1 definite timer (low band, reverse power flow) is timed out	33
TAPLWR2	Asserts when the TD2 definite timer (lower tap) is timed out	33
TAPNEUT	Neutral position AC input	0
TAPRSE2	Asserts when the TD2 definite timer (raise tap) is timed out	33
TIRIG	Time update every 1 second from IRIG-B time message	27
TOOHIGH	TAP_POS > TAPMAX	8
TOOLOW	TAP_POS < TAPMIN	8
TQUAL1	Encoded IRIG time quality bit 1	50
TQUAL2	Encoded IRIG time quality bit 2	50
TQUAL3	Encoded IRIG time quality bit 3	50
TQUAL4	Encoded IRIG time quality bit 4	50
TREA1	C37.118 PMU trigger reason bit	26
TREA2	C37.118 PMU trigger reason bit	26
TREA3	C37.118 PMU trigger reason bit	26
TREA4	C37.118 PMU trigger reason bit	26
TSLOCK	Disables raise/lower toggle switch when asserted (hidden if raise/lower toggle switch not ordered)	47
TSOK	High-accuracy IRIG when asserted	27
VMAXF	Asserts when (load) terminal voltage exceeds the maximum voltage edge in forward operation	30
VMAX-LMT	Asserts when either VMAXF or VMAXR assert	1
VMAXR	Asserts when (load) terminal voltage exceeds the maximum voltage edge in reverse operation	30
VMINF	Asserts when (load) terminal voltage falls below the minimum voltage edge in forward operation	30
VMINLMT	Asserts when either VMINF or VMINR assert	1
VMINR	Asserts when (load) terminal voltage falls below the minimum voltage edge in reverse operation	30
VRED1SV	Voltage reduction input 1 (SELOGIC equation)	37
VRED2SV	Voltage reduction input 2 (SELOGIC equation)	37
VRED3SV	Voltage reduction input 3 (SELOGIC equation)	37
VRIPROG	Asserts when a voltage reduction is in progress	0
VRRSTSV	Voltage reduction reset (SELOGIC equation)	37
VTJVOLT	Switch to change voltage test jacks PT	46
XTAP16L	Asserts when asked for a lower below Tap –16	8
XTAP16R	Asserts when asked for a raise above Tap 16	8

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APPENDIX F

Analog Quantities

The SEL-2431 Voltage Regulator Control contains several analog quantities that can be used for more than one function.

Analog quantities are typically generated and used by a primary function, such as metering, and selected quantities are made available for one or more supplemental functions, such as the load profile recorder.

SEL-2431 analog quantities are generated by the following:

- Metering functions (see *Section 7: Metering and Monitoring*)
- Tap position and operation counters (see *Section 5: Tap Operations*)
- Self-test diagnostics (see *Section 12: Testing and Troubleshooting*)
- Percent voltage reduction (see *Section 4: Control Operating Modes*)
- System date and time and time-related functions (see *Section 6: Logic Functions*)
- SELOGIC counters (see *Section 6: Logic Functions*)

Table F.1 lists analog quantities that can be used in the following specific functions:

- SELOGIC control equations (see *Section 6: Logic Functions*)
- Display points (see *Section 10: Front-Panel Operations*)
- Signal (load) profile recorder (see *Section 7: Metering and Monitoring*)
- DNP (see *Appendix D: DNP3 Communications*)
- Fast Meter (see *Appendix C: SEL Communications Processors*)

Table F.1 Analog Quantities (Sheet 1 of 6)

Label	Description	Units	SELOGIC	Display Points	Signal Profile	DNP	Fast Meter
Fundamental Instantaneous Metering							
IL	Line Current, Magnitude, Primary	A pri	x	x	x	x	x
ILSEC	Line Current, Magnitude, Secondary[a]	A sec	x	x	x	x	
ILA	Line Current, Angle	degrees		x		x	x
VS	S terminal Voltage, Magnitude, Primary	kV pri	x	x	x	x	x
VSSEC	S terminal Voltage, Magnitude, Secondary	V sec	x	x	x	x	x
VSA	S terminal Voltage, Angle	degrees		x		x	x
VL	L terminal Voltage, Magnitude, Primary	kV pri	x	x	x	x	x
VLSEC	L terminal Voltage, Magnitude, Secondary	V sec	x	x	x	x	x
VLA	L terminal Voltage, Angle[b]	degrees		x		x	x
VCMP	Compensated Voltage Magnitude, Primary	kV pri	x	x	x	x	x
VCMPSEC	Compensated Voltage Magnitude, Secondary (**Note:** For Fast Meter this label is shortened to VCMPSC.)	V sec	x	x	x	x	x
VMETER	Voltmeter Voltage	V sec		x			
PL	Real Power	kW pri	x	x	x	x	x

Table F.1 Analog Quantities (Sheet 2 of 6)

Label	Description	Units	SELogic	Display Points	Signal Profile	DNP	Fast Meter
QL	Reactive Power	kVAr pri	x	x	x	x	x
SL	Apparent Power	kVA pri	x	x	x	x	x
PF	Power Factor	per unit	x	x	x	x	x
PF_LEG	Legacy Power Factor	per unit				x	
PFLD	Power Factor: Leading = 1, Lagging = 0	unitless	x	x	x	x	x
PFQ	Power Factor Quadrant (1, 2, 3, 4)	unitless	x	x	x	x	
TAP_POS	Tap position (Note: For Fast Meter, this label is TAPPOS)	unitless	x	x	x	x	x
FREQ	Frequency	Hz	x	x	x	x	x
Demand Metering							
DM_LRDH	Demand Metering Last Reset Date/Time (High Register)	date/time				x	
DM_LRDM	Demand Metering Last Reset Date/Time (Middle Register)	date/time				x	
DM_LRDL	Demand Metering Last Reset Date/Time (Low Register)	date/time				x	
ILFDEM	Forward Demand Line Current	A pri	x	x	x	x	x
PFDEM	Forward Demand Power	kW pri	x	x	x	x	x
QFODEM	Forward OUT Demand Reactive Power (Q1)	kVAr pri	x	x	x	x	x
QFIDEM	Forward IN Demand Reactive Power (Q4)	kVAr pri	x	x	x	x	x
SFDEM	Forward Demand Apparent Power	kVA pri	x	x	x	x	x
ILRDEM	Reverse Demand Line Current	A pri	x	x	x	x	x
PRDEM	Reverse Demand Power	kW pri	x	x	x	x	x
QRODEM	Reverse OUT Demand Reactive Power (Q2)	kVAr pri	x	x	x	x	x
QRIDEM	Reverse IN Demand Reactive Power (Q3)	kVAr pri	x	x	x	x	x
SRDEM	Reverse Demand Apparent Power	kVA pri	x	x	x	x	x
Peak (Demand) Metering							
PD_LRDH	Peak Demand Last Reset Date/Time (High Register)	date/time				x	
PD_LRDM	Peak Demand Last Reset Date/Time (Middle Register)	date/time				x	
PD_LRDL	Peak Demand Last Reset Date/Time (Low Register)	date/time				x	
ILFPK	Forward Peak Demand Line Current	A pri		x		x	x
PFPK	Forward Peak Demand Power	kW pri		x		x	x
QFOPK	Forward OUT Peak Demand Reactive Power (Q1)	kVAr pri		x		x	x
QFIPK	Forward IN Peak Demand Reactive Power (Q4)	kVAr pri		x		x	x
SFPK	Forward Peak Demand Apparent Power	kVA pri		x		x	x
ILRPK	Reverse Peak Demand Line Current	A pri		x		x	x
PRPK	Reverse Peak Demand Power	kW pri		x		x	x
QROPK	Reverse OUT Peak Demand Reactive Power (Q2)	kVAr pri		x		x	x
QRIPK	Reverse IN Peak Demand Reactive Power (Q3)	kVAr pri		x		x	x
SRPK	Reverse Peak Demand Apparent Power	kVA pri		x		x	x
Energy Metering							
EM_LRDH	Energy Metering Last Reset Date/Time (High Register)	date/time				x	
EM_LRDM	Energy Metering Last Reset Date/Time (Middle Register)	date/time				x	
EM_LRDL	Energy Metering Last Reset Date/Time (Low Register)	date/time				x	

Table F.1 Analog Quantities (Sheet 3 of 6)

Label	Description	Units	SELogic	Display Points	Signal Profile	DNP	Fast Meter
MWHOUT	Real Energy OUT	MWh pri		x	x	x	
MWHIN	Real Energy IN	MWh pri		x	x	x	
MVARHOUT	Reactive Energy OUT	MVArh pri		x	x	x	
MVARHIN	Reactive Energy IN	MVArh pri		x	x	x	
Maximum/Minimum Metering							
MM_LRDH	Max/Min Metering Last Reset Date/Time (High Register)	date/time				x	
MM_LRDM	Max/Min Metering Last Reset Date/Time (Middle Register)	date/time				x	
MM_LRDL	Max/Min Metering Last Reset Date/Time (Low Register)	date/time				x	
ILFMX	Forward Line Current, Maximum	A pri		x		x	
ILFMN	Forward Line Current, Minimum	A pri		x		x	
VSFMX	Forward S-terminal primary voltage, Maximum	kV pri		x		x	
VSSFMX	Forward S-terminal secondary voltage, Maximum	V sec		x		x	
VSFMN	Forward S-terminal primary voltage, Minimum	kV pri		x		x	
VSSFMN	Forward S-terminal secondary voltage, Minimum	V sec		x		x	
VLFMX	Forward L-terminal primary voltage, Maximum	kV pri		x		x	
VLSFMX	Forward L-terminal secondary voltage, Maximum	V sec		x		x	
VLFMN	Forward L-terminal primary voltage, Minimum	kV pri		x		x	
VLSFMN	Forward L-terminal secondary voltage, Minimum	V sec		x		x	
VCFMX	Forward compensated primary voltage, Maximum	kV pri		x		x	
VCSFMX	Forward compensated secondary voltage, Maximum	V sec		x		x	
VCFMN	Forward compensated primary voltage, Minimum	kV pri		x		x	
VCSFMN	Forward compensated secondary voltage, Minimum	V sec		x		x	
PFMX	Forward Real Power maximum	kW pri		x		x	
PFMN	Forward Real Power minimum	kW pri		x		x	
QFMX	Forward Reactive Power maximum	kVAr pri		x		x	
QFMN	Forward Reactive Power minimum	kVAr pri		x		x	
SFMX	Forward Apparent Power maximum	kVA pri		x		x	
PFFMX	Forward power factor at max kVA	per-unit		x		x	
SFMN	Forward Apparent Power minimum	kVA pri		x		x	
PFFMN	Forward power factor at min kVA	per-unit		x		x	
FRQFMX	Forward frequency maximum	Hz		x		x	
FRQFMN	Forward frequency minimum	Hz		x		x	
TAPFMX	Forward Tap Position maximum	unitless		x		x	
TAPFMN	Forward Tap Position minimum	unitless		x		x	
ILRMX	Reverse Line Current, Maximum	A pri		x		x	
ILRMN	Reverse Line Current, Minimum	A pri		x		x	
VSRMX	Reverse S-terminal primary voltage, Maximum	kV pri		x		x	
VSSRMX	Reverse S-terminal secondary voltage, Maximum	V sec		x		x	
VSRMN	Reverse S-terminal primary voltage, Minimum	kV pri		x		x	
VSSRMN	Reverse S-terminal secondary voltage, Minimum	V sec		x		x	

Table F.1 Analog Quantities (Sheet 4 of 6)

Label	Description	Units	SELogic	Display Points	Signal Profile	DNP	Fast Meter
VLRMX	Reverse L-terminal primary voltage, Maximum	kV pri		x		x	
VLSRMX	Reverse L-terminal secondary voltage, Maximum	V sec		x		x	
VLRMN	Reverse L-terminal primary voltage, Minimum	kV pri		x		x	
VLSRMN	Reverse L-terminal secondary voltage, Minimum	V sec		x		x	
VCRMX	Reverse compensated primary voltage, Maximum	kV pri		x		x	
VCSRMX	Reverse compensated secondary voltage, maximum	V sec		x		x	
VCRMN	Reverse compensated primary voltage, minimum	kV pri		x		x	
VCSRMN	Reverse compensated secondary voltage, Minimum	V sec		x		x	
PRMX	Reverse Real Power maximum	kW pri		x		x	
PRMN	Reverse Real Power minimum	kW pri		x		x	
QRMX	Reverse Reactive Power maximum	kVAr pri		x		x	
QRMN	Reverse Reactive Power minimum	kVAr pri		x		x	
SRMX	Reverse Apparent Power maximum	kVA pri		x		x	
PFRMX	Reverse power factor at man kVA	per-unit		x		x	
SRMN	Reverse Apparent Power minimum	kVA pri		x		x	
PFRMN	Reverse power factor at min kVA	per-unit		x		x	
FRQRMX	Reverse frequency maximum	Hz		x		x	
FRQRMN	Reverse frequency minimum	Hz		x		x	
TAPRMX	Reverse Tap Position maximum	unitless		x		x	
TAPRMN	Reverse Tap Position minimum	unitless		x		x	
DLT_IL	Line current delta across tap operation	A pri	x				
DLT_ILS	Line current delta across tap operation	mA sec	x				
DLT_VL	L terminal voltage, magnitude delta across tap operation	V pri	x				
DLT_VLS	L terminal voltage, magnitude delta across tap operation	mV sec	x				
DLT_VS	S terminal voltage, magnitude delta across tap operation	V pri	x				
DLT_VSS	S terminal voltage, magnitude delta across tap operation	mV sec	x				
DLT_PL	Real power delta across tap operation	W pri	x				
DLT_QL	Reactive power delta across tap operation	VAr pri	x				
DLT_SL	Apparent power delta across tap operation	VA pri	x				
Harmonics Metering							
ILH01	Fundamental magnitude, Line Current	A pri		x		x	
ILH02	Second harmonic, Line Current	%		x			
ILH03	Third harmonic, Line Current	%		x			
ILH04	Fourth harmonic, Line Current	%		x			
ILH05	Fifth harmonic, Line Current	%		x			
ILH06	Sixth harmonic, Line Current	%		x			
ILH07	Seventh harmonic, Line Current	%		x			
ILH08	Eighth harmonic, Line Current	%		x			
ILH09	Ninth harmonic, Line Current	%		x			
ILH10	Tenth harmonic, Line Current	%		x			

