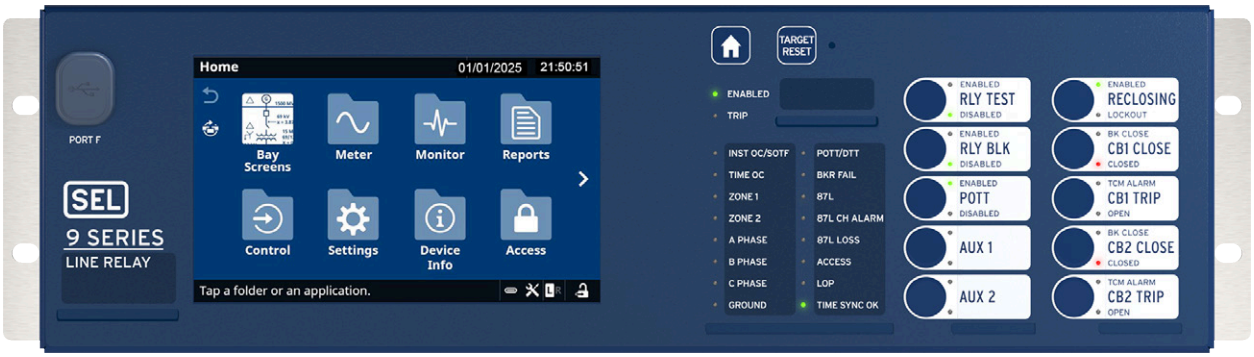
SEL-9L Line Relay



Overview

The SEL-9L Line Relay brings SEL's four decades of line protection experience to the new 9 Series relay platform. The 9 Series platform provides powerful hardware, common firmware, and flexible communications with a focus on usability.

Applications

- **Single- and Dual-Breaker Terminals.** One set of four current inputs (A, B, C, and N) come standard, with a second set of current inputs available as an ordering option.
- **Line Current Differential**[a]**.** Two- or three-terminal line current differential protection using self-installable SFPs with direct fiber (as long as 120 km) or IEEE C37.94 multiplexed communications. Line charging current compensation and in-line transformer protection are included.
- **Distance Protection.** Five phase and ground mho and/or quad distance zones with independent directional settings. Built-in logic for POTT, DCB, and DTT pilot schemes.
- **Reclosing and Breaker Failure.** Integrated reclosing and breaker failure logic for single or dual breakers.

[a] Available via future firmware upgrade.

Key Benefits

- **Universal Hardware.** Ordering is easy—the power supply, CT inputs, and contact inputs are all universal or software-selectable.
- **Flexible Communications.** Six available SFP ports allow for applications of 1 Gbps and 100 Mbps Ethernet, 87L protection (direct fiber or IEEE C37.94), and the new MIRRORED BITS 16 protocol.
- **Flexible and Safe CT and VT Connections.** Polarity reversal settings for each CT input and each set of VT inputs can be used to correct for errors in field wiring or CT use across multiple protection zones. CT terminal blocks automatically short the CT leads upon removal to improve personnel safety.
- **Advanced I/O Monitoring.** Three contact outputs with integrated circuit monitoring allow for recording the voltage across and the current through the outputs. Because these values are also available to use in custom logic, trip circuit monitoring functions can be programmed in the relay without any additional wiring. Voltage across the inputs is also recorded and available for use in SELOGIC® control equations.

- **Device Mode and Behavior.** Simplify testing and settings changes by locally or remotely putting the relay into a test mode in which physical contact outputs will not operate.
- **Touchscreen.** Operate the relay and gather data by launching apps on a 7-inch touchscreen.
- **Fast Startup. Faster Protection.** Enable local protection and issue a trip in less than one second after power is applied to the relay. Currents, voltages, and contact inputs are sampled at 10 kHz, while protection and SELOGIC control equations process every 1 ms.
- **Simpler Event Reports.** Analyze most operations using a single 1 kHz event report that contains raw and filtered data as well as the status of all Relay Word bits in the relay. A 10 kHz raw report is also available to analyze high-resolution power system activity.
- **Cybersecurity.** Improve your security infrastructure with secure booting of digitally signed firmware, role-based access control, a comprehensive device audit log[a], Syslog[a], secure communications using Transport Layer Security (TLS)[a], and secure file transfer over FTPS[a].
- **Expanded Networking Functions.** Create flexible networks with Parallel Redundancy Protocol (PRP), failover, and three independent IP addresses on as many as six Ethernet ports.
- **Powerful Protocols.** Communicate at protection speeds with IEC 61850 GOOSE (Ed. 2.1), IEC 61869-9:2016 Sampled Values, MB16, and MB8 protocols. Accurately synchronize time with PTP, SNTP, and IRIG-B protocols. DNP3, FTP, and IEC 61850 MMS are also available.
- **Reliable Design.** Hardware and firmware specifically designed to reduce the chance of a single event upset causing an output contact to operate.

