



# SEL-401 Protection, Automation, and Control Merging Unit

## Protection, Automation, and Control Merging Unit



## Key Features and Benefits

The SEL-401 Merging Unit publishes IEC 61850-9-2 Sampled Values (SV) data streams according to the IEC 61850-9-2LE (9-2LE) guideline for use by compliant substation relays and provides phase overcurrent and breaker-failure backup protection in the absence of substation network communication.

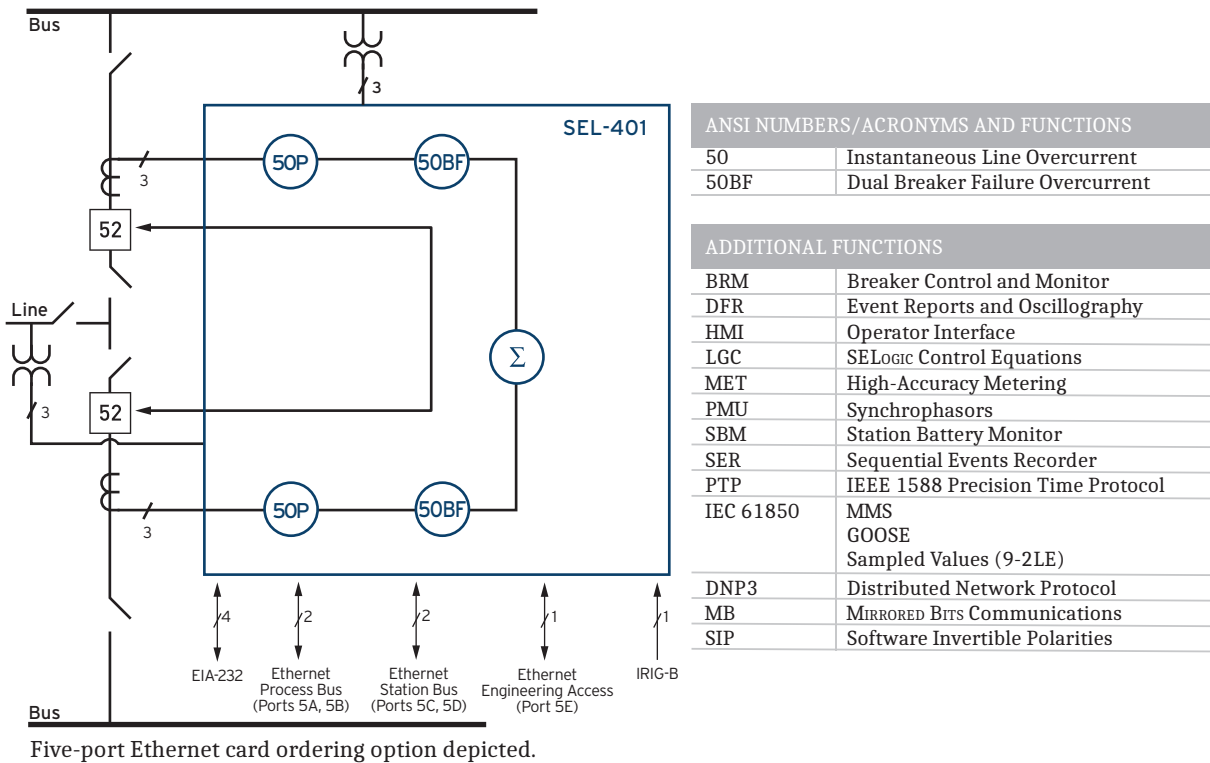
- **Protection.** Use the SEL-401 to support breaker failure and phase overcurrent elements to provide protection during a loss of communication to an SV subscriber.
- **Automation.** Take advantage of enhanced automation features that include 64 programmable local and remote control elements and 32 protection and automation latching elements. Local metering on the large-format front-panel LCD eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, IEEE C37.118 Synchrophasors, IEC 61850 Edition 2 GOOSE messages and MMS reporting, Sequential Events Recorder (SER) reports, breaker monitoring, relay summary event reports, and time synchronization. Use expanded SELOGIC<sup>®</sup> control equations with math and comparison functions in control applications. Incorporate as many as 100 lines of automation logic to speed and improve control actions.
- **IEC 61850-9-2 Sampled Values Merging Unit.** Publishes current and voltage information that is provided to subscribing remote relays instead of the relay by using standard PT and CT inputs to reduce cable lengths, labor costs, and improve the overall safety of the substation.
- **IEC 61850 Operating Modes.** The relay supports IEC 61850 standard operating modes such as Test, Blocked, On, and Off.
- **Digital Relay-to-Relay Communications.** Use MIRRORING BITS<sup>®</sup> communications to monitor internal element conditions between relays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORING BITS channel. The SEL-401 time correlates the data for use in SELOGIC control equations.

- **Parallel Redundancy Protocol (PRP).** Provide seamless recovery from any single Ethernet network failure, in accordance with IEC 62439-3:2010. The station bus and process bus Ethernet networks support PRP.<sup>a</sup>
- **IEEE 1588-2008 Precision Time Protocol (PTP).** Provide high-accuracy timing over an Ethernet network.
- **Dual CT Input.** Combine currents within the relay from two sets of current transformers (CTs) for protection functions, but keep them separately available for monitoring and station integration applications.
- **Monitoring.** Schedule breaker maintenance when accumulated breaker duty indicates possible excess contact wear. Electrical and mechanical operating times are recorded for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems (two independent battery monitors) even if the voltage is low only during trip or close operations.
- **Breaker Failure.** Use high-speed (5/8-cycle) open-pole detection logic to reduce coordination times for critical breaker failure applications. Use the SEL-401 to supply three-pole breaker failure detection for one or two breakers. Necessary logic for three-pole breaker failure retrip and initiation of transfer tripping is included.
- **Oscillography.** Record voltages, currents, and internal logic points at as high as 8 kHz sampling rate. Phasor and harmonic analysis features allow investigation of relay and system performance.
- **Rules-Based Settings Editor.** Communicate with and set the relay using an ASCII terminal, or use the PC-based SEL Grid Configurator software to configure the SEL-401.
- **Sequential Events Recorder (SER).** Record the last 1000 entries, including settings changes, power-ups, and selectable logic elements.
- **Comprehensive Metering.** Improve feeder loading by using built-in, high-accuracy metering functions. Use watt and VAR measurements to optimize feeder operation. Minimize equipment needs with full metering capabilities, including root-mean-square (rms), maximum/minimum, and instantaneous values.
- **Synchrophasors.** Make informed load dispatch decisions based on actual real-time phasor measurements from SEL-401 relays across your power system. Record streaming synchrophasor data from SEL-401 relays for system-wide disturbance recording. Control the power system by using local and remote synchrophasor data.

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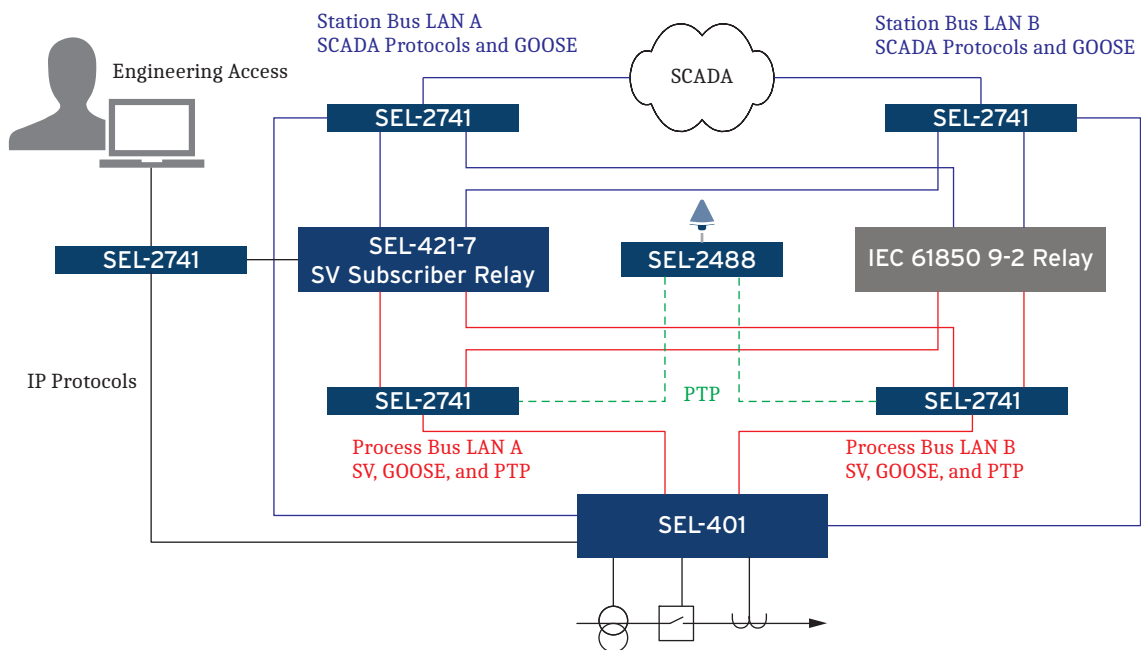
<sup>a</sup> Only the five-port Ethernet card ordering option supports PRP on both the station bus and the process bus.

# Functional Overview



**Figure 1 SEL-401 Functional Overview**

The SEL-401 can provide basic overcurrent and breaker failure protection. Using the process bus, the SEL-401 provides voltage and current information to multiple relays that subscribe to SV. The data can be synchronized using IEEE 1588-2008 PTP or IRIG-B time input. *Figure 2* shows an example PRP network that uses the five-port Ethernet card ordering option.



**Figure 2 Example System Connection and Integration**

# Protection Features

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The SEL-401 publishes SV data streams to relays that can subscribe to these data. The SEL-401 publishes as many as seven outgoing data streams. The default Configured IED Description (CID) file will be configured for four publications but can be configured for as many as seven by using ACSELERATOR Architect<sup>®</sup> SEL-5032 Software.

## Overcurrent Elements

The SEL-401 includes four phase instantaneous overcurrent elements. You can select the operating quantities from the following:

I|A|, I|B|, I|C|, MAX (I|A|, I|B|, I|C|)

## Breaker Failure Protection

A full-function breaker failure system is incorporated into the SEL-401. Current can be individually monitored in two breakers. High-speed open-pole detection logic allows you to set the pickup current below the minimum load for sensitivity without sacrificing high-speed drop-out. Even in cases with delayed current zeros in the secondary of the CT caused by trapped flux, high-speed detection of circuit breaker opening occurs. If breaker failure is initiated on all circuit breaker trips, this feature is essential. A 5/8-cycle reset reduces coordination times, improving stability.