Table F.1 Analog Quantities (Sheet 5 of 6)

Label	Description	Units	SELogic	Display Points	Signal Profile	DNP	Fast Meter
ILH11	Eleventh harmonic, Line Current	%		x			
ILH12	Twelfth harmonic, Line Current	%		x			
ILH13	Thirteenth harmonic, Line Current	%		x			
ILH14	Fourteenth harmonic, Line Current	%		x			
ILH15	Fifteenth harmonic, Line Current	%		x			
ILTHD	THD, Line Current	%	x	x	x	x	
VLH01	Fundamental magnitude, voltage bushing L	kV pri		x		x	
VLH02	Second harmonic, voltage bushing L	%		x		x	
VLH03	Third harmonic, voltage bushing L	%		x		x	
VLH04	Fourth harmonic, voltage bushing L	%		x		x	
VLH05	Fifth harmonic, voltage bushing L	%		x		x	
VLH06	Sixth harmonic, voltage bushing L	%		x		x	
VLH07	Seventh harmonic, voltage bushing L	%		x		x	
VLH08	Eighth harmonic, voltage bushing L	%		x		x	
VLH09	Ninth harmonic, voltage bushing L	%		x		x	
VLH10	Tenth harmonic, voltage bushing L	%		x		x	
VLH11	Eleventh harmonic, voltage bushing L	%		x		x	
VLH12	Twelfth harmonic, voltage bushing L	%		x		x	
VLH13	Thirteenth harmonic, voltage bushing L	%		x		x	
VLH14	Fourteenth harmonic, voltage bushing L	%		x		x	
VLH15	Fifteenth harmonic, voltage bushing L	%		x		x	
VLTHD	THD, voltage bushing L	%	x	x	x	x	
Analog Status Values for DNP							
HWSTA	Hardware Status (1 = good, 0 = failure)	unitless				x	
VRSTA	Voltage Reduction Status[c]	unitless				x	
VLSTA	Voltage Limit Status[d]	unitless				x	
TCSTA	Tap Control Mode Status[e]	unitless				x	
MSSTA	Mode Select Switch Status[f]	unitless				x	
Date/Time							
TIME	Present date/time[g]					x	
DOW	Day of Week[h]		x				
MONTH	Month		x				
HOUR	Hour		x				
MINUTE	Minute		x				
Settings Group							
ACTGRP	Active Setting Group	unitless		x		x	
Voltage Reduction							
PRCNTVR	Percent voltage reduction in progress	unitless	x	x	x	x	
Operations Counter							
OPCNTT	Operations Count, Total[i]	unitless	x	x		x	

Table F.1 Analog Quantities (Sheet 6 of 6)

Label	Description	Units	SELOGIC	Display Points	Signal Profile	DNP	Fast Meter
OPCNTY	Operations Count, Year-to-Date	unitless	x	x		x	
OPCNTM	Operations Count, Month-to-Date	unitless	x	x		x	
OPCNTD	Operations Count, Sliding 24-Hour Window	unitless	x	x		x	
OPCNT	Operations Count, Since Last Reset	unitless	x	x		x	
SELOGIC Counters[h]							
SC01	SC01 present value	unitless	x	x	x	x	
SC02	SC02 present value	unitless	x	x	x	x	
SC03	SC03 present value	unitless	x	x	x	x	
SC04	SC04 present value	unitless	x	x	x	x	
SC05	SC05 present value	unitless	x	x	x	x	
SC06	SC06 present value	unitless	x	x	x	x	
SC07	SC07 present value	unitless	x	x	x	x	
SC08	SC08 present value	unitless	x	x	x	x	

[a] When using ILSEC in a SELOGIC analog comparison, the resolution is limited to 0.01 A sec.
[b] VLA is the reference phase angle for ILA and VSA.
[c] 0 = inactive, 1 = stage 3, 2 = stage 2, 4 = stage 1.
[d] 1 = inactive, 6 = lower limit, 4 = upper limit.
[e] 0 = inactive, 1 = manual and local, 2= auto.
[f] 1 = local manual, 2 = local auto, 3 = remote.
[g] Also available via DNP object 50.
[h] DOW- Day of Week. 1 = Sunday, 2 = Monday, 3= Tuesday, 4 = Wednesday, 5 = Thursday, 6 = Friday, 7 = Saturday.
[i] Also available as DNP Counter Object.

APPENDIX G

Definite-Time Characteristics

Overview

Ideally, a voltage regulator control regulates the system voltage to values within an acceptable "in band" region. If the voltage is too high or too low ("out of band"), the voltage regulator control issues a tap change command to the voltage regulator to bring the voltage back "in band".

Before issuing the first tap change command, the SEL-2431 Voltage Regulator Control qualifies the "out of band" condition with a definite-time delay. This first-tap definite time delay is set with the Group setting F_TD1 (Forward Time Delay 1 for First Tap) or R_TD1 (Reverse Time Delay 1 for First Tap). After the first tap is issued, if the voltage continues to stay "out of band", Group setting TD2 (Time Delay 2 for Subsequent Taps) qualifies subsequent tap change commands.

The first-tap definite time delay has four different reset characteristics that can be selected for specific applications and operating practices. This appendix explains how to select and apply these different reset characteristics for the first-tap definite-time delay, F_TD1 or R_TD1.

Application

Voltage Regulator Application and Power Flow

There are three single-phase voltage regulators per distribution substation feeder position in *Figure G.1*. The SEL-2431 is a single-phase device, so each distribution substation feeder position in *Figure G.1* has three SEL-2431 controls that each control a single-phase voltage regulator.

Figure G.1 shows voltage regulators applied inside the distribution substation. Voltage regulators and accompanying controls are also applied out on the feeder, away from the substation.

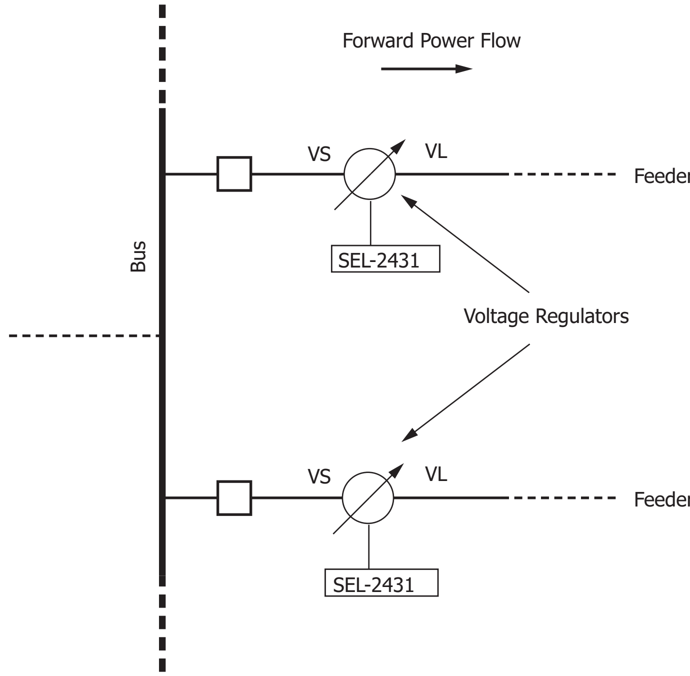

Figure G.1 Distribution Substation With Voltage Regulators In Use on the Feeders

If power flows in the forward direction, the SEL-2431 regulates the load voltage (VL) within an acceptable "in band" range. If power flows in the reverse direction, the SEL-2431 regulates the source voltage (VS) within an acceptable "in band" range.

Line-drop compensation (LDC) is not considered in these examples. See *Line-Drop Compensation (LDC)* on page 3.1 for more information on LDC.

The subsequent explanations and examples in this appendix assume forward power flow with VL as the regulated voltage. Similar reasoning may be used for the condition when the power flow reverses, making VS the regulated voltage.

"In Band" and "Out of Band" Voltage Conditions

To establish the band edges, the settings in *Table G.1* are used.

Table G.1 Voltage Band Settings

Settings	Setting Prompt	Range	Unit	Default Value
F_CNBND	Forward Center Band	96.0–144.0	Vsec	120.0
F_BNDWD	Forward Band Width	1.0–10.0	Vsec	2.0

Using the default band settings: F_CNBND = 120.0 V and F_BNDWD = 2.0; the band edges are calculated as:

- Forward-High-Band-Edge = F_CNBND + F_BNDWD/2
- Forward-High-Band-Edge = 120 + 2/2 = 121 V
- Forward-Low-Band-Edge = F_CNBND – F_BNDWD/2
- Forward-Low-Band-Edge = 120 – 2/2 = 119 V

When the regulated voltage (VL) is higher than 121 V, Device Word bit HBND-FWD (High Band Forward) asserts. When VL is lower than 119 V, Device Word bit LBNDFWD (Low Band Forward) asserts. Both these high and low band scenarios, shown in *Figure G.2*, are deemed “out of band” conditions. The desired voltage range (in between these “out of band” voltage ranges) is deemed an “in band” condition.

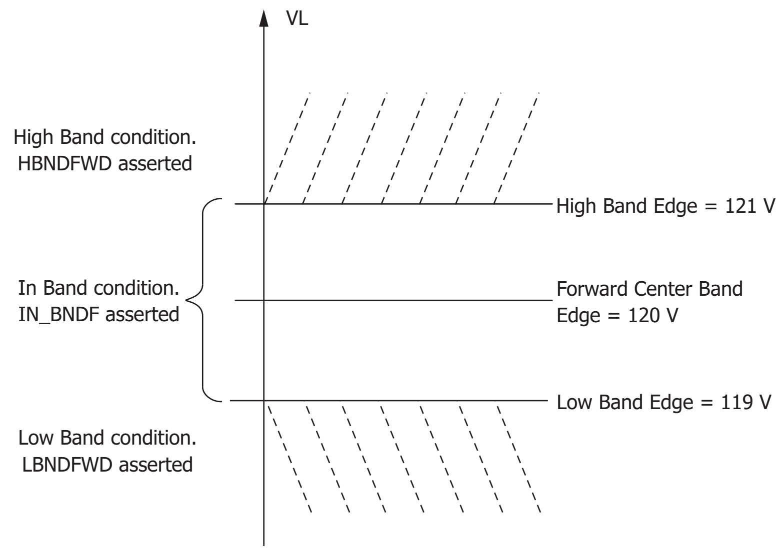

Figure G.2 Band Edge Comparison

Select the Reset Characteristic for the First-Tap Definite-Time Delay

After detecting either a HBNDFWD (high band) or LBNDFWD (low band) condition, the SEL-2431 starts the first-tap timer, F_TD1. When the first-tap timer times out, the SEL-2431 issues the first tap change command to bring the voltage back “in band”.

Table G.2 Forward Time Delay 1 for First Tap

Settings	Setting Prompt	Range	Unit	Default Value
F_TD1	Forward Time Delay 1 for First Tap	1.0 to 999.0	Sec	60.0

Depending on the application, a user can select one of four different reset characteristics for timer F_TD1. The four reset options are:

- FAST
- DISC
- DELAY
- DLY_FRZ (Delay Freeze)

Table G.3 Four Different Reset Characteristics for Timer F_TD1

Settings	Setting Prompt	Range	Unit	Default Value
F_CHAR	Forward Reset Characteristic	FAST, DISC, DELAY, DLY_FRZ	NA	DISC

The following analysis of the four different reset characteristics assumes that VL goes into the “high band” region and HBNDFWD asserts.

FAST Reset Characteristic, F_CHAR = FAST

The most basic method used to reset the first-tap definite time delay is the FAST characteristic. When F_CHAR is set to FAST, the F_TD1 timer resets whenever the regulated voltage drops out of the “high band” region.

Figure G.3 illustrates the FAST characteristic. When VL rises higher than 121 V, timer F_TD1 starts timing. VL drops back “in band” 28 seconds later, and thus timer F_TD1 resets immediately. A short while later, VL goes into the “high band” region again and timer F_TD1 starts timing from the beginning. *Table G.2* shows that F_TD1 is set to 60 seconds. Therefore, as VL stays continuously in the “high band” region for 60 seconds, timer F_TD1 times out. The SEL-2431 issues a tap change command to bring the voltage back “in band”.