[a] Available via future firmware upgrade.

Hardware Overview

Figure 1 shows the SEL-9L front panel. It includes a USB-C port for engineering access, a 7-inch color touchscreen, 38 programmable tricolor LEDs, and 10 programmable pushbuttons with configurable labels.

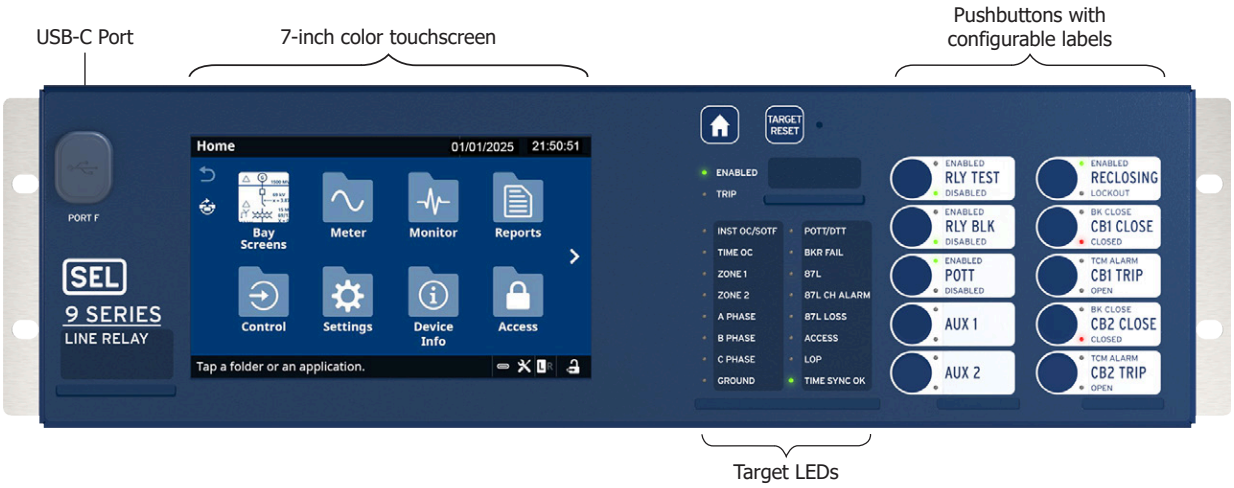


Figure 1 Front Panel

Figure 2 shows the SEL-9L rear panel. All CT inputs come with self-shorting connectors that automatically short the CT leads when the terminal blocks are removed from the relay. All CT inputs universally accept either 5 A or 1 A nominally rated CTs.

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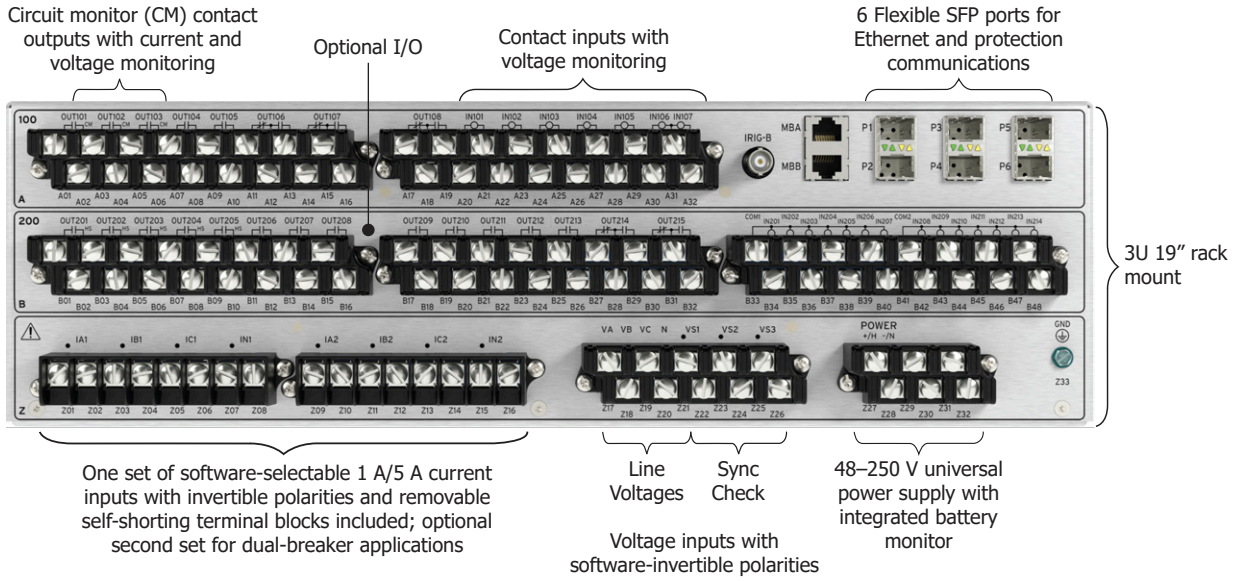