## Six Independent Settings Groups Increase Operation Flexibility

The relay stores six settings groups. Select the active settings group by control input, command, or other programmable conditions. Use these settings groups to cover a wide range of protection and control contingencies. Selectable settings groups make the SEL-401 ideal for applications requiring frequent settings changes and for adapting the protection to changing system conditions.

Selecting a group also selects logic settings. Program group logic to adjust settings for different operating conditions, such as station maintenance, seasonal operations, emergency contingencies, loading, source changes, and adjacent relay settings changes.

## Control Inputs and Outputs

The basic SEL-401 does not include main-board input/output (I/O). The SEL-401 supports a 4U chassis (1 additional I/O board), 5U chassis (2 additional I/O boards), and 6U chassis (3 additional I/O boards). The following additional I/O boards are currently available.

- Eight optoisolated, independent, level-sensitive inputs; thirteen standard Form A and two standard Form C contact outputs
- Eight optoisolated, independent, level-sensitive inputs; thirteen high-current interrupting Form A outputs and two standard Form C contact outputs
- Twenty-four optoisolated, independent, level-sensitive inputs; six high-speed, high-current interrupting, Form A contact outputs and two standard Form A outputs
- Twenty-four optoisolated, independent, level-sensitive inputs and eight standard Form A outputs
- Twenty-four optoisolated, independent, level-sensitive inputs and eight high-speed, high-current interrupting, Form A contact outputs.

Assign the control inputs for control functions, monitoring logic, and general indication. Each control output is programmable using SELOGIC control equations.

## Two-Breaker Control

The SEL-401 contains analog voltage inputs for multiple sources and control inputs to indicate both breaker and disconnect position as well as the logic required to provide full control for two breakers. All analog values are monitored on a per-breaker basis to allow station control access to complete information for individual components of the system.

# Network Connection and Integration

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## Ethernet Card

The Ethernet card has five small form-factor pluggable (SFP) ports.<sup>b</sup> PORT 5A and PORT 5B are reserved for the process bus network. PORT 5C and PORT 5D are reserved for the station bus network. The process and station bus

networks support PRP and fast failover redundancy modes. PORT 5E operates on an isolated network with a unique IP address making it ideal for engineering and data access. All ports support 100 Mbps speeds. PORT 5A and PORT 5B also support 1 Gbps speeds to satisfy potentially large traffic requirements on the process bus. The

process bus, station bus, and engineering access networks use separate MAC addresses and are logically delineated, including in the CID file.<sup>c</sup>

The Ethernet card provides PTP for data time synchronization. Use popular Telnet applications for easy terminal communications with SEL relays and other devices. Transfer data at high speeds for fast HMI updates and file uploads. The Ethernet card communicates using File Transfer Protocol (FTP) applications for easy and fast file transfers.

Provide operations with situational awareness of the power system by using the IEEE C37.118-2005, Standard for Synchrophasors for Power Systems. Communicate with SCADA and other substation IEDs by using DNP3 or MMS and GOOSE messaging.

Choose Ethernet connection media options for primary and stand-by connections:

- 10/100BASE-T twisted-pair network<sup>d</sup>
- 100BASE-FX fiber-optic network
- 1000BASE-X fiber-optic network<sup>e</sup>

## Telnet and FTP

The SEL-401 is equipped with an Ethernet communications card that supports Telnet and FTP that enhance communications sessions. Use Telnet to access relay settings and metering and event reports remotely using the ASCII interface. Transfer settings files to and from the relay by using FTP.

## DNP3 LAN/WAN

The DNP3 LAN/WAN option provides the SEL-401 with DNP3 Level 2 Outstation functionality over Ethernet. Custom DNP3 data maps can be configured for use with specific DNP3 masters.

## HTTP Web Server

The relay can serve read-only webpages displaying certain settings, metering, and status reports. As many as four users can access the embedded HTTP server simultaneously.

<sup>b</sup> SFP transceivers are not included with the card and must be ordered separately. See [selinc.com/products/sfp](http://selinc.com/products/sfp) for a list of compatible SFP transceivers.

<sup>c</sup> This paragraph describes the five-port Ethernet card ordering option. It does not apply to the four-port Ethernet card ordering option.

<sup>d</sup> Four-port Ethernet card ordering option only.

<sup>e</sup> Gigabit speeds are only available on **PORT 5A** and **PORT 5B** of the five-port Ethernet card ordering option.

# IEC 61850 Ethernet Communications

IEC 61850 Edition 2 Ethernet-based communications provide interoperability between intelligent electronic devices within the substation. Logical nodes using IEC 61850 Edition 2 allow standardized interconnection of intelligent devices from different manufacturers for monitoring and control of the substation. Reduce wiring between various manufacturers' devices and simplify operating logic. Eliminate system remote terminal units (RTUs) by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

The SEL-401 supports IEC 61850 Edition 2 protocols operating on 100 Mbps or 1 Gbps Ethernet.<sup>c</sup> Use the Ethernet protocol for relay monitoring and control functions, including the following.

- The SEL-401 supports self-monitoring of the Ethernet links and validates the data quality, which reduces the need for periodic testing of the communications network.
- The SEL-401 can publish as many as four data streams of SV data and provide basic backup overcurrent and breaker failure protection in the absence of substation network communication.
- As many as 128 incoming GOOSE messages, which can be used to control as many as 256 control bits in the relay with <3 ms latency from device to device. These messages provide binary control inputs to the relay for high-speed control functions and monitoring.
- As many as eight outgoing GOOSE messages, which can be configured for Boolean or analog data. Boolean data are provided with <3 ms latency from device to device. Use outgoing GOOSE messages for high-speed control and monitoring of external breakers, switches, and other devices.
- IEC 61850 Edition 2 Data Server: The SEL-401 is equipped with embedded Ethernet protocol and provides data according to predefined logical node objects. As many as seven simultaneous client associations are supported by each relay. Relevant Relay Word bits are available within the logical node data, so status of relay elements, inputs, outputs, or SELOGIC equations can be monitored using the data server provided in the relay.
- The SEL-401 supports IEC 61850 standard operating modes such as Test, Blocked, On, and Off.

Use Architect to manage the IEC 61850 configuration for devices on the network. This Microsoft Windows-based software provides easy-to-use displays for identifying and binding IEC 61850 network data between logical nodes by using IEC 61850-compliant CID files. CID files are used by Architect to describe the data that will be provided by the IEC 61850 logical node within each relay.

# Metering and Monitoring

## Metering Capabilities

The SEL-401 provides metering capabilities, as listed in *Table 1*.

**Table 1 Metering Capabilities**

Capabilities	Description
<b>Instantaneous Quantities</b>	
Voltages VA,B,C (Y), VA,B,C (Z), V $\phi\phi$ , 3V0, V1, 3V2	0–300 V with phase quantities for each of the six voltage sources available as a separate quantity.
Currents IA,B,C (W), IA,B,C (X) IAL, IBL, ICL, (combined currents) IGL, I1L, 3I2L (combined currents)	Phase quantities for each of the two current sources are available as a separate quantity or combined as line quantities.
<b>Power/Energy Metering Quantities</b>	
MW, MVAR, MVA, PF, single-phase and three-phase	Available for each input set and as combined quantities for the line.
<b>Synchrophasors</b>	
Voltages (Primary Magnitude, Angle) VA,B,C (Y), VA,B,C (Z)	Primary phase quantities (kV) for each of the six voltage sources available.
Currents (Primary Magnitude, Angle) IA,B,C (W), IA,B,C (X)	Primary phase quantities (A) for each of the six current sources available.
Frequency FREQ dF/dT	Frequency (Hz) as measured by frequency source potential inputs. Rate-of-change in frequency (Hz/s).

## Event Reporting and SER

Event reports and Sequential Events Recorder (SER) features simplify post-fault analysis and help improve your understanding of both simple and complex protective scheme operations. These features also aid in testing and troubleshooting merging unit and relay settings and protection schemes. Oscillograms are available in binary COMTRADE and ASCII COMTRADE formats.

## SV Reporting

The SEL-401 includes a comprehensive report of the SV communication stream. The ASCII command **COM SV** displays statistics information from the SV stream to aid in troubleshooting.

## Oscillography and Event Reporting

In response to a user-selected internal or external trigger, the voltage, current, and element status information contained in each event report confirms merging unit, scheme, and system performance for every fault. Decide how much detail is necessary when an event report is triggered: 8 kHz, 4 kHz, 2 kHz, or 1 kHz resolution analog data. The merging unit stores from 5 seconds of data

per fault (at 1 kHz resolution) to 2 seconds per fault (at 8 kHz resolution). Reports are stored in nonvolatile memory. Relay settings that are operational in the relay at the time of the event are appended to each event report.

## Event Summary

Each time the SEL-401 generates a standard event report, it also generates a corresponding Event Summary. This is a concise description of an event that includes the following information:

- Merging unit/terminal identification
- Event date and time
- Event type
- System frequency at time of trigger
- Phase voltages
- Pre-fault and faulted phase current levels
- Pre-fault and fault-calculated zero- and negative-sequence currents
- Active group targets
- Status of all MIRRORED BITS channels
- Trip and close times of day
- Breaker status (open/close)

With an appropriate setting, the merging unit will automatically send an event summary in ASCII text to one or more serial ports each time an event report is triggered.

## SER

Use this feature to gain a broad perspective of merging unit and relay element operation. Items that trigger an SER entry are selectable and can include input/output change of state, element pickup/dropout, etc. The merging unit SER stores the latest 1,000 entries.

## High-Accuracy Timekeeping

Using high-accuracy IRIG-B or IEEE 1588 from a global positioning satellite clock, the SEL-401 can time-tag oscillography to within 10  $\mu$ s accuracy. This high accuracy can be combined with the high sampling rate of the merging unit to synchronize data from across the system with an accuracy of better than 1/4 electrical degree. This allows examination of the power system state at given times, including load angles, system swings, and other system-wide events. Triggering can be via external signal (contact or communications port), set time, or system event. Optimal calibration of this feature requires a knowledge of primary input component (VT and CT) phase delay and error.

A standard-accuracy IRIG-B time-code input synchronizes the SEL-401 time to within  $\pm 1 \mu$ s of the time-source input. A convenient source for this time code is an SEL communications processor (via serial PORT 1 on the SEL-401).

## Substation Battery Monitor for DC Quality Assurance

The SEL-401 measures and reports the substation battery voltage for two-battery systems. Two sets of programmable threshold comparators and associated logic provide alarm and control of two separate batteries and chargers. The merging unit also provides dual ground detection. Monitor these thresholds with an SEL communications processor and trigger messages, telephone calls, or other actions.