NOTE: The FAST characteristic is similar to a sequential mode selection in some other voltage regulator controls.

The problem with the FAST characteristic is that such short excursions into the “in band” region could occur indefinitely, resulting in no tap change for a condition that is not “in band” most of the time.

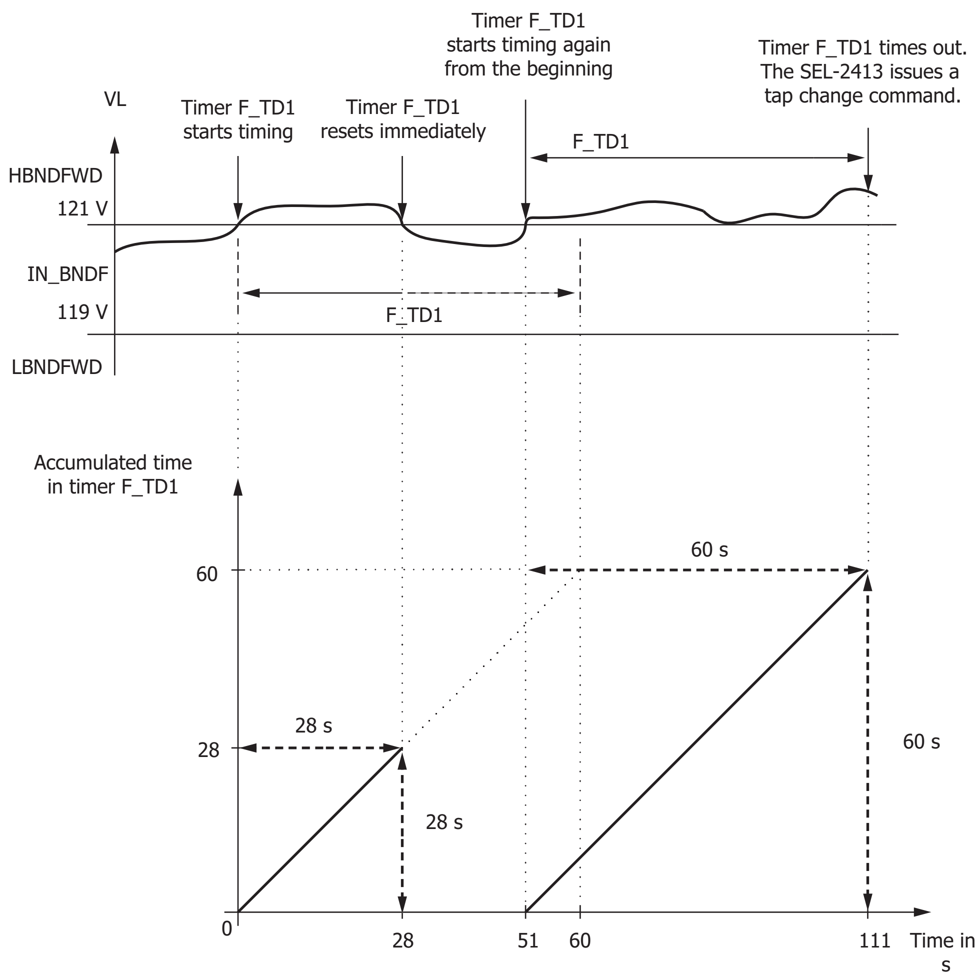

Figure G.3 Reset Characteristic for Timer F_TD1 When F_CHAR = FAST

DISC Reset Characteristic, F_CHAR = DISC

The DISC reset characteristic is similar in behavior to the resetting of a traditional induction disc relay. When the regulated voltage drops back “in band”, the first-tap timer starts resetting at the rate of F_DISC seconds (see *Table G.4*) for every second of elapsed time.

To coordinate with existing controls, the typical settings for F_DISC are from 0.60 to 1.10.

Table G.4 Forward Disc-Like Reset Factor Setting

Settings	Setting Prompt	Range	Unit	Default Value
F_DISC	Forward Disc-Like Reset Factor	0.10–2.00	NA	0.60

Figure G.4 shows an example of how the DISC reset characteristic works when the regulated voltage goes back "in band".

When VL enters the "high band" region (HBNDFWD), timer F_TD1 starts timing. 40 seconds later, VL drops back "in band" and timer F_TD1 starts resetting like an induction disc relay. Timer F_TD1 resets at the rate of 0.60 seconds for every second of elapsed time because F_DISC is set to 0.60. VL stays "in band" for 20 seconds and as a result, timer F_TD1 resets back by 12 seconds (20 • 0.60 = 12).

NOTE: The DISC characteristic is similar to a time-integrating mode selection in some other voltage regulator controls.

Then, VL returns to the "high band" region again. Timer F_TD1 at that time contains a value of 28 seconds. *Table G.2* shows that F_TD1 is set to 60 seconds. Therefore, after the regulated voltage stays in the "high band" region for another 32 continuous seconds, timer F_TD1 times out. The SEL-2431 issues a tap change command to bring the voltage back "in band".

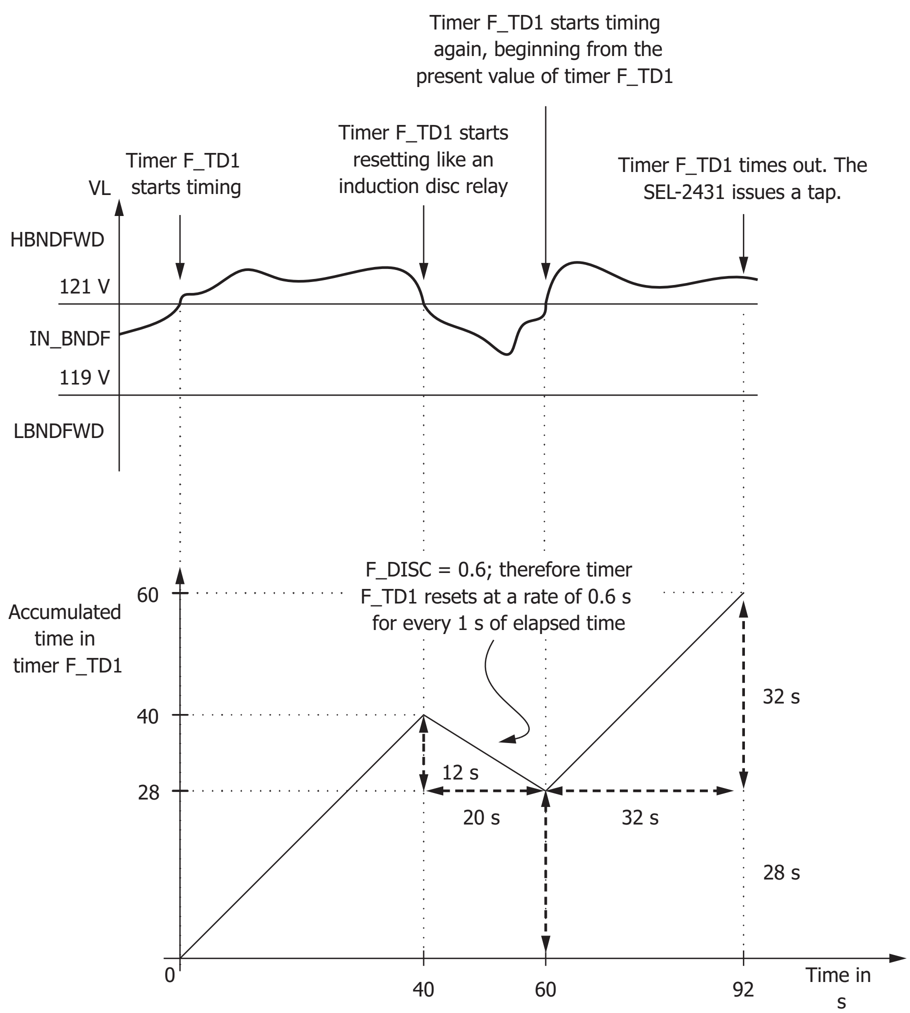

Figure G.4 Reset Characteristic for Timer F_TD1 When F_CHAR = DISC

Operating in the DISC mode, the SEL-2431 first-tap timer resets like an induction disc relay whenever the regulated voltage goes back "in band". However, if the regulated voltage goes to the opposite band (e.g., high band to low band), or the power flow changes direction, the SEL-2431 first-tap timer resets immediately. *Figure G.5* shows how the DISC resetting characteristic works when the regulated voltage goes to the opposite band.

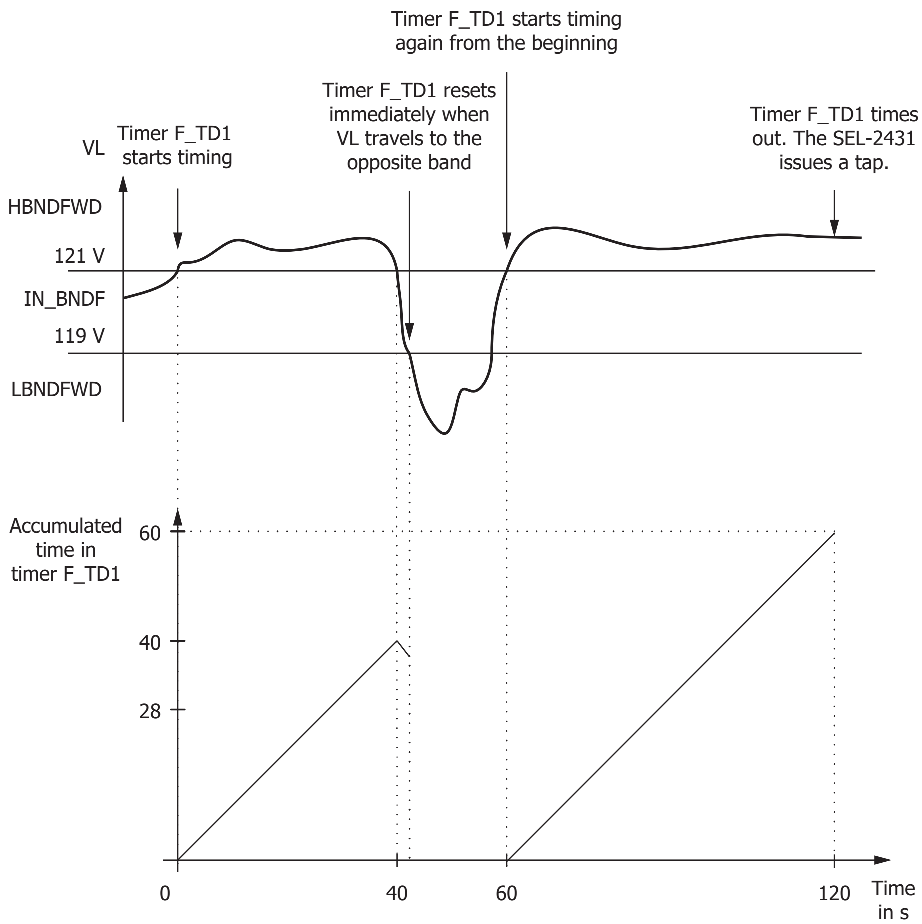

Figure G.5 Reset Characteristic for Timer F_TD1 When F_CHAR = DISC and VL Travels to the Opposite Band (High Band to Low Band)

DELAY Reset Characteristic, F_CHAR = DELAY

When operating in the F_CHAR = FAST mode, short excursions into the "in band" region can result in no tap change for a condition that is "out of band" most of the time. A third reset characteristic is offered to deal with this problem. When F_CHAR is set to DELAY, timer setting F_DLYRS keeps the F_TD1 timer from resetting if the voltage makes an excursion back "in band" for less than F_DLYRS time.

Table G.5 Forward Delay on Reset Setting

Settings	Setting Prompt	Range	Unit	Default Value
F_DLYRS	Forward Delay on Reset	0.0 to 999.0	Sec	0.0

Set F_DLYRS to a non-zero value, for example: F_DLYRS = 10.0.

In DELAY mode, timer F_TD1 continues to time while the regulated voltage drops "in band" (if the "in band" excursion lasts shorter than F_DLYRS time).

Figure G.6 illustrates how the DELAY reset characteristic works when the regulated voltage drops "in band" for less than F_DLYRS time (= 10 sec). When VL rises higher than 121 V, timer F_TD1 starts timing. 18 seconds later, VL drops back "in band" for 8 seconds and timer F_TD1 continues timing. Then, VL goes into the "high band" region again. A short while later, VL goes back "in band" for 5 seconds and timer F_TD1 continues timing. When timer F_TD1 times out, the SEL-2431 issues a tap change command to bring the voltage back "in band".