The measured dc voltage is reported in the METER display via serial port communication, on the LCD, and in the event report. Use the event report data to see an oscillo-

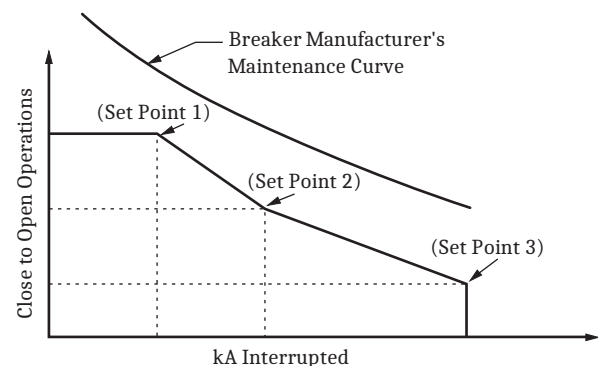
graphic display of the battery voltage. Monitor the substation battery voltage drops during trip, close, and other control operations.

## Breaker Monitor Feature Allows for Wear-Based Breaker Maintenance Scheduling

Circuit breakers experience mechanical and electrical wear at each operation. Effective scheduling of breaker maintenance takes into account the manufacturer's published data of contact wear versus interruption levels and operation count. The SEL-401 dual-breaker monitor feature compares the breaker manufacturer's published data to the integrated actual interrupted current and number of operations.

- Every time the breaker trips, the merging unit integrates interrupted current. When the result of this integration exceeds the threshold set by the breaker wear curve (*Figure 3*), the relay can alarm via an output contact or the front-panel display. With this information, you can schedule breaker maintenance in a timely, economical fashion.
- The merging unit monitors the last and the average mechanical and electrical interruption time. You can easily determine if operating time is increasing beyond reasonable tolerance to schedule proactive breaker maintenance. You can activate an alarm point if operation time goes beyond a preset value.

Breaker motor run time, pole scatter, pole discrepancy, and breaker inactivity are also monitored.



**Figure 3 Breaker Contact Wear Curve and Settings**

# Automation

## Flexible Control Logic and Integration Features

Use the SEL-401 control logic to do the following:

- Replace traditional panel control switches
- Eliminate RTU-to-relay wiring
- Replace traditional latching relays
- Replace traditional indicating panel lights

Eliminate traditional panel control switches with 64 local control points. Set, clear, or pulse local control points with the front-panel pushbuttons and display. Program the local control points to implement your control scheme via SELOGIC control equations. Use the local control points for such functions as trip testing, enabling/disabling reclosing, and tripping/closing circuit breakers.

Eliminate RTU-to-relay wiring with 64 remote control points. Set, clear, or pulse remote control points via serial port commands. Incorporate the remote control points into your control scheme via SELOGIC control equations. Use remote control points for SCADA-type control operations (for example, trip, close, or settings group selection).

Replace traditional latching relays for such functions as “remote control enable” with 32 latching control points. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the latch control points via control inputs, remote control points, local control points, or any programmable logic condition. The latch control points retain states when the relay loses power.

Replace traditional indicating panel lights and switches with as many as 24 latching target LEDs and as many as 12 programmable pushbuttons with LEDs. Define custom messages (such as BREAKER OPEN or BREAKER CLOSED) to report power system or relay conditions on the large-format LCD. Control which messages are displayed via SELOGIC control equations by driving the LCD via any logic point in the relay.

## Open Communications Protocols

The SEL-401 does not require special communications software. ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port are all that is required. *Table 2* lists a synopsis of the terminal protocols.

**Table 2 Open Communications Protocol**

Type	Description
ASCII	Plain-language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter, Fast Operate, and Fast SER	Binary protocol for machine-to-machine communication. Quickly updates SEL-2032 Communications Processors, RTUs, and other substation devices with metering information, relay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so that control operator metering information is not lost while a technician is transferring an event report.
Ymodem	Support for reading event, settings, and oscillography files.
DNP3 Level 2 Outstation	Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and settings groups.
IEEE C37.118	Phasor measurement protocol.
IEC 61850 Edition 2	Ethernet-based international standard for interoperability between intelligent devices in a substation.

## SELogIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations put relay logic in the hands of the protection engineer. Assign the relay inputs to suit your application, logically combine selected relay elements for various control functions, and assign outputs to your logic functions.

Programming SELOGIC control equations consists of combining relay elements, inputs, and outputs with SELOGIC control equation operators (see *Table 3*). Any element in the Relay Word can be used in these equations. The SEL-401 is factory-set for use without additional logic in most situations. For complex or unique applications, these expanded SELOGIC functions allow superior flexibility.



**Table 3    SELogic Control Equation Operators**

Operator Type	Operators	Comments
Boolean	AND, OR, NOT	Allows combination of measuring units.
Edge Detection	F_TRIG, R_TRIG	Operates at the change of state of an internal function.
Comparison	>, ≥, =, ≤, <, < >	
Arithmetic	+, −, *, /	Uses traditional math functions for analog quantities in an easily programmable equation.
Numerical	ABS, SIN, COS, LN, EXP, SQRT	
Precedence Control	( )	Allows multiple and nested sets of parentheses.
Comment	#	Provides for easy documentation of control and protection logic.

Use the new alias capability to assign more meaningful relay variable names. This improves the readability of customized programming. Use as many as 200 aliases to rename any digital or analog quantity. The following is an example of possible applications of SELOGIC control equations that use aliases:

```

==>SET T <Enter>
1: PMV01, THETA
(assign the alias "THETA" to math variable PMV01)
2: PMV02, TAN
(assign the alias "TAN" to math variable PMV02)
==>SET L <Enter>
1: # CALCULATE THE TANGENT OF THETA
2: TAN:=SIN(THETA) / COS(THETA)
(use the aliases in an equation)

```

Add programmable control functions to your protection and automation systems. New functions and capabilities enable the use of analog values in conditional logic statements. The following are examples of possible applications of SELOGIC control equations with expanded capabilities:

- Scale analog values for SCADA retrieval.
- Initiate remedial action sequence based on load flow before fault conditions.
- Interlock breakers and disconnect switches.
- Restrict breaker tripping in excessive duty situations without additional relays.
- Construct a compensated overvoltage element for open line overvoltage protection.

- Hold momentary change-of-state conditions for SCADA polling.
- Provide a combination of frequency or rate-of-change-of-frequency functions.

## Relay-to-Relay Digital Communication (MIRRORED BITS)

The SEL-patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication. In the SEL-401, MIRRORED BITS can operate simultaneously on any two serial ports for three-terminal power system operation.

The SEL-401 offers the following serial communication features:

- Four independent EIA-232 serial ports
- Full access to event history, relay status, and meter information
- Strong password protection for settings and group switching
- DNP3 Level 2 Outstation
- Patented SEL Fast Message Interleaving of ASCII and binary data for SCADA communications, including access to SER, relay element targets, event data, and more

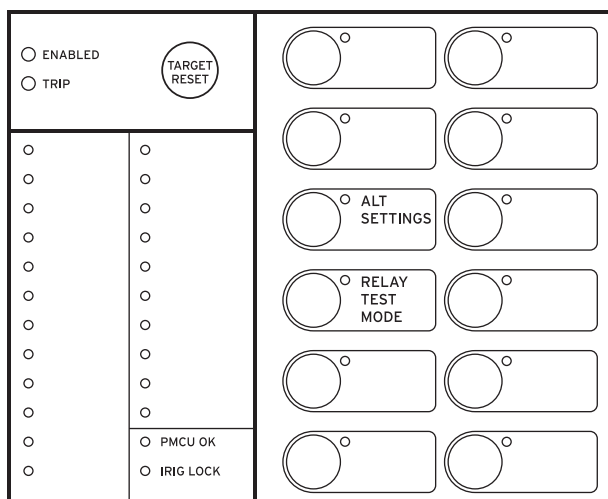
# Advanced Front-Panel Operation

## Front-Panel Display

The LCD shows event, metering, settings, and relay self-test status information.

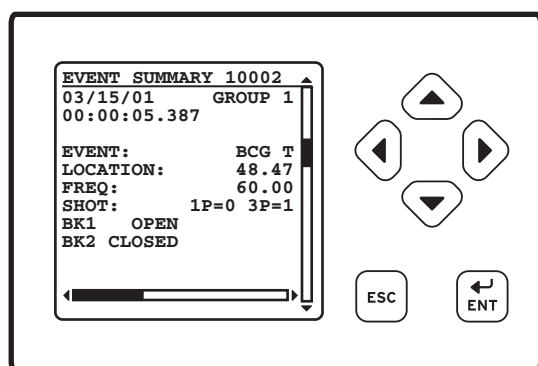
The LCD is controlled by the navigation pushbuttons (*Figure 5*), automatic messages the relay generates, and user-programmed analog and digital display points. The

rotating display scrolls through alarm points, display points, and metering screens. If none are active, the relay scrolls through displays of the fundamental and rms metering screens. Each display remains for a user-programmed time (1–15 seconds) before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.



**Figure 4 Factory-Default Status and Trip Target LEDs (12-Pushbutton, 24-Target LED Option)**

Close-up view of the front panel of the SEL-401 are shown in *Figure 4* and *Figure 5*. The front panel includes a 128 x 128 pixel, 3" x 3" LCD screen; LED target indicators; and pushbuttons with indicating LEDs for local control functions. The asserted and deasserted colors for the LEDs are programmable. Configure any of the direct-acting pushbuttons to navigate directly to any HMI menu item. Quickly view events, alarm points, display points, or the SER.



**Figure 5 Factory-Default Front-Panel Display and Pushbuttons**

## Bay Control

The SEL-401 provides dynamic bay one-line diagrams on the front-panel screen with disconnect and breaker control capabilities for 25 predefined user-selectable bay

types. The bay control is equipped to control as many as ten disconnects and two breakers, depending on the one-line diagram selected. Certain one-line diagrams provide status for as many as three breakers and five disconnect switches. Operate disconnects and breakers with ASCII commands, SELOGIC control equations, Fast Operate Messages, and from the one-line diagram. The one-line diagram includes user-configurable apparatus labels and as many as six user-definable analog quantities.

## One-Line Bay Diagrams

The SEL-401 bay control offers a variety of preconfigured one-line diagrams for common bus configurations. Once a one-line diagram is selected, the user has the ability to customize the names for all of the breakers, disconnect switches, and buses. Most one-line diagrams contain analog display points. These display points can be set to any of the available analog quantities with labels, units, and scaling. These values are updated in real-time along with the breakers and switch position to give instant status and complete control of a bay. *Figure 6* through *Figure 9* demonstrate some of the preconfigured bay arrangements available in the SEL-401.