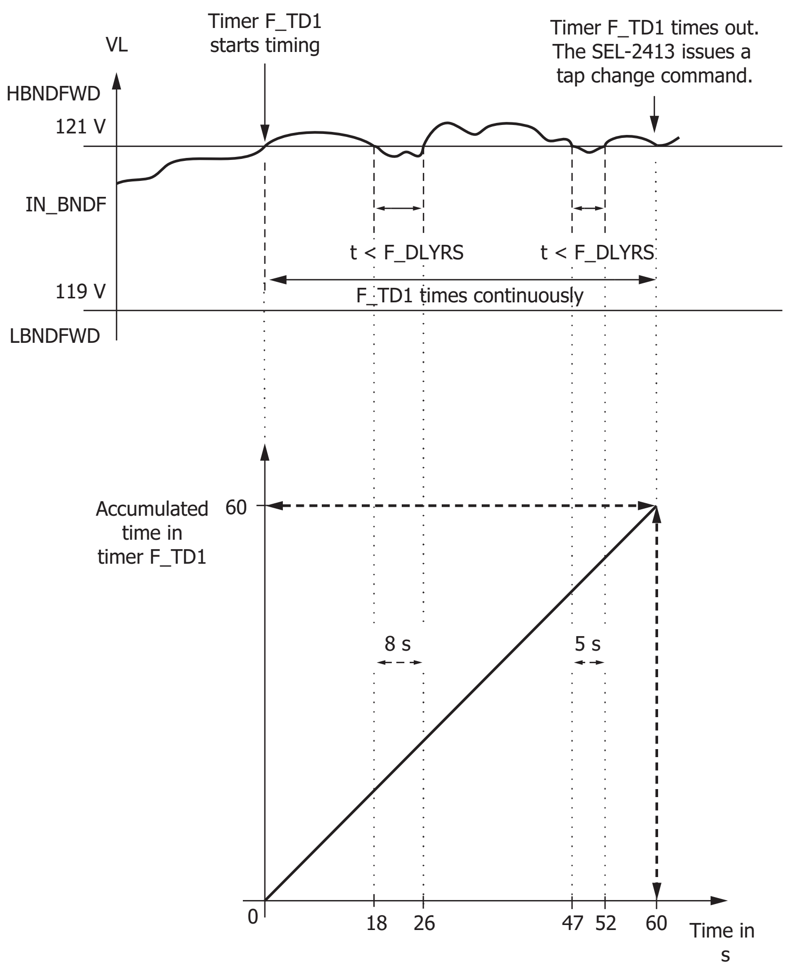

Figure G.6 Reset Characteristic for Timer F_TD1 When F_CHAR = DELAY and VL Drops Back "In Band" for Less Than F_DLYRS Time

If the regulated voltage stays "in band" as long as 10 seconds, timer F_TD1 resets immediately.

Figure G.7 illustrates how the DELAY reset characteristic works when the regulated voltage drops "in band" for as long as F_DLYRS time. When VL rises higher than 121 V, timer F_TD1 starts timing. 18 seconds later, VL drops back "in band" and timer F_TD1 continues timing. 10 seconds later, timer F_DLYRS expires while VL still stays "in band", causing timer F_TD1 to reset immediately. A short while later, VL returns to the "high band" region and timer F_TD1 starts timing from the beginning. VL remains in the "high band" region until timer F_TD1 times out. The SEL-2431 issues a tap change command to bring the voltage back "in band".

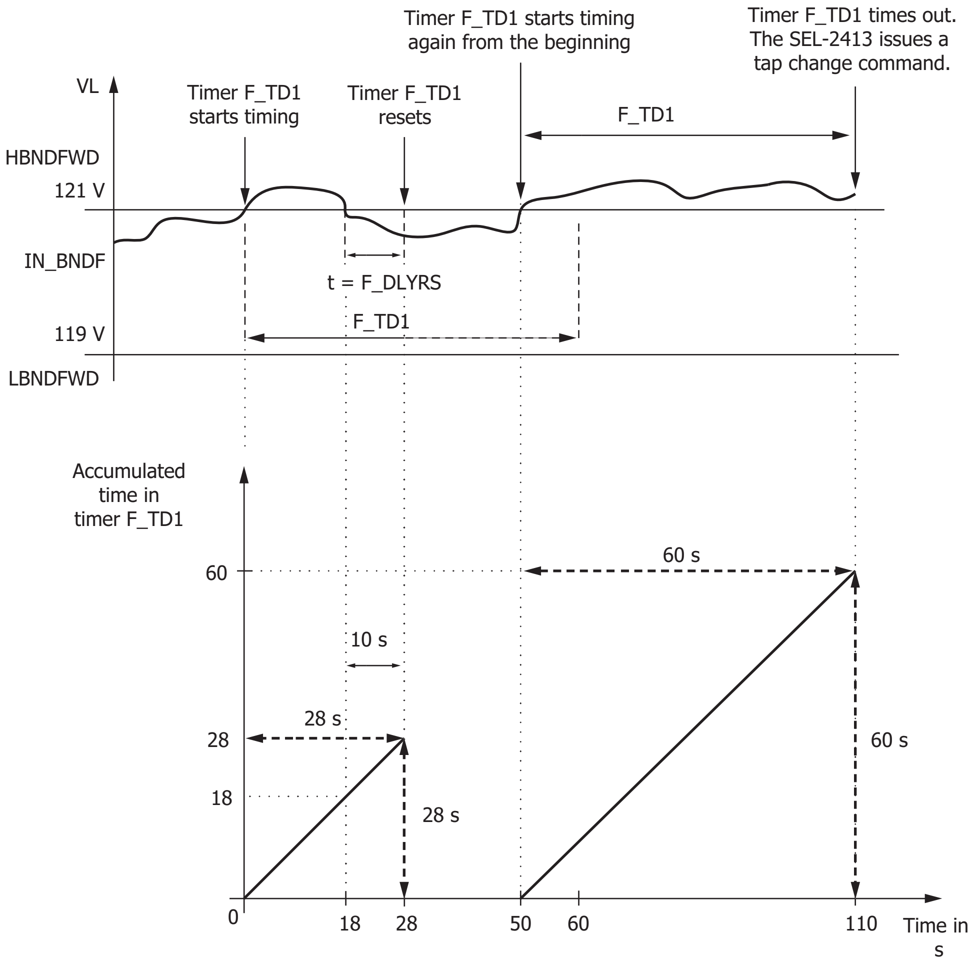

Figure G.7 Reset Characteristic for Timer F_TD1 When F_CHAR = DELAY and VL Drops Back "In Band" for Longer Than F_DLYRS Time

When F_DLYRS = 0, the DELAY reset characteristic behaves exactly the same as the FAST reset characteristic (see *Figure G.3*).

The DELAY mode prevents timer F_TD1 from resetting when the regulated voltage goes back "in band" momentarily. However, the DELAY mode does not keep timer F_TD1 from resetting if the regulated voltage makes an excursion to the opposite band (passing right through the "in band" region, similar to *Figure G.5*). If the regulated voltage goes to the opposite band or the power flow changes direction, timer F_TD1 resets right away.

With setting F_CHAR = DELAY, the SEL-2431 avoids the problem of frequent short excursions into the "in band" region causing the regulator to never tap for a mostly "out of band" condition. Moreover, the DELAY reset characteristic provides effective timing coordination with other voltage regulator controls (to the source side and the load side) by keeping the timing on timer F_TD1 continuous.

DELAY FREEZE Reset Characteristic, F_CHAR = DLY_FRZ

Different from the DELAY reset characteristic, when F_CHAR is set to DLY_FRZ, the SEL-2431 freezes timer F_TD1 whenever the regulated voltage enters the "in band" region. If the "in band" excursion is shorter than F_DLYRS time, the device resumes timing as soon as the regulated voltage returns to the “out of band” region. If the “in band” excursion lasts as long as F_DLYRS time, the device resets immediately, similar to *Figure G.7*.

Figure G.8 illustrates the DLY_FRZ characteristic. When VL rises to higher than 121 V, timer F_TD1 starts timing. Fifteen seconds later, VL drops back “in band” and timer F_TD1 freezes and keeps its present value. Nine seconds later, VL returns to the “high band” region and timer F_TD1 resumes timing. Timer F_TD1 does not reset because VL stays “in band” for less than F_DLYRS time (10 seconds). A short while later, VL goes “in band” again for 5 seconds and timer F_TD1 also freezes during this excursion. When VL returns to “high band”, timer F_TD1 resumes timing. Then, VL stays in the “high band” region until timer F_TD1 times out. The SEL-2431 issues a tap change command to bring the voltage back “in band”.

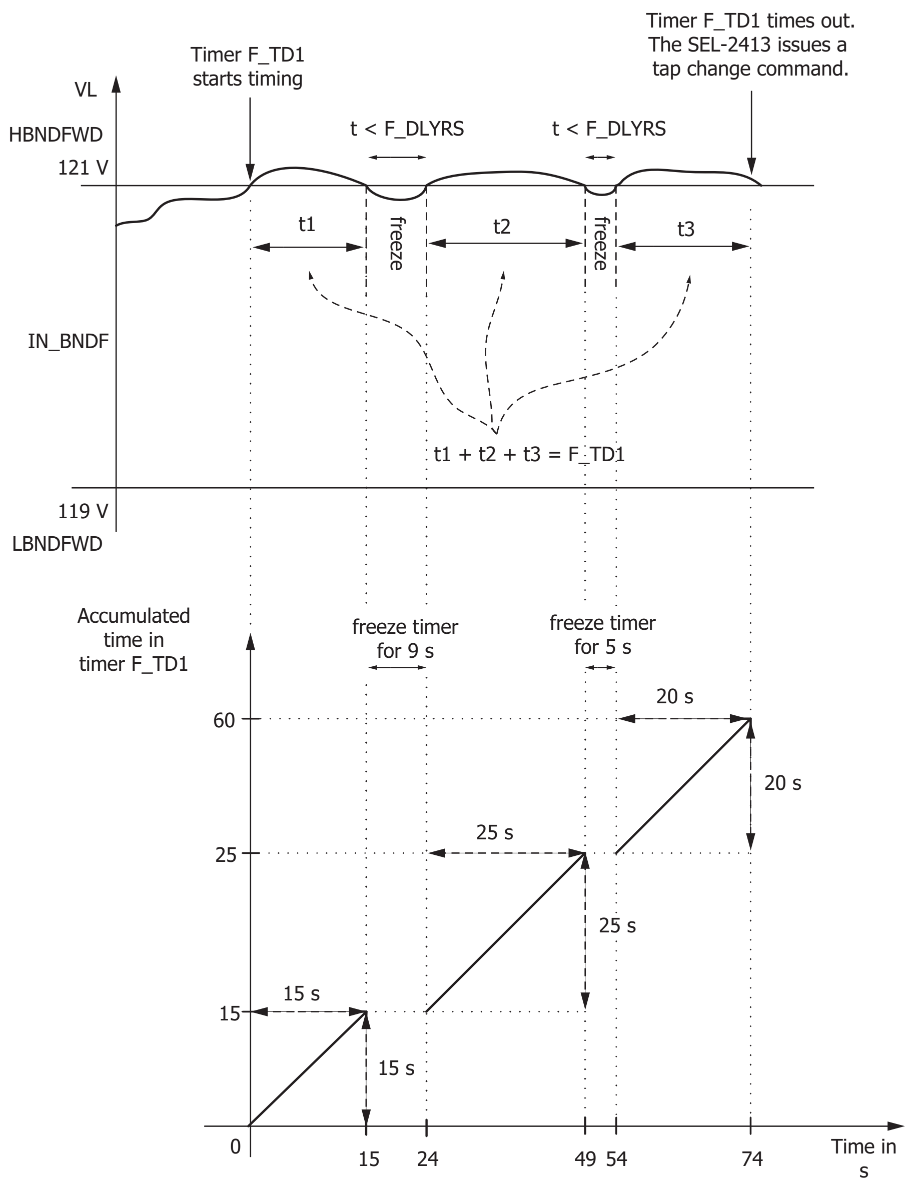

Figure G.8 Reset Characteristic for Timer F_TD1 When F_CHAR = DLY_FRZ and VL Drops Back “In Band” for Less Than F_DLYRS Time

If the regulated voltage makes an excursion from “high band” to “low band” (passing right through the “in band” region), or if the power flow changes direction, F_TD1 timer resets immediately, similar to *Figure G.5*.

Because the timing on F_TD1 is not continuous, timing coordination with other devices is not maintained. This “delay freeze” scheme should be used when timing coordination with other devices is not a concern, or where minimal tap operations are desired (e.g., the voltage regulator is old and should not be tapping much, so as to reduce wear and tear).

Conclusion

In summary, the four reset characteristic options for the first-tap definite-time delay are:

- FAST: reset immediately when the voltage goes back “in band”.
- DISC: reset like an induction-disc relay when voltage goes back “in band”.
- DELAY: timer F_DLYRS starts timing when voltage goes back “in band”. The definite-time characteristic timer (F_TD1) continues to time while timer F_DLYRS is timing. If timer F_DLYRS times out before timer F_TD1 times out (the voltage remains “in band” too long), timer F_TD1 resets.
- DLY_FRZ: timer F_DLYRS starts timing when voltage goes back “in band”. Timer F_TD1 freezes while timer F_DLYRS is timing. When the voltage returns to “out of band” (before timer F_DLYRS times out), timer F_TD1 continues timing from where it left off when frozen. If timer F_DLYRS times out (the voltage remains “in band” too long), timer F_TD1 resets.

A particular reset characteristic option is selected based on specific voltage regulator coordination needs and operating practices.

APPENDIX H

Synchrophasors

Overview

The SEL-2431 Voltage Regulator Control provides Phasor Measurement Unit (PMU) capabilities when connected to a suitable IRIG-B time source. Synchrophasor is used as a general term that can refer to data or protocol.