The operator can see all valuable information on a bay before making a critical control decision. Programmable interlocks help prevent operators from incorrectly opening or closing switches or breakers. The SEL-401 will not only prevent the operator from making an incorrect control decision but can notify and/or alarm when an incorrect operation is initiated.

## Circuit Breaker Operations From the Front Panel

*Figure 6–Figure 9* are examples of some of the selectable one-line diagrams in the SEL-401. The one-line diagram is selectable from the Bay settings. Additional settings for defining labels and analog quantities are also found in the Bay settings. One-line diagrams are composed of the following:

- Bay Names and Bay Labels
- Busbar and Busbar Labels
- Breaker and Breaker Labels
- Disconnect Switches and Disconnect Switch Labels
- Analog Display Points

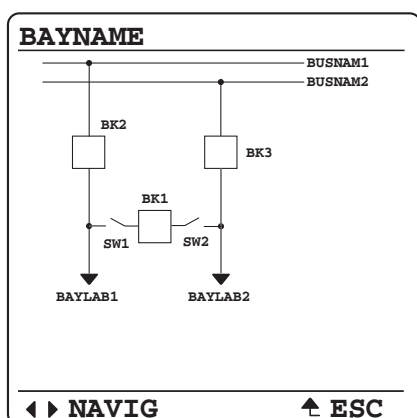


Figure 6 Breaker-and-a-Half

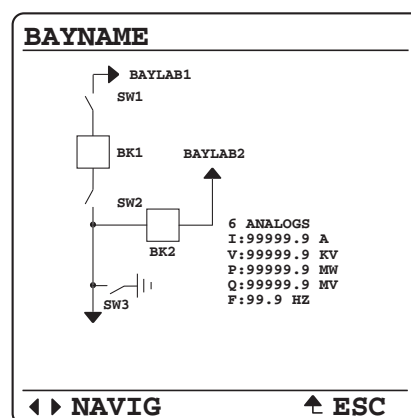


Figure 7 Ring Bus With Ground Switch

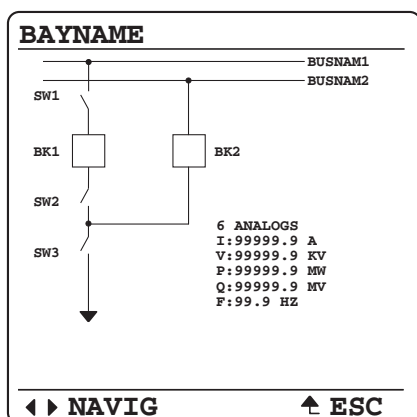


Figure 8 Double Bus/Double Breaker

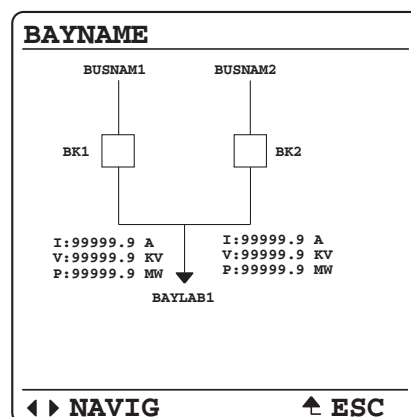


Figure 9 Source Transfer Bus

## Rack-Type Breakers Mosaics

The SEL-401 supports the display of rack-type (also referred to as truck-type) circuit breakers. The rack-type breakers have three positions: racked out, test, and racked in. When in the test or racked-in positions, the breaker can be displayed as open or closed. When racked out, there is no breaker open/close display. The rack-type breakers are a display-only functionality and do not impact any circuit breaker control capabilities.

## Status and Trip Target LEDs

The SEL-401 includes programmable status and trip target LEDs, as well as programmable direct-action control pushbuttons on the front panel.

The SEL-401 features a versatile front panel that you can customize to fit your needs. Use SELOGIC control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs, operator control pushbuttons, and LEDs. The blank slide-in label set is included with the SEL-401. Functions

are simple to configure using SEL Grid Configurator. Label sets can be printed from a laser printer by using templates supplied with the merging unit or hand labeled on supplied blank labels.

## Alarm Points

You can display messages on the SEL-401 front-panel LCD that indicate alarm conditions in the power system. The merging unit uses alarm points to place these messages on the LCD.

Figure 11 shows a sample alarm points screen. The merging unit is capable of displaying as many as 66 alarm points. The merging unit automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. The alarm points message is user-configurable and can be triggered using inputs, communication, or the SEL-2600 or be conditional by using powerful SELOGIC control equations. The asterisk next to the alarm point indicates an active alarm. The inactive alarms can be cleared using the front-panel navigation pushbuttons.

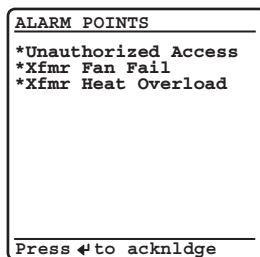


Figure 10 Sample Alarm Points Screen

## Advanced Display Points

Create custom screens showing metering values, special text messages, or a mix of analog and status information. *Figure 11* shows an example of how display points can be used to show circuit breaker information and current

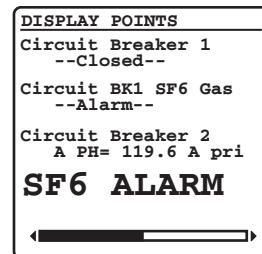


Figure 11 Sample Display Points Screen

## Software

### SEL Grid Configurator

SEL Grid Configurator combines an easy-to-use interface, powerful protection visualization, and comprehensive reporting to deliver a seamless and efficient configuration and commissioning experience. You want to be confident that your SEL-401 will perform as

expected, and SEL Grid Configurator is the key tool to help you verify that the relay configuration is exactly what you expect.

### Protection Element View

The Protection Elements View in SEL Grid Configurator provides a single place to enable and configure settings for all protection functions.

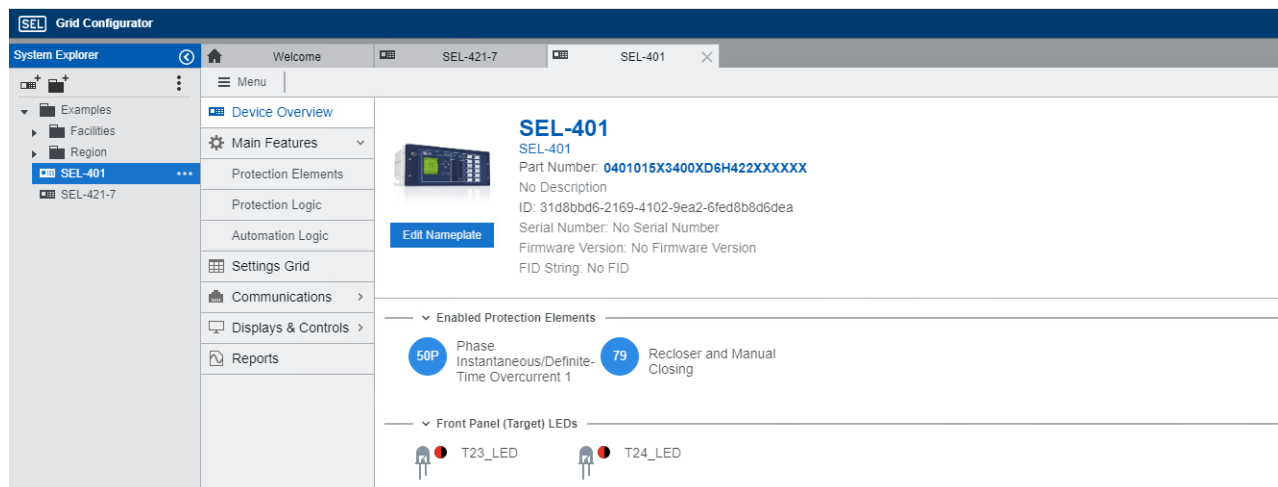


Figure 12 Protection Element View

## Bay Screen Lookup

SEL Grid Configurator provides an easy to use bay screen lookup tool for the SEL-401 that helps significantly decrease the time needed to find the mimic diagram applicable to your installation.



Figure 13 SEL Grid Configurator Bay Screen Mimic Lookup Tool

## Device Reporting

Whether during commissioning or normal operation, you need to quickly and accurately identify and download all relevant IED reports. The reporting view in SEL Grid Configurator enables you to view and download reports for one or many devices. Filter by date, report type, or device type and download reports to your computer.

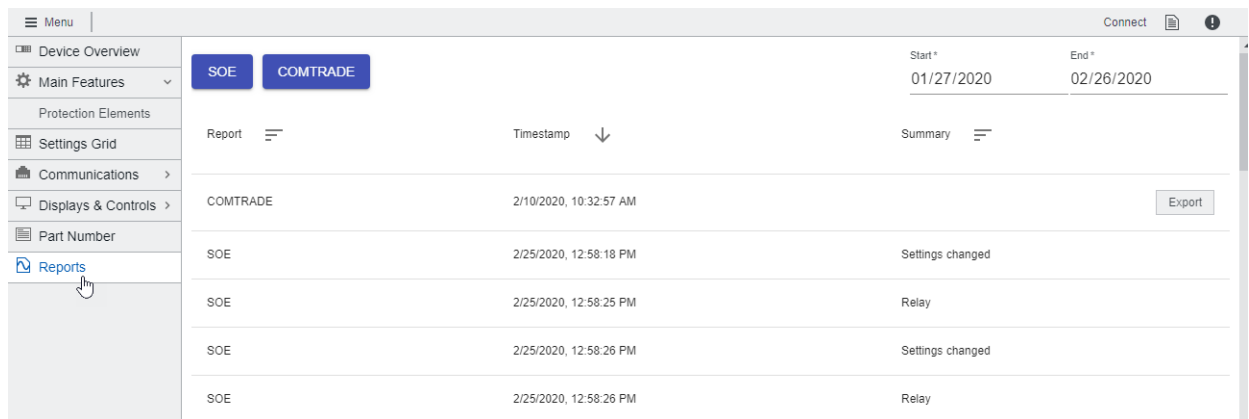


Figure 14 View Reports

## Architect IEC 61850 Configurator

Design and configure the SEL-401 in IEC 61850 installations using SEL Grid Configurator and Architect together. Architect provides a means to configure and

document the IEC 61850 communications settings between SEL devices and devices from multiple manufacturers. For SV applications, Architect also provides a means to configure your SV publications and subscriptions.

## SEL SYNCHROWAVE Event Visualization

Use SYNCHROWAVE Event to display and analyze disturbance events. Records from multiple relays can be easily merged and time-aligned; allowing easy analysis of an event spanning one or more generating facilities.