This section covers the following topics:

See *IRIG-B* on page 9.5 for the requirements of the IRIG-B time source. Synchrophasors are still measured if the high-accuracy time source is not connected, however, the data is not time-synchronized to any external reference, as indicated by Device Word bits TSOK = logical 0 and PMDOK = logical 0.

Introduction

The word synchrophasor is derived from two words: synchronized and phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver, such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as a number of SEL-2431 voltage regulator controls, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other offline analysis functions.

NOTE: A C37.118-compliant IRIG-B time source is available via an EIA-232 or EIA-485 4-Wire communications card in Port 1.

The SEL-2431 Global settings contain the synchrophasor settings, including the choice of the synchrophasor data set the relay will transmit. Use the Port settings to select which serial port(s) are reserved for synchrophasor protocol. See *Settings for IEEE C37.118 Protocol Synchrophasors*.

The SEL-2431 generates time status Device Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELOGIC variables and programmable digital trigger information are also added to the Device Word bits for synchrophasors—see *Synchrophasor Device Word Bits* on page H.10.

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. The synchrophasor protocol available in the SEL-2431 allows for a centralized device to collect data efficiently from several phasor measurement units (PMUs). Some possible uses of a system-wide synchrophasor system include the following:

- Power-system state measurement
- Wide-area network protection and control schemes
- Small-signal analysis
- Power-system disturbance analysis

The SEL-2431 uses only one synchrophasor protocol, C37.118. IEEE C37.118 compliant synchrophasor data are available on multiple serial ports when the port setting PROTO = PMU.

You can view synchrophasor data over a serial port set to PROTO = SEL (see *View Synchrophasors by Using the MET PM Command* on page H.11.)

Synchrophasor Measurement

NOTE: The synchrophasor data stream is separate from the other control and metering functions.

The phasor measurement unit in the SEL-2431 measures voltage and current on a constant-time basis. These samples are synchronized to the high-accuracy IRIG-B time source, and occur at a fixed frequency of either 60 Hz or 50 Hz, depending on Global setting NFREQ. The relay then filters the measured samples according to Global setting PMAPP = FAST or NARROW—see *PMAPP*. The phase angle is measured relative to an absolute reference, which is represented by a cosine function in *Figure H.1*. The time-of-day is shown for the two time marks.

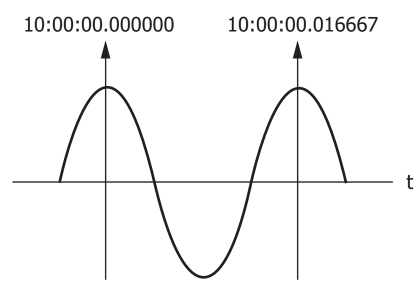

Figure H.1 High-Accuracy Clock Controls Reference Signal (60 Hz System)

The instrument transformers (PTs or CTs) and the interconnecting cables may introduce a time shift in the measured signal. Global settings VS1COMP, VS2COMP, and ICOMP, entered in degrees, are added to the measured phasor angles to create the corrected phasor angles, as shown in *Figure H.2*. The VS1COMP, VS2COMP, and ICOMP settings may be positive or negative values. The corrected angles are displayed in the **MET PM** command and transmitted as part of synchrophasor messages.

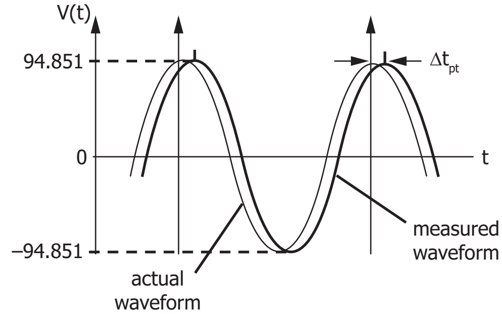

Figure H.2 Waveform at Relay Terminals May Have Phase Shift

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{\text{freq}}\right)} \bullet 360° = \Delta t_{pt} \bullet \text{freq} \bullet 360°$$

Equation H.1

If the time shift on the pt measurement path Δt_{pt} = 0.784 ms and the nominal frequency, $\text{freq}_{\text{nominal}}$ = 60Hz, use *Equation H.2* to obtain the correction angle:

$$0.784 \bullet 10^{-3}\text{s} \bullet 60\text{s}^{-1} \bullet 360° = 16.934°$$

Equation H.2

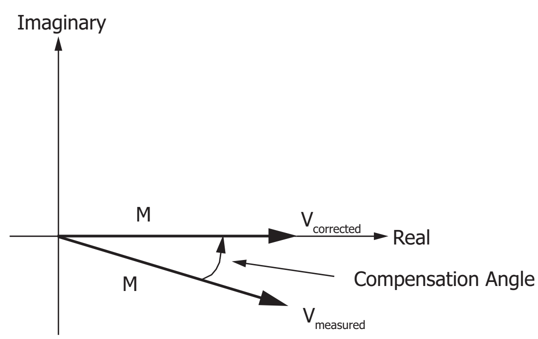

Figure H.3 Correction of Measured Phase Angle

Because the sampling reference is based on the GPS clock (IRIG-B signal) and not synchronized to the power system, an examination of successive synchrophasor data sets will almost always show some angular change between samples of the same signal. This is not a malfunction of the relay or the power system, but is merely a result of viewing data from one system with an instrument with an independent time base. In other words, a power system has a nominal frequency of either 50 or 60 Hz, but on closer examination, it is usually running a little faster or slower than nominal.

Settings for IEEE C37.118 Protocol Synchrophasors

The phasor measurement unit (PMU) settings are listed in *Table H.1*. The SEL-2431 uses C37.118 message format for PMU applications because of increased settings flexibility and the availability of software and hardware for synchrophasor concentration, processing, and control.

The Global enable setting EPMU must be set to Y before the remaining SEL-2431 synchrophasor settings are available. No synchrophasor data collection can take place when EPMU = N.

You must make the port settings in *Table H.4* to transmit data with synchrophasor protocol. It is possible to set EPMU = Y without using any ports for synchrophasor protocols. For example, the serial port **MET PM** ASCII command can still be used.

Table H.1 PMU Settings in the SEL-2431 (Global Settings)

Global Settings	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MRATE	Messages per Second {1, 2, 5, 10, 25, or 50 when NFREQ = 50} {1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ = 60}	60
PMAPP	PMU Application (FAST = Fast Response, NARROW = Narrow Bandwidth)	NARROW
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	STATION A
PMID	PMU Hardware ID (1–65534)	1
PHDATAV	Phasor Data Set, Voltages (ALL, NA)	ALL
VS1COMP	Phase Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
VS2COMP	Phase Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI	Phasor Data Set, Currents (ALL, NA)	ALL
ICOMP	Phase Current Angle Compensation Factor (–179.99 to 180 degrees)	0.00
NUMDSW	Number of 16-bit Digital Status Words (0, 1)	0

[a] Set EPMU = Y to access the remaining settings.

Table H.2 PMU Settings in the SEL-2431 (Logic Settings)

Logic Settings	Description	Default
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)	VMINLMT AND NOT TREA4 AND NOT TREA2
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)	VMAXLMT AND NOT TREA4
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)	0
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)	TAPDONE OR ER
PMTRIG	Trigger (SELOGIC Equation)	TREA1 OR TREA2 OR TREA3 OR TREA4

Descriptions of Synchrophasor Settings

Definitions for the settings in *Table H.1* are as follows.

MRATE

Selects the message rate in messages per second for synchrophasor data streaming on serial ports.

Choose the MRATE setting that suits the needs of your PMU application. This setting is one of four settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth for C37.118 Protocol* on page H.8 for detailed information.

PMAPP

Selects the type of digital filters used in the synchrophasor algorithm:

- The Narrow Bandwidth setting (NARROW) represents filters with a cutoff frequency approximately 0.25 of MRATE. The response in the frequency domain is narrower, and response in the time domain is slower. This method results in synchrophasor data that are free of aliasing signals and well suited for post-disturbance analysis.
- The Fast Response setting (FAST) represents filters with a higher cutoff frequency. The response in frequency domain is wider and the response in the time domain is faster. This method results in synchrophasor data that can be used in synchrophasor applications requiring more speed in tracking system parameters.

PHCOMP

Enables or disables frequency-based compensation for synchrophasors.

For most applications, set PHCOMP = Y to activate the algorithm that compensates for the magnitude and angle errors of synchrophasors for frequencies that are off nominal. Use PHCOMP = N if you are concentrating the SEL-2431 synchrophasor data with other PMU data that do not employ frequency compensation.

PMSTN and PMID

Defines the name and number of the PMU.

The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHDATAV, VS1COMP, and VS2COMP

PHDATAV selects whether to include synchrophasor voltage in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. This setting is one of four settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page H.8 for detailed information.

- PHDATAV = ALL will transmit VS1 AND VS2 when 2ND_PT = Y
- PHDATAV = ALL will transmit VS1 when 2ND_PT = N
- PHDATAV = NA will not transmit any voltages

Table H.3 describes the order of synchrophasors inside the data packet.

The VS1COMP and VS2COMP settings allow correction for any steady-state voltage phase errors (from the potential transformers or wiring characteristics). VS1COMP corrects the VS1 voltage for phase angle error, and VS2COMP corrects the VS2 voltage for phase angle error. See *Synchrophasor Measurement* on page H.2 for details on this setting.

PHDATAI and ICOMP

PHDATAI selects whether to include synchrophasor current in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. This setting is one of four settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page H.8 for detailed information.

- PHDATAI = ALL will transmit IL
- PHDATAI = NA will not transmit any currents

The ICOMP setting allows correction for any steady-state phase errors (from the current transformers or wiring characteristics). See *Synchrophasor Measurement* on page H.2 for details on these settings.

Table H.3 describes the order of synchrophasors inside the data packet. Synchrophasors are transmitted in the order indicated from the top to the bottom of the table. Magnitude values are transmitted first and angle values are transmitted second. Synchrophasors are only transmitted if specified to be included by the PHDATAV and PHDATAI settings. For example, if PHDATAV = ALL and PHDATAI = NA, voltage VL and VS will be transmitted, and no current will be transmitted.

Table H.3 Synchrophasor Order in Data Stream (Voltage and Current)

Synchrophasors[a]
Current (ILPM)
Voltage (VLPM)
Voltage (VSPM)

[a] Synchrophasors are included in the order shown (for example current [ILPM], if selected, will always precede voltage [VLPM] and voltage [VSPM]).

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

This setting is one of four settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth for C37.118 Protocol* on page H.8 for detailed information.

The choices for this setting depend on the synchrophasor system design. The inclusion of digital data can help indicate voltage regulator status or other operational data to the synchrophasor processor. See *IEEE C37.118 PMU Setting Example* on page H.12 for a suggested use of the digital status word fields.

Setting NUMDSW = 0 sends no user-definable digital status words.

Setting NUMDSW = 1 sends the user-definable digital status words containing Device Word bits SV01–SV08 and eight additional bits reserved for future implementation.

The digital status words are sent after voltage (VS) in the synchrophasor data packet starting with SV01 and continuing through SV08. The following eight reserved bits are reported as 0.

TREA1, TREA2, TREA3, TREA4, and PMTRIG

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations in Global settings. The SEL-2431 evaluates these equations and places the results in Device Word bits with the same names: TREA1–TREA4, and PMTRIG.

NOTE: The PM Trigger function is not associated with the SEL-2431 Event Report Trigger ER, a SELOGIC control equation in Report settings.

The trigger reason equations represent the Trigger Reason bits in the STAT field of the data packet. After the trigger reason bits are set to convey a message, the PMTRIG Equation should be asserted for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The SEL-2431 automatically sets the TREA1–TREA4 or PMTRIG Device Word bits based on their default SELOGIC equation. The operation of these bits can only be changed by reprogramming.

You can use these bits to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The SEL-2431 synchrophasor processing and protocol transmission are not affected by the status of these bits.

Serial Port Settings for IEEE C37.118 Synchrophasors

IEEE C37.118 compliant synchrophasors are available via serial port. The associated serial port settings are shown in *Table H.4*.

Table H.4 SEL-2431 Serial Port Settings for Synchrophasors

Setting	Description	Default
PROTO	Protocol (SEL, DNP, PMU)	SEL[a]
SPEED	Data Speed (300 to 57600)	9600
STOP	Stop Bits (1, 2)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

[a] Set PROTO = PMU to enable C37.118 synchrophasor protocol on this port.

The serial port settings for PROTO = PMU, shown in *Table H.4*, do not include the settings BITS and PARITY; these two settings are internally fixed as BITS = 8, PARITY = N.

Serial port setting PROTO cannot be set to PMU (see *Table H.4*) when Global setting EPMU = N. Synchrophasors must be enabled (EPMU = Y) before PROTO can be set to PMU. If the PROTO setting for any serial port is PMU, EMPU cannot be set to N.

If you use a computer terminal session or QuickSet connected to a serial port, and then set that same serial port PROTO setting to PMU, you will lose the ability to communicate with the relay through ASCII commands. If this happens, either connect via another serial port (that has PROTO = SEL) or use the front-panel HMI SET/SHOW screen to change the port PROTO setting back to SEL.

C37.118 Synchrophasor Protocol

The SEL-2431 complies with *IEEE C37.118, Standard for Synchrophasors for Power Systems*.

The protocol is available on serial ports 1 and 2 by setting the corresponding Port setting PROTO = PMU.

This subsection does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The SEL-2431 allows several options for transmitting synchrophasor data. These are controlled by Global settings described in *Settings for IEEE C37.118 Protocol Synchrophasors* on page H.4. You can select how often to transmit the synchrophasor messages (MRATE) and which synchrophasors to transmit (PHDATAV and PHDATAI).

The SEL-2431 automatically includes the frequency and rate-of-change-of-frequency in the synchrophasor messages.

The relay can include 8 digital status values, as controlled by Global setting NUMDSW.

The SEL-2431 always includes the results of four synchrophasor trigger reason SELOGIC equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC equation result PMTRIG, in the synchrophasor message.

Communications Bandwidth for C37.118 Protocol

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

If the SPEED setting on any serial port set with PROTO = PMU is insufficient for the PMU Global settings, the SEL-2431 or SEL-5030 software will display an error message and fail to save settings until the error is corrected.

The C37.118 synchrophasor message format always includes 18 bytes for the message header and terminal ID, time information, and status bits. Each item is assigned a quantity which is used to calculate the number of bytes per message.

For the synchophasor item, the possible values are as follows:

- 0 for no phasors
- 1 for a single phasor (IL or VL)
- 2 for two phasors (IL and VL or VL and VS)
- 3 for all phasors (IL, VL, and VS)

The selection of synchrophasor data, numeric format, and programmable digital data will add to the byte requirements. *Table H.5* can be used to calculate the number of bytes in a synchrophasor message.

Table H.5 Size of a C37.118 Synchrophasor Message

Item (Possible Quantities)	Bytes per Quantity	Minimum Number of Bytes	Maximum Number of Bytes
Fixed		18	18
Synchrophasors (0, 1, 2, or 3)	4 {PHNR = I}	0	12
Frequency (2)	2 {FNR = I}	4	4
Digital Status Words (0–1)	2	0	2
Total (Minimum and Maximum)		22	36

Table H.6 lists the data rate settings available on any SEL-2431 serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 20 bytes.

Table H.6 Serial Port Bandwidth for Synchrophasors (in Bytes)

Global Setting MRATE	Port Setting SPEED							
	300	1200	2400	4800	9600	19200	38400	57600
1	25	103	207	414	829	1658	3316	4974
2		51	103	207	414	829	1658	2487
4 (60 Hz only)		25	51	103	207	414	829	1243
5		20	41	82	165	331	663	994
10			20	41	82	165	331	497
12 (60 Hz only)				34	69	138	276	414
15 (60 Hz only)				27	55	110	221	331
20 (60 Hz only)				20	41	82	165	248
25 (50 Hz only)					33	66	132	198
30 (60 Hz only)					27	55	110	165
50 (50 Hz only)						33	66	99
60 (60 Hz only)						27	55	82

Referring to *Table H.5* and *Table H.6*, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one synchrophasor and this message would consume 26 bytes. This type of message could be sent at any message rate (MRATE) when SPEED = 19200 or higher.

Another example application has messages comprised of three synchrophasors and one digital status word. This type of message would consume 36 bytes. This message could be sent at any message rate (MRATE) when SPEED = 38400 or 57600, as fast as MRATE = 30 when SPEED = 19200, and as fast as MRATE = 20 when SPEED = 9600.

Protocol Operation

The SEL-2431 will only transmit synchrophasor messages over serial ports that have setting PROTO = PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-2431 with IEEE C37.118 commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so that the synchrophasor processor can automatically build a database structure.

Transmit Mode Control

The SEL-2431 will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The SEL-2431 can also indicate when a configuration change occurs, so that the synchrophasor processor can request a new configuration block and keep its database up-to-date.

The SEL-2431 will only respond to configuration block request messages when it is in the non-transmitting mode.

Independent Ports

Each serial port with the PROTO = PMU setting is independently configured and enabled for synchrophasor commands. The ports are not required to have the same SPEED setting, although the slowest SPEED setting on a PROTO = PMU port will affect the maximum Global MRATE setting that can be used.

Synchrophasor Device Word Bits

Table H.7 and *Table H.8* list the SEL-2431 Device Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Device Word bits in *Table H.7* follow the state of the SELOGIC control equations of the same name, listed at the bottom of *Table H.2*. These Device Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field.

Table H.7 Synchrophasor Trigger Device Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC Equation)
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)

The Time-Synchronization Device Word bits in *Table H.8* indicate the present status of the high-accuracy timekeeping function of the SEL-2431 (see *Configuring High-Accuracy Timekeeping* on page H.14).

Table H.8 Time-Synchronization Device Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
TSOK	Time synchronization OK. Asserts while time is based on high-accuracy IRIG-B time source of sufficient accuracy for synchrophasor measurement.
PMDOK	Phasor measurement data OK. Asserts when the SEL-2431 is enabled, synchrophasors are enabled (Global Setting EPMU = Y), Device Word bit TSOK = 1, and the relay is properly tracking frequency (FREQ_EN = 1). A few seconds may be required for PMDOK to assert when the relay is first powered, after any of the settings in *Table H.1* are changed, or when an IRIG-B time signal is first connected.

View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-2431 synchrophasor measurements. See *METER Command (Metering Data)* on page 9.23 for general information on the **MET** command.

There are multiple ways to use the **MET PM** command:

- ➤ As a test tool, to verify connections and scaling
- ➤ As an analytical tool, to capture synchrophasor data at an exact time, in order to compare this information with similar data captured in other phasor measurement unit(s) at the same time.
- ➤ As a method of periodically gathering synchrophasor data through a communications processor.

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings PHDATAV and PHDATAI. The **MET PM** command can function even when no ports are sending synchrophasor data.

The **MET PM** command only displays data when the Device Word bit TSOK = logical 1. *Figure H.4* shows a sample **MET PM** command response. The synchrophasor data are also available in the QuickSet HMI and have a similar format to *Figure H.4*.

NOTE: Ensure that port setting AUTO = Y on the active communications port for the **MET PM <time>** response to be displayed at <time>. Otherwise use **MET PM HIS** to view a previously triggered MET PM report.

The **MET PM** ***time*** command can be used to direct the SEL-2431 to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure H.4* occurring just after 14:14:12, with the time stamp 14:14:12.000.

This method of data capture always reports from the exact second, even if the time parameter is entered with fractional seconds. For example, entering **MET PM 14:14:12.200** results in the same data capture as **MET PM 14:14:12**, because the relay ignored the fractional seconds.

See *MET PM—Synchrophasor Metering* on page 9.23 for complete command options, and error messages.

MET PM HIS recalls the most recently triggered synchrophasor meter report. This is useful when synchrophasor data from multiple relays must be captured on a single PC. For example, connect to each relay and issue the **MET PM 14:14:00** command. At 14:14, each relay will issue a response similar to *Figure H.4*. After 14:14, connect to each relay, issue the **MET PM HIS** command, and capture the results. Since **MET PM HIS** recalls the last MET PM report, the data captured from every relay will be from the same time.

```
=>MET PM <Enter>

SEL-2431                                Date: 10/04/2010   Time: 13:51:51.000
Voltage Reg

                                                                 PMDOK = 1
Time Quality   Maximum time synchronization error:     0.000 (ms)  TSOK = 1

Synchrophasors
                Load Voltage     Source Voltage
MAG (kV)           7.086            7.082
ANG (DEG)         -2.813           -2.812

                Load Current
MAG (A)            0.104
ANG (DEG)         90.000

FREQ (Hz) 59.980
Rate-of-change of FREQ (Hz/s)    0.02

Digitals

SV08    SV07    SV06    SV05    SV04    SV03    SV02    SV01
 0       0       0       0       0       0       0       0

=>
```

Figure H.4 Sample MET PM Command Response

IEEE C37.118 PMU Setting Example

NOTE: This example assumes that there is a second PT installed (i.e., both VS and VL are available) and an EIA-232 card is installed in communications port 1.

A utility is upgrading its distribution system to use the SEL-2431 for voltage regulation. The utility also wants to collect phasor measurement data to monitor voltages and currents throughout the distribution system.

The PMU data collection requirements call for the following data, collected at 10 messages per second:

- Frequency
- Load voltage (VL) and source voltage (VS)
- Line current
- Indication when the voltage regulator is in the neutral position
- Indication when voltage reduction is active

The utility is able to meet the requirements with the SEL-2431, an SEL-2407 Satellite-Synchronized Clock, and an SEL-3306 Synchrophasor Processor at the substation.

This example will cover the PMU settings in the SEL-2431 controls.

Some system details:

- The nominal frequency is 60 Hz.
- The VS1 PT and wiring have a phase error of 1.20 degrees (lagging) at 60 Hz.
- The VS2 PT and wiring have a phase error of 1.25 degrees (lagging) at 60 Hz
- The voltage regulator CT and wiring have a phase error of 1.50 degrees (lagging) at 60 Hz.
- The synchrophasor data will be using Port 2, and the maximum data rate allowed is 19200.
- The system designer specified fast synchrophasor response, because the data are being used for system monitoring.

Determining Settings

The protection engineer performs a bandwidth check, using *Table H.5*, and determines the required message size. The system requirements, in order of appearance in *Table H.5*, are:

- ➤ All Voltage and Current Synchrophasors
- ➤ 2 digital status bits, which require one status word

The message size is 18 + 3 • 4 + 2 • 2 + 1 • 2 = 36 bytes. Using *Table H.6*, the engineer verifies that the port data rate of 19200 is adequate for the message, at 10 messages per second.

The SELOGIC Variables SV07 and SV08 will be used to transmit the neutral position status and voltage reduction status, respectively.

Make the Global settings as shown in *Table H.9*.

Table H.9 Example Synchrophasor Global Settings

Setting	Description	Value
NFREQ	Nominal System Frequency (50, 60 Hz)	60
EPMU	Enable Synchronized Phasor Measurement (Y, N)	Y
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)	10
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	F
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	SAMPLE1
PMID	PMU Hardware ID (1–65534)	14
PHDATAV	Phasor Data Set, Voltages (ALL, NA)	ALL
VS1COMP	Phase Voltage Angle Compensation Factor (–179.99 to 180 degrees)	1.20
VS2COMP	Phase Voltage Angle Compensation Factor (–179.99 to 180 degrees)	1.25
PHDATAI	Phasor Data Set, Currents (ALL, NA)	ALL
IPCOMP	Phase Current Angle Compensation Factor (–179.99 to 180 degrees)	1.50
NUMDSW	Number of 16-bit Digital Status Words (0 or 1)	1

Table H.10 Example Synchrophasor Logic Settings

Logic Setting	Description	Value
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)	NA
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)	NA
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)	NA
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)	NA
PMTRIG	Trigger (SELOGIC Equation)	NA

The two Device Word bits required in this example must be placed in certain SELOGIC variables. Make the settings in *Table H.11* in all four setting groups.

Table H.11 Example Synchrophasor SELOGIC Settings

Setting	Value
SV07	TAPNEUT
SV08	VRED1SV OR VRED2SV OR VRED3SV

Make the *Table H.12* settings for serial port 2, using the **SET P 2** command.

Table H.12 Example Synchrophasor Port Settings

Setting	Description	Value
PROTO	Protocol (SEL, DNP, PMU)	PMU
SPEED	Data Speed (300 to 57600)	19200
STOPBIT	Stop Bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

Configuring High-Accuracy Timekeeping

The SEL-2431 features high-accuracy timekeeping when supplied with an IRIG-B signal. When the supplied clock signal is sufficiently accurate, the SEL-2431 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.

IRIG-B

The SEL-2431 has one input connector that accepts IRIG-B (Inter-Range Instrumentation Group-B) demodulated time-code format: the IRIG-B pins of Communications Port 1, when Port 1 contains an EIA-232 or 4-Wire EIA-485 card.

The IRIG-B connection can be used for high-accuracy timekeeping purposes, with up to 1 µs accuracy with an appropriate time source. This input can also be used for general-purpose timekeeping, and the relay will have up to 5 ms accuracy. See *Table H.13* for SEL-2431 timekeeping mode details.

Table H.13 SEL-2431 Timekeeping Modes

Item	Internal Clock	Normal Accuracy IRIG	High-Accuracy IRIG
Best accuracy (condition)	Depends on last method of setting, plus internal clock drift[a]	5 ms (when IRIG-B signal not meeting requirements for high-accuracy IRIG is connected)	1 µs (when time source jitter is less than 500 ns, and time-error is less than 1 µs)[b]
IRIG-B Connection Required	None	Communications Port 1	Communications Port 1
Device Word bits	TIRIG = logical 0 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 1

[a] The SEL-2431 internal clock can be synchronized via DNP3, SEL-2030 Communications Processor, or ASCII **TIM** command.

[b] The time-error check only applies when Global setting IRIGC = C37.118.

The SEL-2431 determines the suitability of the IRIG-B signal 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).

When IRIGC = C37.118, the SEL-2431 will assert Device Word bit TSOK only when these two tests are met. When IRIGC = NONE, the relay will assert TSOK when the first test is met.

Table H.14 Time and Date Management

Label	Prompt	Default Value
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When EPMU = Y, IRIGC is forced to C37.118.