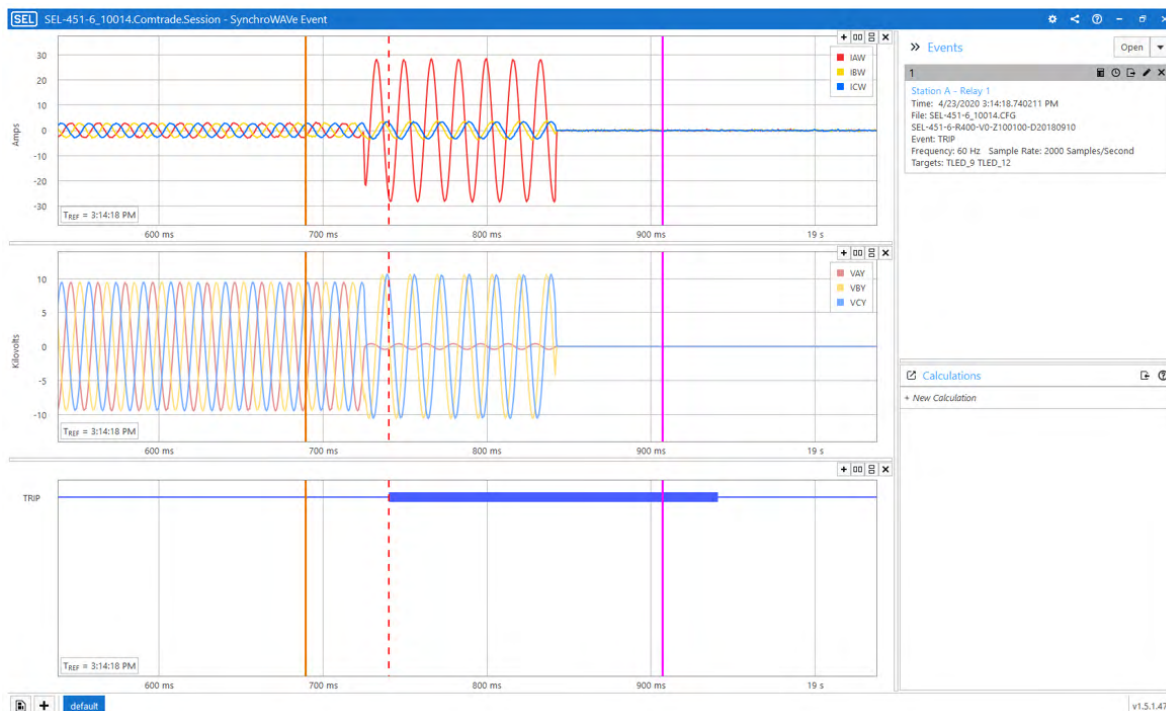


Figure 15 SYNCHROWAVE

## TEAM Event Collection

Use ACSELERATOR TEAM<sup>®</sup> SEL-5045 Software for automatic event archiving and secure remote file retrieval. The same software can be used to archive COMTRADE and SOE files from the SEL-401 and other relays in your system.

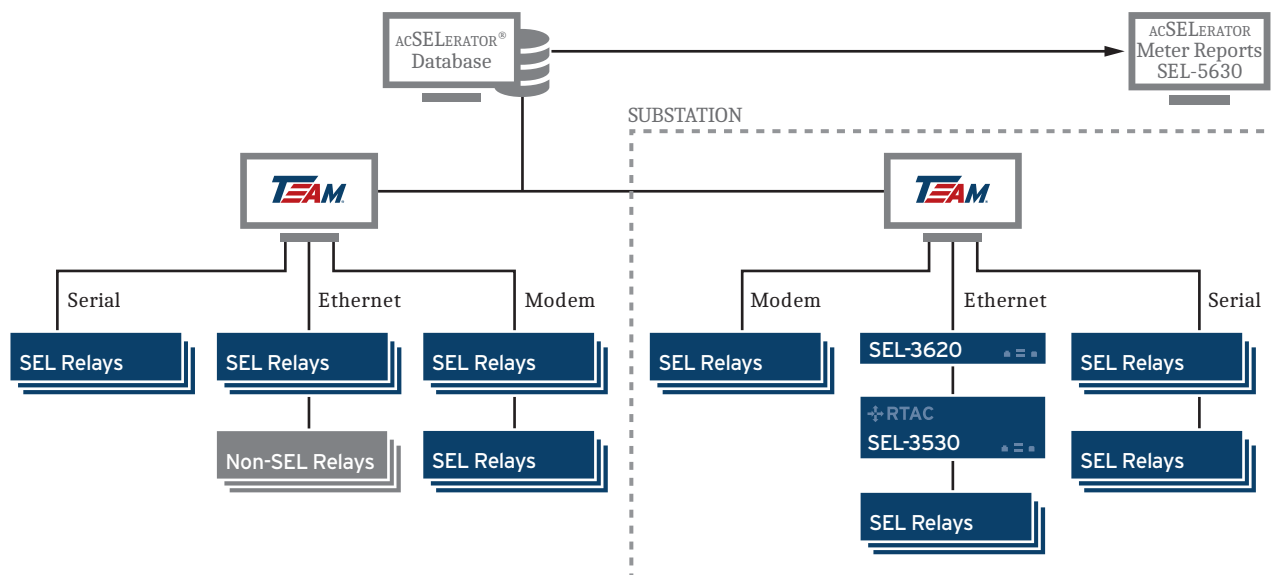


Figure 16 TEAM Works With Multiple Devices in a Variety of Configurations to Meet System Needs

# Diagrams and Dimensions

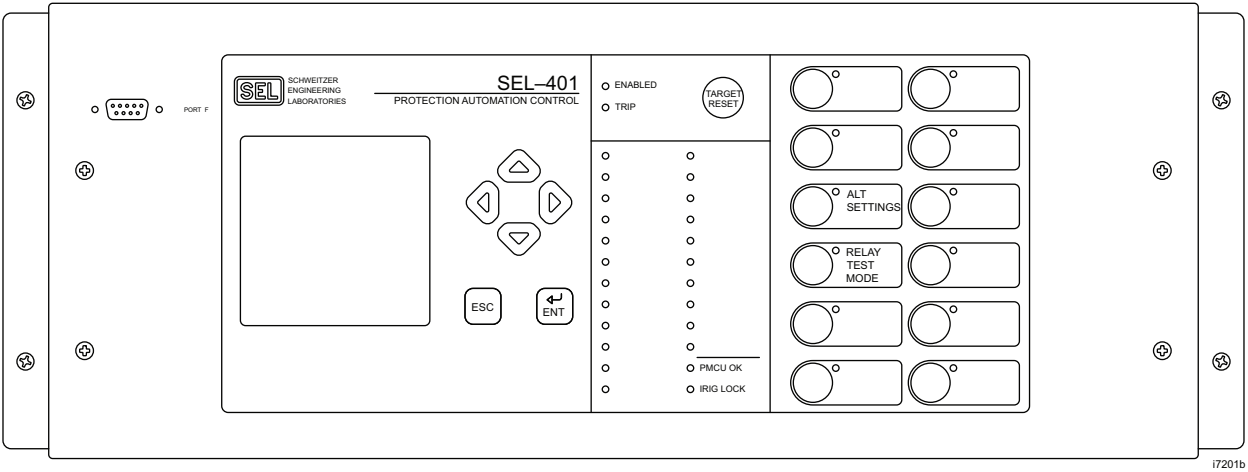
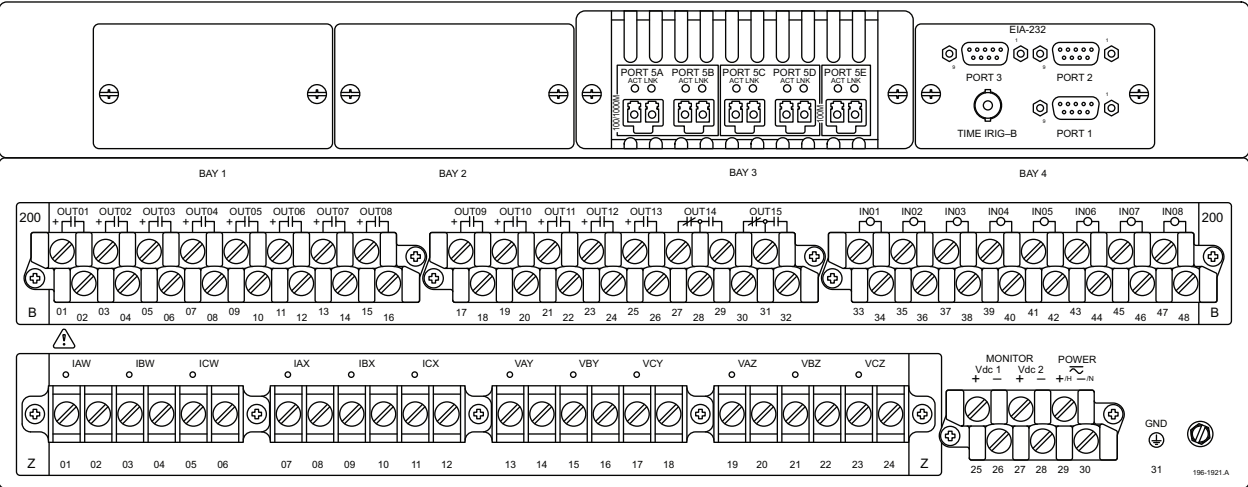
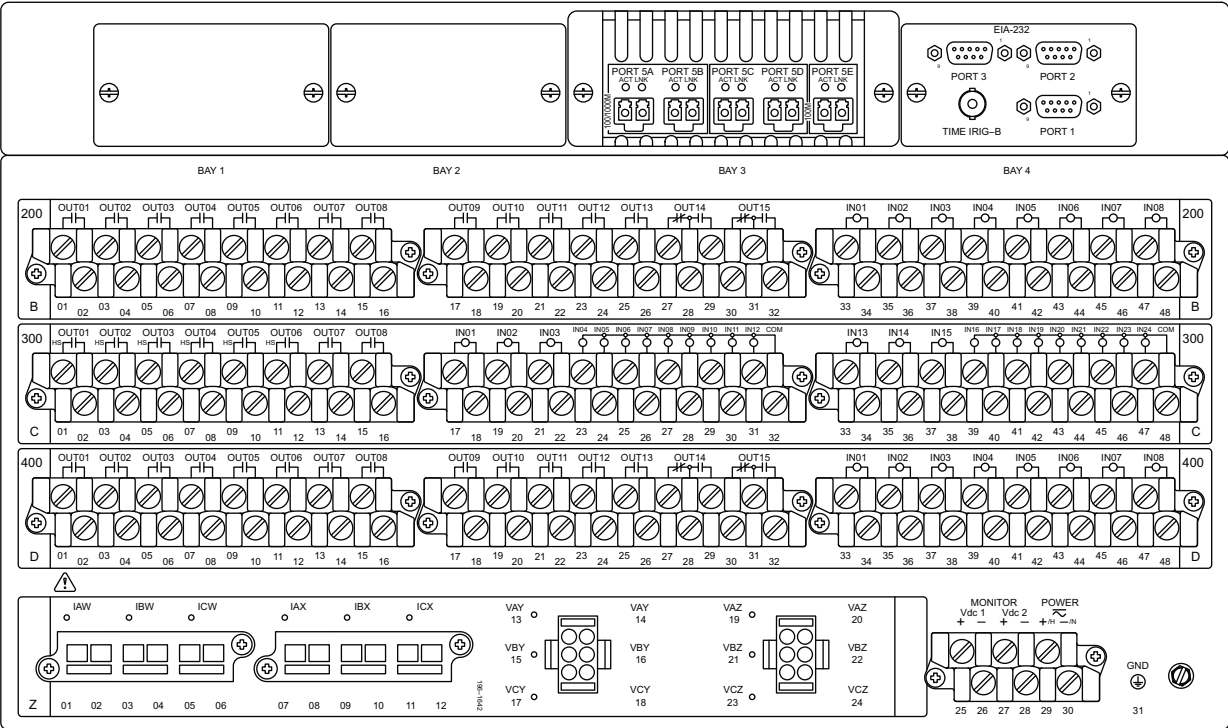