A time quality value is determined based on the four-bit Time Quality indicator code defined in the IEEE C37.118 standard. When Global setting IRIGC = C37.118, the raw time quality information from the IRIG-B signal is placed into four Device Word bits TQUAL1, TQUAL2, TQUAL3, and TQUAL4. For example, if TQAUL1 = 1, TQUAL2 = 0, TQUAL3 = 1, and TQUAL4 = 0, the binary time quality indicator code received from the clock via the IRIG signal is 0101, which corresponds to 10 microseconds time error. The time quality is shown in the MET PM report beside the label `Time Quality Maximum time synchronization error:` viewed with the **MET PM** command.

When IRIGC = C37.118, the relay also decodes Leap Second Pending, Leap Second Direction, Daylight Savings Pending, and Daylight Savings control bits that are present in the IRIG-B signal. The status of these control bits is reflected in Device Word bits LPSECP, LPSEC, DSTP, and DST, respectively.

When IRIGC = NONE, the TQUAL1, TQUAL2, TQUAL3, TQUAL4, LPSECP, LPSEC, DSTP, and DST Device Word bits are not updated. When Global setting EPMU = Y, IRIGC is forced to C37.118.

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.

This example assumes that you have successfully established communication with the relay. In addition, you must be familiar with relay access levels and passwords.

Step 1. Confirm that the relay is operating.

Step 2. Prepare to control 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 3. Connect the cable.

Attach the IRIG-B signal with the appropriate cable (as outlined under *IRIG-B* on page 9.5) from the GPS receiver IRIG-B output to the SEL-2431 Communications Port 1.

Step 4. Confirm/Enable automatic detection of high-accuracy timekeeping.

a. Wait at least 20 seconds for the SEL-2431 to acquire the clock signal, and then, at a communications terminal, type **TAR TIRIG <Enter>**

The relay will return one row from the Device Word, as shown in *Figure H.5*. Only the state of the TIRIG and TSOK Device Word bits are discussed in the troubleshooting steps below.

```
=>TAR TIRIG <Enter>

TSOK     TIRIG    IRIGOK   *        *        *        SALARM   HALARM
1        1        1        0        0        0        0        0
=>
```

Figure H.5 Confirming the High-Accuracy Timekeeping Device Word Bits

b. The TIRIG and TSOK Device Word bits should be asserted (logical 1), indicating that the relay is in the high-accuracy IRIG timekeeping mode.

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 high-accuracy mode:

- ➢ Global setting IRIGC = C37.118, but the IRIG-B clock does not use the IEEE C37.118 Control Bit assignments.
- ➢ The IRIG-B signal jitter is too high.
- ➢ The termination resistor, required by some IRIG clocks, is not installed.
- ➢ Global setting IRIGC = C37.118, but the time-source clock is reporting that its time error is greater than 1 µs.

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.

APPENDIX I

Cybersecurity Features

Introduction and Security Environment

Product Function

The SEL-2431 Voltage Regulator Control is designed for use with many standard single-phase, 32-tap step-voltage regulators that are commonly deployed by electric utilities to automatically level voltage profiles along the distribution feeder. The SEL-2431 is available for both new and retrofit applications. The advanced communications features allow easy sharing of data in a substation environment while the storage of operations counter, Sequential Events Recorder (SER), Event Report, and Load Profile data are logged in nonvolatile memory for use in remote installations where communications are not yet available.

Security Requirements

The SEL-2431 is designed and intended for use only within operational technology (OT) networks protected by layered defenses specific to OT environments. This device supports SCADA and industrial protocols that lack sophisticated security features, including Telnet and ICCP. Strict network segmentation should be used to ensure this traffic does not traverse corporate networks. OT devices should not be visible or directly accessible from public-facing networks. The SEL-2431 provides a number of features to help meet cybersecurity design requirements.

Obtaining Version Information

To find the firmware version number in your SEL-2431 Voltage Regulator Control, view the status report through use of the serial port **STATUS** command or the front-panel `Status` menu.

The firmware revision number is after the R and the release date is after the D. For example, the following is firmware revision number 100, release date June 1, 2007.

FID=SEL-2431-R100-V0-Z001001-D20070601

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.

External Interfaces

Each physical serial port and Ethernet port is always enabled. Rear communication ports are optional. The SEL-2431 comes standard with a Type A USB port to interface with USB flash drives. As outlined in *Section 3: Front-Panel Interface* of the *SEL-2431 Voltage Regulator Control Field Reference Guide*, you can store the USB authentication key for the SEL-2431 on the USB flash drive and use it to gain Level 2 access to the front panel of the SEL-2431. Consider the USB flash drive as a physical key to the SEL-2431, eliminating the need to type the Access Level 2 password through the front panel. Because of the access it provides, keep any USB flash drive containing the USB authentication key physically secure.

To create an authentication key, navigate to **Front Panel > USB Flash Drive** in ACSELERATOR QuickSet SEL-5030 Software. Then use USB Flash Drive tools to create and store the USB authentication key on the USB flash drive. Note that although strong cryptography is used in creating an authentication key, obtaining access to an authentication key may make it easier for an attacker to determine the Access Level 2 password. If ensuring physical security of the authentication key is difficult, you may want to only use manual password entry.

Table I.1 Logical Ports

IP Port Default	Port Selection Setting	Network Protocol	Default State	Port Enable Setting	Purpose
23	TPORT	TCP	Disabled	ETELNET	Telnet access for general engineering terminal access
4712/4713	PMOTCP1/PMOUDP1	TCP/UDP	Disabled	PMOTS1	Synchrophasor data output, Session 1
4722/4713	PMOTCP2/PMOUDP2	TCP/UDP	Disabled	PMOTS2	Synchrophasor data output, Session 2
20000	DNPNUM	TCP/UDP	Disabled	EDNP	DNP for SCADA functionality

Access Controls

Privilege Levels

The SEL-2431 supports four levels of access, as described in *Access Levels* on page 9.12. Refer to this section to learn how each level is accessed and how to change passwords. It is good security practice to change the default passwords of each access level and to use a unique password for each level.

Local Accounts (or Access Levels)

The SEL-2431 does not support local accounts.

Passwords

The SEL-2431 supports strong passwords with as many as 12 characters, using any printable character, to allow users to select complex passwords if they so choose. SEL recommends that passwords have a minimum of eight characters and include at least one of each of the following: lowercase letter, uppercase letter, number, and special character.

Physical Access Controls

Physical security of cybersecurity assets is a common concern. In retrofit applications, SEL-2431 controls are normally installed within a control enclosure that provides physical security. In applications that include the SEL-2431 Enclosure, the enclosure has been designed with a pad lockable slotted-drive cam lock and the cable entrances support security sleeves, adding a level of physical security to the enclosure.

Logging Features

Internal Log Storage

The SEL-2431 SER is a useful tool for capturing a variety of relay events. In addition to capturing state changes of user-selected Relay Word bits, it captures all startups, settings changes, and group switches. See *Section 11: Analyzing Events*.

Alarm Contact

You can monitor physical ingress by wiring a door sensor to one of the SEL-2431 contact inputs. You can then map this input for SCADA monitoring or add it to the SER log so that you can monitor when physical access to the control occurs. It is also possible to wire an electronic latch to an SEL-2431 contact output. You could then map this output for SCADA control.

Malware Protection Features

The SEL-2431 has inherent and continuous monitoring for malware. For a full description of this, see selinc.com/mitigating_malware/.

Product Updates

It is recommended to monitor for instruction manual releases and read the most recent entry in *Appendix A: Firmware and Manual Versions*.

If SEL finds a security vulnerability with the SEL-2431, it will be disclosed using our standard security notification process. For a full description of this process, see selinc.com/support/security-notifications/.

Obtaining Updates

This device supports digitally signed firmware upgrades. SEL uses the SHA-256 secure hash algorithm to compress and digitally sign firmware upgrade files. The signature ensures that the file has been provided by SEL and that its contents have not been altered. When the file is uploaded to the relay, the signature is verified using a public key stored on the relay. If the relay cannot verify the signature, it rejects the file. See *Appendix B: Firmware Upgrade Instructions* for more information on firmware upgrades.

Update Verification

The SEL-2431 has the ability to install firmware updates in the field. Verify the authenticity and integrity of firmware updates by using the Firmware Hash page at selinc.com/products/firmware/.

Contact SEL

For further questions or concerns about SEL product security, please contact SEL:

Email: security@selinc.com or phone +1-509-332-1890.

Glossary

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.

ACSELERATOR QuickSet SEL-5030 A Windows®-based program that simplifies settings and provides analysis support.

Active Settings Group The settings group that the SEL-2431 is presently using from among six settings groups available in the relay.

Analog Quantities Variables represented by such fluctuating measurable quantities as tap position, 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.

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-amperes (VA), kilovolt-amperes (kVA), or megavolt-amperes (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.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The SEL-2431 uses ASCII text characters to communicate, using front- and rear-panel serial ports on the voltage regulator control.

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-2431 input. To close a normally open output contact. To open a normally closed output contact.

Auto Auto/Manual control in Auto position (manual raise/lower controls disabled).

Autoconfiguration The ability to determine device type, model number, metering capability, port ID, data rate, passwords, relay elements, and other information that an IED (e.g., SEL-2032/SEL-2030/SEL-2020 Communications Processors) needs to automatically communicate with intelligent electronic devices.

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.

Band Width The band width, expressed in volts and centered on the center band, in which the control does not attempt to control the voltage. A larger band width setting reduces the number of voltage regulator operations compared to a smaller setting.

Bidirectional Selectable operating mode. Designed for applications where the power flow is expected to be forward or reverse. Regulation occurs on the L-bushing side of the regulator for forward power flow, and on the S-bushing side of the regulator for reverse power flow. If a no-load situation arises, the control does not perform any tap-changes and stays at the last tap position (unless a BIASMODE setting is made).

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators, such as AND, NOT, and OR.

Center Band The desired system voltage, expressed on a secondary base, typically scaled at the utilization voltage level.

Closed Delta Three voltage regulators connected line-to-line, usually on a three-wire system. All three closed-delta regulators in a three-phase bank are either leading or lagging units, depending on phase connections. Consult the voltage regulator instruction manual for wiring details.

Cogeneration Selectable operating mode. Designed for applications where the power flow is expected to be forward or reverse, but the source for reverse power is a cogeneration facility without the ability to affect the overall system (bus) voltage. Regulation occurs on the L-bushing side of the regulator (using forward LDC settings for forward power flow and reverse LDC settings for reverse power flow). If a no-load situation arises, the control does not perform any tap-changes, and stays at the last tap position (unless a BIASMODE setting is made).

Contact Input See Control Input.

Contact Output See Control Output.

Control Input Voltage regulator control input for monitoring the state of external circuits.

Control Output Voltage regulator control output that affects the state of other equipment.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

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-2431 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 that the SEL-2431 uses in DNP protocol.

Delta-Connected Line-to-line connected voltage regulator (may be open delta, or closed-delta).

Demand Meter A measuring function that calculates a thermal average of instantaneous measurements over time.

Device Word Bit A single relay element or logic result. A Device 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 Device Word bits in SELOGIC control equations.

DNP3 (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.).

EIA-232 Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

ESD (Electrostatic Discharge) The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

Event History A quick look at recent voltage regulator control activity that includes a standard report header; event number, date, time, line current, etc.

Event Report A collection of data stored by the voltage regulator control in response to a triggering condition, such as a fault or ASCII **TRI** command. The data show voltage regulator control measurements before and after the trigger, in addition to the states of control elements, voltage regulator control inputs, and voltage regulator control outputs each processing interval. Use event reports to analyze voltage regulator control and system performance.

External Source A set of terminals on the front-panel of the SEL-2431 that enables a temporary power source to energize the control and the attached 120 Vac circuitry (e.g., motor raise/lower circuits) of the voltage regulator.

Fast Meter SEL binary serial port command used to collect metering data with SEL devices.

Fast Operate SEL binary serial port command used to perform control with SEL devices.

Firmware The nonvolatile program stored in the voltage regulator control that defines device operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Flexible Distributed Generation Selectable operating mode. Designed for applications where the power flow is expected to be forward or reverse and the change in power flow direction can be due to either the stiffer utility source switching sides or cogeneration/distributed generation (DG) on either side of the voltage regulator. Regulation occurs on the L-bushing side of the regulator for the stiffer source being on the S-bushing side, and on the S-bushing side of the regulator for the stiffer source being on the L-bushing side. The stiffer source is surmised by monitoring voltage changes for tap operations (not by power flow direction). If a no-load situation arises, the control does not perform any tap-changes and stays at the last tap position (unless a BIASMODE setting is made).

Forward Power flow out from the L-bushing.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

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 regulator type, date format, nominal system frequency, settings group selection, and current and voltage ratings.

GUI Graphical user interface.

Holding Switch Cooper/McGraw-Edison voltage regulators use an internal switch to seal in a raise or lower operation. The SEL-2431 monitors the holding switch current to determine when a tap change is complete.

HMI Human-machine interface.

Idle Reverse Selectable operating mode. Similar to Locked Forward mode. Designed for applications where the power flow is expected to be forward. Regulation occurs on the L-bushing side of the regulator. If a no-load or reverse power situation arises, the control does not perform any tap-changes, and stays at the last tap position.