Figure 17 4U Front Panel, Rack-Mount Option



Five-port Ethernet card ordering option depicted.

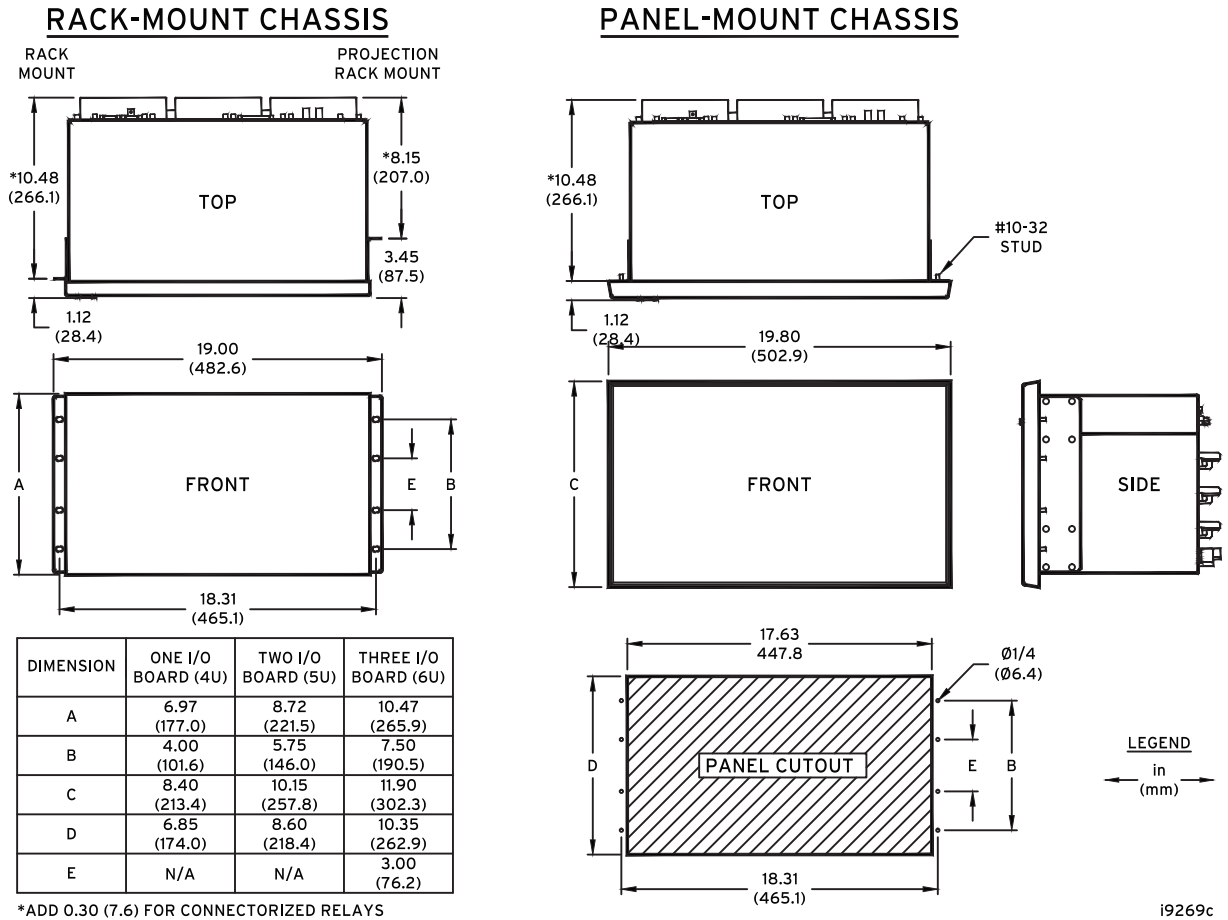
Figure 18 4U Rear Panel, High-Speed INTC (200 Slot) Interface Board



Five-port Ethernet card ordering option depicted.

i7203c

Figure 19 6U Rear Panel, Connectorized Terminal Block, One (INT4) I/O Board Option



i9269c

Figure 20 SEL-401 Dimensions for Rack- and Panel-Mount Models



# Specifications

**Note:** The SEL-401 has a processing delay of about 1 ms. Protection and control operating times of an SV relay that receives SV messages from an SEL-401 are delayed by the total network delays, which includes the processing delay. Use caution when setting the SV relay coordination times to account for the total network delay.

## Compliance

Designed and manufactured under an ISO 9001 certified quality management system

### FCC Compliance Statement

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

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

CE Mark

RCM Mark

## General

### AC Analog Inputs

Sampling Rate: 8 kHz

### AC Current Input (Secondary Circuit)

Current Range Rating (With DC Offset at X/R = 10, 1.5 Cycles)

1 A Nominal: 0.1–18.2 A

5 A Nominal: 0.5–91 A

### Continuous Thermal Rating

1 A Nominal: 3 A  
4 A (+55°C)

5 A Nominal: 15 A  
20 A (+55°C)

### Saturation Current (Linear) Rating

1 A Nominal: 20 A

5 A Nominal: 100 A

### A/D Current Limit (peak)

1 A Nominal: 49.5 A

5 A Nominal: 247.5 A

**Note:** Signal clipping can occur beyond this limit.

### One-Second Thermal Rating

1 A Nominal: 100 A

5 A Nominal: 500 A

### One-Cycle Thermal Rating

1 A Nominal: 250 A peak

5 A Nominal: 1250 A peak

### Burden Rating

1 A Nominal: ≤0.1 VA @ 1 A

5 A Nominal: ≤0.5 VA @ 5 A

### AC Voltage Inputs

Three-phase, four-wire (wye) connections are supported.

Rated Voltage Range: 55–250 V<sub>LN</sub>

Operational Voltage Range: 0–300 V<sub>LN</sub>

Ten-Second Thermal Rating: 600 Vac

Burden: ≤0.1 VA @ 125 V

## Frequency and Rotation

Nominal Frequency Rating: 50 ± 5 Hz  
60 ± 5 Hz

Phase Rotation: ABC or ACB

Frequency Tracking Range: 40–65 Hz  
<40 Hz = 40 Hz  
>65 Hz = 65 Hz

Default Slew rate: 15 Hz/s

## Power Supply

### 24–48 Vdc

Rated Voltage: 24–48 Vdc

Operational Voltage Range: 18–60 Vdc

Vdc Input Ripple: 15% per IEC 60255-26:2013

Interruption: 20 ms at 24 Vdc, 100 ms at 48 Vdc  
per IEC 60255-26:2013

Burden: <35 W

### 48–125 Vdc or 110–120 Vac

Rated Voltage: 48–125 Vdc, 110–120 Vac

Operational Voltage Range: 38–140 Vdc  
85–140 Vac

Rated Frequency: 50/60 Hz

Operational Frequency Range: 30–120 Hz

Vdc Input Ripple: 15% per IEC 60255-26:2013

Interruption: 14 ms at 48 Vdc, 160 ms at 125 Vdc per  
IEC 60255-26:2013

Burden: <35 W, <90 VA

### 125–250 Vdc or 110–240 Vac

Rated Voltage: 125–250 Vdc, 110–240 Vac

Operational Voltage Range: 85–300 Vdc  
85–264 Vac

Rated Frequency: 50/60 Hz

Operational Frequency Range: 30–120 Hz

Vdc Input Ripple: 15% per IEC 60255-26:2013

Interruption: 46 ms at 125 Vdc, 250 ms at 250 Vdc per  
IEC 60255-26:2013

Burden: <35 W, <90 VA

## Control Outputs

**Note:** IEEE C37.90-2005 and IEC 60255-27:2013

Update Rate: 1/8 cycle

Make (Short Duration Contact Current): 30 Adc  
1,000 operations at 250 Vdc  
2,000 operations at 125 Vdc

Limiting Making Capacity: 1000 W at 250 Vdc (L/R = 40 ms)

Mechanical Endurance: 10,000 operations

## Standard

Rated Voltage: 24–250 Vdc  
110–240 Vrms

Operational Voltage Range: 0–300 Vdc  
0–264 Vrms

Operating Time: Pickup ≤ 6 ms (resistive load)  
Dropout ≤ 6 ms (resistive load)

Short-Time Thermal Withstand:	50 A for 1 s
Continuous Contact Current:	6 A at 70°C 4 A at 85°C
Contact Protection:	MOV protection across open contacts 264 Vrms continuous voltage 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 10 operations in 4 seconds, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break L/R = 40 ms (DC) PF = 0.4 (AC)
24 Vdc	0.75 Adc	0.75 Adc
48 Vdc	0.63 Adc	0.63 Adc
125 Vdc	0.30 Adc	0.30 Adc
250 Vdc	0.20 Adc	0.20 Adc
110 Vrms	0.30 Arms	0.30 Arms
240 Vrms	0.20 Arms	0.20 Arms

#### Hybrid (High-Current Interrupting)

Rated Voltage:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup $\leq 6$ ms (resistive load) Dropout $\leq 6$ ms (resistive load)
Short Time Thermal Withstand:	50 Adc for 1 s
Continuous Contact Current:	6 Adc at 70°C 4 Adc at 85°C
Contact Protection:	MOV protection across open contacts 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
24 Vac	10 Adc	10 Adc (L/R = 40 ms)
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