Inverted Voltage regulator configuration. Type B = “Inverted” and features a utility or shunt winding on the L-terminal side of the tap-changer.

L-Bushing Standard labeling for one of the three high-voltage connections on a step-type voltage regulator. The “L” stands for “load”, in the normal, or forward, power flow convention. Also called the L-terminal.

Lag Delta configuration where the line current lags the voltage signal, typically by 30 degrees.

Lead Delta configuration where the line current leads voltage signal, typically by 30 degrees.

Line-Drop Compensation (LDC) Method of attempting to keep a regulation point out on the system at a constant voltage. The voltage drop between the voltage regulator and this regulation point is calculated using measured current and voltage and applying these values to line impedance-related settings.

Local Remote/Local control in Remote position (acts like “Supervisory Off”).

Local Bits The Device Word bit outputs of local control switches that you access through the SEL-2431 front panel. Local control switches replace traditional panel-mounted control switches.

Locked Forward Selectable operating mode. Designed for applications where the power flow is expected to be forward. Regulation occurs on the L-bushing side of the regulator. If a reverse power situation arises, the control does not perform any tap-changes and stays at the last tap position.

Locked Reverse Selectable operating mode. Designed for applications where the power flow is expected to be reverse. Regulation occurs on the S-bushing side of the regulator. If a forward power situation arises, the control does not perform any tap-changes and stays at the last tap position.

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.

Lower A lower operation moves the tap position to a numerically lower number, and lowers the L-terminal voltage in a forward power flow situation. In reverse power flow situations, a lower operation raises the S-terminal voltage.

Manual Auto/Manual control in Manual position (automatic raise/lower function disabled).

Maximum/Minimum Meter Type of meter data presented by the SEL-2431 that includes a record of the maximum and minimum of each value, along with the date and time that each maximum and minimum occurred.

Motor Current The voltage regulator tap-changer motor has separate inputs for raise and lower operations. The SEL-2431 monitors the raise and lower current to track regulator operations.

Neutral Position A “straight-through” tap position on a voltage regulator that is neither boosting nor bucking the system voltage. Also referred to as tap position 0.

Nonvolatile Memory Device memory that persists over time to maintain the contained data even when the device is de-energized.

NOT Operator A logical operator that produces the inverse value.

Open Delta Two voltage regulators connected line-to-line, usually one a three-wire system. One open-delta regulator is a leading unit, and the other is a lagging unit. Consult the voltage regulator instruction manual for wiring details.

Operating Mode The voltage regulator control can be configured to act differently in forward, reverse, and zero power flow situations, as defined by the control operating mode setting. The supported operating modes are Locked Forward, Locked Reverse, Idle Reverse, Bidirectional, Cogeneration, and Flexible Distributed Generation.

Operations Counter A counter that keeps track of voltage regulator operations or tap changes. The SEL-2431 also keeps track of the number of times each tap position is entered.

Operations Counter Switch Voltage regulators made by Siemens/Allis-Chalmers, Howard Industries, and General Electric (GE) provide an operations counter switch signal. The SEL-2431 uses the Operations Counter Switch signal to determine when a tap change is complete.

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.

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 line currents and power readings. The SEL-2431 stores peak demand values and the date and time these occurred to nonvolatile storage every four hours, overwriting the previously stored value if the new value is larger. Should the voltage regulator control lose control power, the voltage regulator control restores the previously recorded peak demand information.

R_TRIG Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.

Raise A raise operation moves the tap position to a numerically higher number, and raises the L-terminal voltage in a forward power flow situation. In reverse power flow situations, a raise operation lowers the S-terminal voltage.

Remote Remote/Local control in Remote position (acts like "Supervisory On").

Reverse Power flow out from the S-bushing.

Reversing Switch A mechanically controlled switch inside the voltage regulator that controls whether the tap-changer is adding or subtracting from the effective turns-ratio.

RTU Remote Terminal Unit.

RXD Received data.

S-Bushing Standard labeling for one of the three high-voltage connections on a step-type voltage regulator. The "S" stands for "source" in the normal, or forward, power flow convention. Also called the S-terminal.

SCADA Supervisory control and data acquisition.

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-2431 has self-tests that validate the voltage regulator control power supply, microprocessor, memory, and other critical systems.

SELOGIC Control Equation A voltage regulator control setting that allows you to control a function (such as a control output) using a logical combination of voltage regulator control element outputs and fixed logic outputs.

SELOGIC Expression Builder A rules-based editor within QuickSet for programming SELOGIC control equations.

Sequential Events Recorder A voltage regulator control function that stores a record of the date and time of each assertion and deassertion of every Device Word bit in a list that you set in the voltage regulator control. SER provides a useful way to determine the order and timing of events of a device operation.

SER Sequential Events Recorder or the voltage regulator control serial port command to request a report of the latest 1024 sequential events.

SL-Bushing Standard labeling for one of the three high-voltage connections on a step-type voltage regulator. The "SL" stands for source-load and is connected to the system neutral for line-to-neutral connected voltage regulators. For line-to-line connected voltage regulators, the SL terminal is connected to a phase conductor. Also called the SL-terminal.

Status Failure A severe out-of-tolerance internal operating condition. The voltage regulator control issues a status failure message and enters a control-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise voltage regulator control operation, yet are beyond expected limits. The voltage regulator control issues a status warning message and continues to operate.

Straight Voltage regulator configuration. Type A = "Straight" and features a utility or shunt winding on the S-terminal side of the tap-changer.

Tap-Changer The motor-operated mechanism inside the voltage regulator that connects various transformer taps to obtain discrete voltage steps, typically 5/8 of a percent.

Tap Position The tap position of the voltage regulator (physical tap position), or the SEL-2431 internal tap position (control tap position). Tap position ranges from –16 to +16. Tap position 0 is the same as neutral position, but only the NEUTRAL POSITION indicator should be used for verification of neutral position. Tap positions > 0 indicate a raising (boost) of voltage in the nominal load (forward) direction. Tap positions < 0 indicate a lowering (buck) of voltage in the nominal load (forward) direction.

Tap-Position Indicator A mechanical indication on the outside of a voltage regulator, typically connected by a cable to the tap-changer mechanism, and housed behind a weatherproof window.

Time Delay The time that an out-of-band condition must exist before a tap change operation can begin.

Type A ANSI voltage regulator configuration. Type A = “Straight” and features a shunt winding on the S-terminal side of the tap-changer.

Type B ANSI voltage regulator configuration. Type B = “Inverted” and features a shunt winding on the L-terminal side of the tap-changer.

Volt Meter A set of terminals on the front-panel of the SEL-2431 that allows connection of a hand-held digital voltmeter to measure present load-side voltage.

Wye-Connected Line-to-neutral connection. Often used in single-phase applications on solidly grounded systems.

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SEL-2431 Command Summary

Command	Description
Access Level 0	
ACCESS	Go to Access Level 1.
BNAMES	ASCII names of all voltage regulator control status bits in Compressed ASCII format (Fast Meter).
CASCII	Display the Compressed ASCII configuration message.
DNAMES	ASCII names of all Device Word bits in Compressed ASCII format (Fast Meter).
ID	Display the firmware ID, user ID, device code, part number, and configuration information.
QUIT	Reduce access level to Access Level 0 (exit voltage regulator control).
Access Level 1	
2ACCESS	Go to Access Level 2.
CEVENT *n*	Display the Compressed ASCII event report for event *n*.
CHISTORY	Display the Compressed ASCII version of the **HISTORY** command.
COUNTER *k*	Show the SELOGIC counter values. Enter *k* for repeat count.
CPROFILE	Display the Compressed ASCII version of the **PROFILE** command.
CSTATUS	Display the Compressed ASCII version of the **STATUS** command.
DATE	Show date.
DATE *date*	Enter date in accordance with Date Format setting DATE_F = MDY, YMD, or DMY.
FILE DIR|READ|SHO	Transfer data from the voltage regulator control to a PC.
GROUP	Display active settings group number.
HELP	Display available commands or command help at each access level.
HISTORY C	Clear the brief summary and corresponding event reports.
HISTORY R	Clear the brief summary and corresponding event reports.
HISTORY *n*	Show brief summary of the *n* latest event reports.
LDP *date1 date2*	Show rows in the Signal Profile report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
LDP *row1 row2*	Show rows *row1* through *row2* in the Signal Profile report.
LDP C	Clear the Signal Profile Report.
MAP *p*	Display DNP3 map for Port *p*.
METER D	Display demand and peak demand data. Select **MET D R D** or **MET D R P** to reset.
METER E	Display energy metering data. Select **MET E R** to reset.
METER H	Display THD and harmonic metering data.
METER *k*	Display fundamental (instantaneous) metering data. Enter *k* for repeat count.
METER M	Display maximum/minimum metering data. Select **MET M R** to reset.

Command	Description
METER D R D	Reset demand metering data.
METER E R	Reset energy metering data.
METER M R	Reset maximum metering data.
METER D R P	Reset peak demand metering data.
PROFILE *date1 date2*	Show rows in the Signal Profile report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
PROFILE *row1 row2*	Show rows *row1* through *row2* in the Signal Profile report.
PROFILE C	Clear the Signal Profile Report.
SER C	Clear/reset recently SER records.
SER *date1 date2*	Show rows in the Sequential Events Recorder (SER) event report from dates *date1* to *date2*. Entry of dates is dependent on the Date Format setting DATE_F (= MDY, YMD, or DMY).
SER *row1 row2*	Show rows *row1* through *row2* in the Sequential Events Recorder (SER) event report.
SHOW D *n*	Show DNP map *n* settings (*n* = 1–2).
SHOW F	Show Front Panel settings.
SHOW G	Show Global settings.
SHOW L *n*	Show SELOGIC control equation settings for settings Group *n* (*n* = 1–6).
SHOW *n*	Show “regular” settings for settings Group *n* (*n* = 1–6).
SHOW P *n*	Show Port settings for Port *n* (*n* = 1, 2, 3, F).
SHOW R	Show Report settings.
STATUS *k*	Show voltage regulator control self-test status. Enter *k* for repeat count (defaults to 1).
STATUS S	Display the memory and execution utilization for the SELOGIC control equations.
TAP	Display the tap position change counts (total and per-tap position).
TAP P	Display the present tap position stored in the voltage regulator control’s memory.
TAP P *x*	Change the present tap position stored in the voltage regulator control’s memory to *x*.
TAP R	Reset all tap position counters.
TAP W	Preload tap position counter values.
TARGET *n k*	Display control elements for a row in the Device Word table. If *n* is a row number from the Device Word table, display row *n*. If *n* is an element name, display the row containing element *n*. Enter *k* for repeat count.
TIME	Show or set time (24-hour time). Show the present time by entering **TIME**. Set the present time by entering **TIME *xx:xx:xx***.
TRIGGER	Trigger an event report.
VERSION	Show firmware version and options.
Access Level 2	
CONTROL RB*nn k*	Set, clear, or pulse internal Remote Bit *nn* (*nn* is the Remote Bit number from 01–16). Parameter *k* can be the following: **S** To set Remote Bit *nn* (assert RB*nn*). **C** To clear Remote Bit *nn* (deassert RB*nn*). **P** To pulse Remote Bit *nn* (assert RB*nn* for 1 cycle).

Command	Description
CONTROL O *n m*	Pulse digital output *n* (*n* is the output contact from OUT101–OUT104). Parameter *m* is the time duration from 1–30 seconds, 1 second is default if unspecified.
COPY *m n*	Copy settings and logic equations from settings Group *m* to settings Group *n*.
FILE WRITE	Transfer settings files from a PC to the voltage regulator control.
GROUP *n*	Change active settings group to settings Group *n* (*n* = 1–4).
L_D	Download firmware to the voltage regulator control.
LOWER	Lower the tap position of the regulator by one position.
PAR	Set SEL-2431 part number.
PAS 1 *xxxxxx*	Change Access Level 1 password to *xxxxxx*.
PAS 2 *xxxxxx*	Change Access Level 2 password to *xxxxxx*.
PULSE OUT*nnn s*	Pulse output contact OUT*nnn* (*nnn* = 101–104, 201, 202) for *s* (1–30) seconds. Parameter OUT*nnn* must be specified; *s* defaults to 1 if not specified.
RAISE	Raise the tap position of the regulator by one position.
R_S	Restore the factory-default setting and passwords and reboot the voltage regulator control (only available if there is a diagnostic failure).
SET D *n*	Change DNP map *n* settings (*n* = 1–2).
SET F	Change Front Panel settings.
SET G	Change Global settings.
SET L *n*	Change SELOGIC control equation settings for settings Group *n* (*n* = 1–6).
SET *n*	Change “regular” settings for settings group *n* (*n* = 1 –6).
SET P *n*	Change Port settings for Port *n* (*n* = 1, 2, F).
SET R	Change Report settings.
STATUS C/R	Clear status warning or failure and reboot the voltage regulator control.

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SEL-2431 Command Summary

Command	Description
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BNAMES	ASCII names of all voltage regulator control status bits in Compressed ASCII format (Fast Meter).
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LOWER	Lower the tap position of the regulator by one position.
PAR	Set SEL-2431 part number.
PAS 1 *xxxxxx*	Change Access Level 1 password to *xxxxxx*.
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