**Note:** Do not use hybrid control outputs to switch ac control signals.

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

Rated Voltage:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup $\leq 10$ $\mu$ s (resistive load) Dropout $\leq 8$ ms (resistive load)
Short Time Thermal Withstand:	50 Adc for 1 s
Continuous Contact Current:	6 Adc at 70°C 4 Adc at 85°C
Contact Protection:	MOV protection across open contacts 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
24 Vdc	10 Adc	10 Adc (L/R = 40 ms)
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

**Note:** Do not use hybrid control outputs to switch ac control signals.

#### Control Inputs

Optoisolated (For Use With AC or DC Signals)

Main Board:	No I/O
INT2, INT7, INT8, and INTE Interface Board:	8 inputs with no shared terminals
INT4, INTC, and INTD Interface Board:	6 inputs with no shared terminals 18 inputs with shared terminals (2 groups of 9 inputs with each group sharing one terminal)
Voltage Options:	24, 48, 110, 125, 220, 250 V
Current Draw:	<5 mA at nominal voltage <8 mA for 110 V option
Sampling Rate:	2 kHz

DC Thresholds (Dropout thresholds indicate level-sensitive option)

24 Vdc:	Pickup 19.2–30.0 Vdc; Dropout <14.4 Vdc
48 Vdc:	Pickup 38.4–60.0 Vdc; Dropout <28.8 Vdc
110 Vdc:	Pickup 88.0–132.0 Vdc; Dropout <66.0 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout <75 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout <132 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout <150 Vdc

AC Thresholds (Ratings met only when recommended control input settings are used)

24 Vac:	Pickup 16.4–30.0 Vac rms; Dropout <10.1 Vac rms
48 Vac:	Pickup 32.8–60.0 Vac rms; Dropout <20.3 Vac rms
110 Vac:	Pickup 75.1–132.0 Vac rms; Dropout <46.6 Vac rms
125 Vac:	Pickup 89.6–150.0 Vac rms; Dropout <53.0 Vac rms
220 Vac:	Pickup 150.3–264.0 Vac rms; Dropout <93.2 Vac rms
250 Vac:	Pickup 170.6–300 Vac rms; Dropout <106 Vac rms
Current Drawn:	<5 mA at nominal voltage <8 mA for 110 V option
Sampling Rate:	2 kHz

#### Communications Ports

EIA-232:	1 front and 3 rear
Serial Data Speed:	300–57600 bps

Ethernet Card Slot for the Four-Port Ethernet Card

Ordering Option:	10/100BASE-T
Connector Type:	RJ45
Ordering Option:	100BASE-FX fiber-optic Ethernet
Mode:	Multi
Wavelength (nm):	1300
Source:	LED

Connector Type: LC  
 Min. TX Pwr. (dBm): -19  
 Max. TX Pwr. (dBm): -14  
 RX Sens. (dBm): -32  
 Sys. Gain (dB): 13

#### Ethernet Card Slot for the Five-Port Ethernet Card

Ordering Option: 100BASE-FX fiber-optic Ethernet SFP transceiver  
 Part Number: 8103-01 or 8109-01  
 Mode: Multi  
 Wavelength (nm): 1310  
 Source: LED  
 Connector Type: LC  
 Min. TX Pwr. (dBm): -24  
 Max. TX Pwr. (dBm): -14  
 Min. RX Sens. (dBm): -31  
 Max. RX Sens. (dBm): -12  
 Approximate Range: 2 km  
 Transceiver Internal Temperature Accuracy:  $\pm 3.0^{\circ}\text{C}$   
 Transmitter Average Optical Power Accuracy:  $\pm 3.0\text{ dB}$   
 Received Average Optical Input Power Accuracy:  $\pm 3.0\text{ dB}$   
 Ordering Option: 1000BASE-LX fiber-optic Ethernet SFP transceiver  
 Part Number: 8130-01, 8130-02, 8130-03, or 8130-04  
 Mode: Single  
 Wavelength (nm): 1310  
 Source: LED  
 Connector Type: LC

	Part Number			
	8130-01	8130-02	8130-03	8130-04
Min. TX Pwr. (dBm)	-9.5	-6	-5	-2
Max. TX Pwr. (dBm)	-3	-1	0	3
Min. RX Sens. (dBm)	-21	-22	-24	-24
Max. RX Sens. (dBm)	-3	-3	-3	-3
Approximate Range (km)	10	20	30	40

Transceiver Internal Temperature Accuracy:  $\pm 3.0^{\circ}\text{C}$   
 Transmitter Average Optical Power Accuracy:  $\pm 3.0\text{ dB}$   
 Received Average Optical Input Power Accuracy:  $\pm 3.0\text{ dB}$   
 Ordering Option: 1000BASE-XD fiber-optic Ethernet SFP transceiver  
 Part Number: 8130-05  
 Mode: Single  
 Wavelength (nm): 1550  
 Source: LED  
 Connector Type: LC  
 Min. TX Pwr. (dBm): -5

Max. TX Pwr. (dBm): 0  
 Min. RX Sens. (dBm): -24  
 Max. RX Sens. (dBm): -3  
 Approximate Range: 50 km  
 Transceiver Internal Temperature Accuracy:  $\pm 3.0^{\circ}\text{C}$

Transmitter Average Optical Power Accuracy:  $\pm 3.0\text{ dB}$   
 Received Average Optical Input Power Accuracy:  $\pm 3.0\text{ dB}$

Ordering Option: 1000BASE-ZX fiber-optic Ethernet SFP transceiver  
 Part Number: 8130-06, 8130-08, or 8130-10  
 Mode: Single  
 Wavelength (nm): 1550  
 Source: LED  
 Connector Type: LC

	Part Number		
	8130-06	8130-08	8130-10
Min. TX Pwr. (dBm)	0	1	5
Max. TX Pwr. (dBm)	5	5	8
Min. RX Sens. (dBm)	-24	-36	-36
Max. RX Sens. (dBm)	-3	-10	-10
Approximate Range (km)	80	160	200

Transceiver Internal Temperature Accuracy:  $\pm 3.0^{\circ}\text{C}$   
 Transmitter Average Optical Power Accuracy:  $\pm 3.0\text{ dB}$   
 Received Average Optical Input Power Accuracy:  $\pm 3.0\text{ dB}$

Ordering Option: 1000BASE-SX fiber-optic Ethernet SFP transceiver  
 Part Number: 8131-01  
 Mode: Multi  
 Wavelength (nm): 850  
 Source: LED  
 Connector Type: LC  
 Min. TX Pwr. (dBm): -9  
 Max. TX Pwr. (dBm): -2.5  
 Min. RX Sens. (dBm): -18  
 Max. RX Sens. (dBm): 0  
 Approximate Range: 300 m for 62.5/125  $\mu\text{m}$ ; 550 m for 50/125  $\mu\text{m}$

Transceiver Internal Temperature Accuracy:  $\pm 3.0^{\circ}\text{C}$   
 Transmitter Average Optical Power Accuracy:  $\pm 3.0\text{ dB}$   
 Received Average Optical Input Power Accuracy:  $\pm 3.0\text{ dB}$

#### Time Inputs

##### IRIG-B Input—Serial PORT 1

Input: Demodulated IRIG-B  
 Rated I/O Voltage: 5 Vdc  
 Operating Voltage Range: 0–8 Vdc  
 Logic High Threshold:  $\geq 2.8\text{ Vdc}$

Logic Low Threshold:	≤0.8 Vdc
Input Impedance:	2.5 kΩ
<b>IRIG-B Input—BNC Connector</b>	
Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operating Voltage Range:	0–8 Vdc
Logic High Threshold:	≥2.2 Vdc
Logic Low Threshold:	≤0.8 Vdc
Input Impedance:	50 Ω or >1 kΩ
Dielectric Test Voltage	0.5 kVac
<b>PTP</b>	
Input:	IEEE 1588 PTPv2
Profiles:	Default, C37.238-2011 (Power Profile), IEC/IEEE 61850-9-3-2016 (Power Utility Profile)
Synchronization Accuracy:	±100 ns @ 1-second synchronization intervals when communicating directly with master clock

### Operating Temperature

–40° to +85°C (–40° to +185°F)

**Note:** LCD contrast impaired for temperatures below –20° and above +70°C.  
Stated temperature ranges not applicable to UL applications.

### Humidity

5% to 95% without condensation

### Weight (Maximum)

4U Rack Unit:	10.2 kg (22.5 lb)
5U Rack Unit:	11.8 kg (26 lb)
6U Rack Unit:	13.5 kg (30 lb)

### Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

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

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

### Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes:

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

## Type Tests

### Installation Requirements

Overvoltage Category:	2
Pollution Degree:	2

### Safety

Product Standards	IEC 60255-27:2013 IEEE C37.90-2005 21 CFR 1040.10
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Dielectric Strength:	IEC 60255-27:2013, Section 10.6.4.3 2.5 kVac, 50/60 Hz for 1 min: Analog Inputs, Contact Outputs, Digital Inputs 3.6 kVdc for 1 min: Power Supply, Battery Monitors 2.5 kVdc for 1 min: IRIG-B 1.1 kVdc for 1 min: Ethernet
Impulse Withstand:	IEC 60255-27:2013, Section 10.6.4.2 IEEE C37.90-2005 Common Mode: ±1.0 kV: Ethernet ±2.5 kV: IRIG-B ±5.0 kV: All other ports Differential Mode: 0 kV: Analog Inputs, Ethernet, IRIG-B, Digital Inputs ±5.0 kV: Standard Contact Outputs, Power Supply Battery Monitors +5.0 kV: Hybrid Contact Outputs
Insulation Resistance:	IEC 60255-27:2013, Section 10.6.4.4 >100 MΩ @ 500 Vdc
Protective Bonding:	IEC 60255-27:2013, Section 10.6.4.5.2 <0.1 Ω @ 12 Vdc, 30 A for 1 min
Object Penetration:	IEC 60529:2001 + CRGD:2003 Protection Class: IP30
Max Temperature of Parts and Materials:	IEC 60255-27:2013, Section 7.3
Flammability of Insulating Materials:	IEC 60255-27:2013, Section 7.6 Compliant

### Electromagnetic (EMC) Immunity

Product Standards:	IEC 60255-26:2013 IEC 60255-27:2013 IEEE C37.90-2005
Surge Withstand Capability (SWC):	IEC 61000-4-18:2006 + A:2010 IEEE C37.90.1-2012 Slow Damped Oscillatory, Common and Differential Mode: ±1.0 kV ±2.5 kV Fast Transient, Common and Differential Mode: ±4.0 kV
Electrostatic Discharge (ESD):	IEC 61000-4-2:2008 IEEE C37.90.3-2001 Contact: ±8 kV Air Discharge: ±15 kV
Radiated RF Immunity:	IEEE C37.90.2-2004 IEC 61000-4-3:2006 + A1:2007 + A2:2010 20 V/m (>35 V/m, 80% AM, 1 kHz) Sweep: 80 MHz to 1 GHz Spot: 80, 160, 450, 900 MHz 10 V/m (>15 V/m, 80% AM, 1 kHz) Sweep: 80 MHz to 1 GHz Sweep: 1.4 GHz to 2.7 GHz Spot: 80, 160, 380, 450, 900, 1850, 2150 MHz
Electrical Fast Transient Burst (EFTB):	IEC 61000-4-4:2012 Zone A: ±2 kV: Communication ports ±4 kV: All other ports

Surge Immunity:	IEC 61000-4-5:2005 Zone A: ±2 kV <sub>L-L</sub> ±4 kV <sub>L-E</sub> ±4 kV: Communication Ports <b>Note:</b> Cables connected to IRIG-B ports shall be less than 10 m in length for Zone A compliance. Zone B: ±2 kV: Communication Ports
Conducted Immunity:	IEC 61000-4-6:2013 20 V/m; (>35 V/m, 80% AM, 1 kHz) Sweep: 150 kHz–80 MHz Spot: 27, 68 MHz
Power Frequency Immunity (DC Inputs):	IEC 61000-4-16:2015 Zone A: Differential: 150 V <sub>RMS</sub> Common Mode: 300 V <sub>RMS</sub>
Power Frequency Magnetic Field:	IEC 61000-4-8:2009 Level 5: 100 A/m; ≥60 Seconds; 50/60 Hz 1000 A/m 1 to 3 Seconds; 50/60 Hz <b>Note:</b> 50G1P ≥0.05 (ESS = N, 1, 2) 50G1P ≥0.1 (ESS = 3, 4)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999/A1:2001/A2:2008 IEC 61000-4-29:2000 AC Dips & Interruptions Ripple on DC Power Input DC Dips & Interruptions Gradual Shutdown/Startup (DC only) Discharge of Capacitors Slow Ramp Down/Up Reverse Polarity (DC only)
Damped Oscillatory Magnetic Field:	IEC 61000-4-10:2016 Level 5: 100 A/m
<b>EMC Compatibility</b>	
Product Standards:	IEC 60255-26:2013
Emissions:	IEC 60255-26:2013, Section 7.1 Class A 47 CFR Part 15B Class A Canada ICES-001 (A) / NMB-001 (A)
<b>Environmental</b>	
Product Standards:	IEC 60255-27:2013
Cold, Operational:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Cold, Storage:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Dry Heat, Operational:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Dry Heat, Storage:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Test Db: +25 °C to +55 °C, 6 cycles (12 + 12-hour cycle), 95% RH
Damp Heat, Steady State:	IEC 60068-2-78:2013 Severity: 93% RH, +40 °C, 10 days
Vibration Resistance:	IEC 60255-21-1:1988 Class 2 Endurance, Class 2 Response
Shock Resistance:	IEC 60255-21-2:1988 Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response
Seismic:	IEC 60255-21-3:1993 Class 2 Quake Response

## Event Reports

### High-Resolution Data

Rate:	8000 samples/second 4000 samples/second 2000 samples/second 1000 samples/second
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Output Format:	Binary COMTRADE
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**Note:** Per IEEE C37.111-1999, *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems*.

### Event Reports

Storage:	35 quarter-second events or 24 half-second events
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Maximum Duration:	Five records of 24 seconds each of 4000 samples/second
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### Event Summary

Storage:	100 summaries
----------	---------------

### Breaker History

Storage:	128 histories
----------	---------------

### Sequential Events Recorder (SER)

Storage:	1000 entries
Trigger Elements:	250 relay elements
Resolution:	0.5 ms for contact inputs 1/8 cycle for all elements

## Processing Specifications

### AC Voltage and Current Inputs

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

### Digital Filtering

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

### Protection and Control Processing

8 times per power system cycle.  
Reclosing logic runs once per power system cycle.

### Control Points

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

## Relay Element Pickup Ranges and Accuracies

### Phase Instantaneous/Definite-Time Overcurrent Elements

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

Accuracy (Steady State)	
5 A Model:	±0.05 A plus ±3% of setting
1 A Model:	±0.01 A plus ±3% of setting
Transient Overreach:	<5% of pickup
Time Delay:	0.00–16000.00 cycles, 0.125 cycle steps
Timer Accuracy:	±0.125 cycle plus ±0.1% of setting

Maximum Operating Time: 1.5 cycles  
\*Operate time is relay processing time only and does not include SV delay, 1.5 ms minimal.

## Breaker-Failure Instantaneous Overcurrent

### Setting Range

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

### Accuracy

5 A Model:	$\pm 0.05$ A plus $\pm 3\%$ of setting
1 A Model:	$\pm 0.01$ A plus $\pm 3\%$ of setting

Transient Overreach: <5% of setting

Maximum Pickup Time: 1.5 cycles

Maximum Reset Time: 1 cycle

Timers Setting Range: 0–6000 cycles, 0.125 cycle steps  
(All but BFIDOn, BFISPN)  
0–1000 cycles, 0.125 cycle steps (BFIDOn,  
BFISPN)

Time-Delay Accuracy: 0.125 cycle plus  $\pm 0.1\%$  of setting

## Bay Control

Breakers:	2 (control), 3rd indication
Disconnects (Isolators):	10 (maximum)
Timers Setting Range:	1–99999 cycles, 1-cycle steps
Time-Delay Accuracy:	$\pm 0.1\%$ of setting, $\pm 0.125$ cycle

## Timer Specifications

### Setting Ranges

Breaker Failure:	0–6000 cycles, 0.125 cycle steps (All but BFIDOn, BFISPN) 0–1000 cycles, 0.125 cycle steps (BFIDOn, BFISPN)
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## Station DC Battery System Monitor Specifications

Rated Voltage:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Sampling Rate:	DC1: 2 kHz DC2: 1 kHz
Processing Rate:	1/8 cycle
Operating Time:	Less than 1.5 cycles (all elements except ac ripple) Less than 1.5 seconds (ac ripple element)
Setting Range	
	15–300 Vdc, 1 Vdc steps (all elements except ac ripple)
	1–300 Vac, 1 Vac steps (ac ripple element)
Accuracy	
Pickup Accuracy:	$\pm 3\% \pm 2$ Vdc (all elements except ac ripple) $\pm 10\% \pm 2$ Vac (ac ripple element)

## Metering Accuracy

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

### Currents

#### Phase Current Magnitude

5 A Model:	$\pm 0.2\%$ plus $\pm 4$ mA (2.5–15 A sec)
1 A Model:	$\pm 0.2\%$ plus $\pm 0.8$ mA (0.5–3 A sec)

#### Phase Current Angle

All Models:	$\pm 0.2^\circ$ in the current range $0.5 \cdot I_{NOM}$ to $3.0 \cdot I_{NOM}$
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#### Sequence Currents Magnitude

5 A Model:	$\pm 0.3\%$ plus $\pm 4$ mA (2.5–15 A sec)
1 A Model:	$\pm 0.3\%$ plus $\pm 0.8$ mA (0.5–3 A sec)

### Sequence Current Angle

All Models:	$\pm 0.3^\circ$ in the current range $0.5 \cdot I_{NOM}$ to $3.0 \cdot I_{NOM}$
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## Voltages

Phase and Phase-to-Phase Voltage Magnitude:  $\pm 0.1\%$  (33.5–300  $V_{L-N}$ )

Phase and Phase-to-Phase Angle:  $\pm 0.5^\circ$  (33.5–300  $V_{L-N}$ )

Sequence Voltage Magnitude:  $\pm 0.1\%$  (33.5–300  $V_{L-N}$ )

Sequence Voltage Angle:  $\pm 0.5^\circ$  (33.5–300  $V_{L-N}$ )

## Frequency (Input 40–65 Hz)

Accuracy:	$\pm 0.01$ Hz
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## Power

MW (P), Per Phase (Wye), 3 $\phi$  (Wye or Delta) Per Terminal

$\pm 1\%$  (0.1–1.2)  $\cdot I_{NOM}$ , 33.5–300 Vac, PF = 1, 0.5 lead, lag (1 $\phi$ )  
 $\pm 0.7\%$  (0.1–1.2)  $\cdot I_{NOM}$ , 33.5–300 Vac, PF = 1, 0.5 lead, lag (3 $\phi$ )

MVA (S), Per Phase (Wye), 3 $\phi$  (Wye or Delta) Per Terminal

$\pm 1\%$  (0.1–1.2)  $\cdot I_{NOM}$ , 33.5–300 Vac, PF = 1, 0.5 lead, lag (1 $\phi$ )  
 $\pm 0.7\%$  (0.1–1.2)  $\cdot I_{NOM}$ , 33.5–300 Vac, PF = 1, 0.5 lead, lag (3 $\phi$ )

PF, Per Phase (Wye), 3 $\phi$  (Wye or Delta) Per Terminal

$\pm 1\%$  (0.1–1.2)  $\cdot I_{NOM}$ , 33.5–300 Vac, PF = 1, 0.5 lead, lag (1 $\phi$ )  
 $\pm 0.7\%$  (0.1–1.2)  $\cdot I_{NOM}$ , 33.5–300 Vac, PF = 1, 0.5 lead, lag (3 $\phi$ )

## Synchrophasors

Number of Synchrophasor Data Streams: 5

Number of Synchrophasors for Each Stream:

15 phase synchrophasors (6 voltage and 9 currents)  
5 positive-sequence synchrophasors (2 voltage and 3 currents)

Number of User Analogs for Each Stream: 16 (any analog quantity)

Number of User Digitals for Each Stream: 64 (any Relay Word bit)

Synchrophasor Protocol: IEEE C37.118-2005, SEL Fast Message (legacy)

Synchrophasor Data Rate: As many as 60 messages per second

Synchrophasor Accuracy:

Voltage Accuracy:  $\pm 1\%$  Total Vector Error (TVE)  
Range 30–150 V,  $f_{NOM} \pm 5$  Hz

Current Accuracy:  $\pm 1\%$  Total Vector Error (TVE)  
Range (0.1–20)  $\cdot I_{NOM}$  A,  $f_{NOM} \pm 5$  Hz

Synchrophasor Data Recording: Records as much as 120 s  
IEEE C37.232-2011 File Naming Convention

# Technical Support

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

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