Figure 2 Rear Panel

The SEL-9L includes one set of VT inputs, typically used to measure line voltage, and an additional three VT inputs that can be used for synchronism-check applications. VTs must be connected in wye and output a voltage of 0–300 Vac rms.

The polarity of each individual CT input and each set of VT inputs can be inverted using relay settings.

The SEL-9L includes a variety of different types of contact inputs and outputs. The operating voltages of the contact inputs are set individually via software. The contact outputs have no voltage settings and can operate over a wide range of voltages as defined in *Specifications on page 25*. More details on the different contact I/O available in the relay can be found in *Models and Options on page 3*.

Models and Options

The SEL-9L can be ordered with either single-breaker (SEL-9L-1) or dual-breaker (SEL-9L-2) support. The SEL-9L-1 includes one set of CT inputs (A, B, C, and N) for single-breaker applications, and the SEL-9L-2 includes two sets of CT inputs for dual-breaker applications.

Base Unit

The SEL-9L comes standard with the top row of contacts shown in *Figure 2*. These contacts are described in *Table 1*.

Table 1 Standard Contact I/O

Quantity	Type	Description
Contact Outputs		
3	Circuit Monitoring, Form A	High-speed, high-current-interrupting with built-in circuit monitoring. Require dc voltage, but are not polarity-dependent.
2	Standard Form A	Operate on dc or ac voltage; not polarity-dependent.

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Quantity	Type	Description
3	Standard Form C	Operate on dc or ac voltage; not polarity-dependent.
Contact Inputs		
5	Individual	Each input can be individually set to operate on 24 Vdc, 48 Vdc, 110 Vdc, 125 Vdc, 220 Vdc, 250 Vdc, 110–120 Vac, or 220–240 Vac.
2	Shared reference	

The firmware in the SEL-9L comes with a base feature package that includes a basic set of protection elements and features. These base features are shown in black in *Figure 3*.

Options

The second row of contacts shown in *Figure 2* is optional and is described in *Table 2*.

Table 2 Optional Contact I/O

Quantity	Type	Description
Contact Outputs		
5	High-Speed Form A	High-speed, high-current-interrupting. Require dc voltage, but are not polarity-dependent.
8	Standard Form A	Operate on dc or ac voltage; not polarity-dependent.
2	Standard Form C	Operate on dc or ac voltage; not polarity-dependent.
Contact Inputs		
14	2 sets of 7, each with a shared reference	Each input can be individually set to operate on 24 Vdc, 48 Vdc, 110 Vdc, 125 Vdc, 220 Vdc, 250 Vdc, 110–120 Vac, or 220–240 Vac.

Most transmission line applications will require protection features beyond the base set shown in black in *Figure 3*. Optional features (shown in blue in *Figure 3*) can be added as needed to obtain the necessary protection elements and protocols for your specific application. Optional features can be added at the time of order or at a later time through a license file upgrade.

Accessories

The SEL-9L comes standard with a single 100 Mbps Ethernet SFP (SEL part number 8109-01). Additional SFPs can be ordered for use in various applications. *Table 8* provides a list of available SFPs.

Functional Overview

Firmware Features

The firmware in the SEL-9L comes with a base feature package that includes a basic set of protection elements and features. You can add optional features as needed to obtain the necessary protection elements and protocols for your specific application. Optional features can be added at any time through a feature file upgrade.

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Figure 3 shows the features available in the SEL-9L base feature package (black) as well as available optional features (blue). Each of these features is described in *Table 3* (with both IEEE and IEC 61850 naming conventions, if defined) and detailed further in this data sheet.

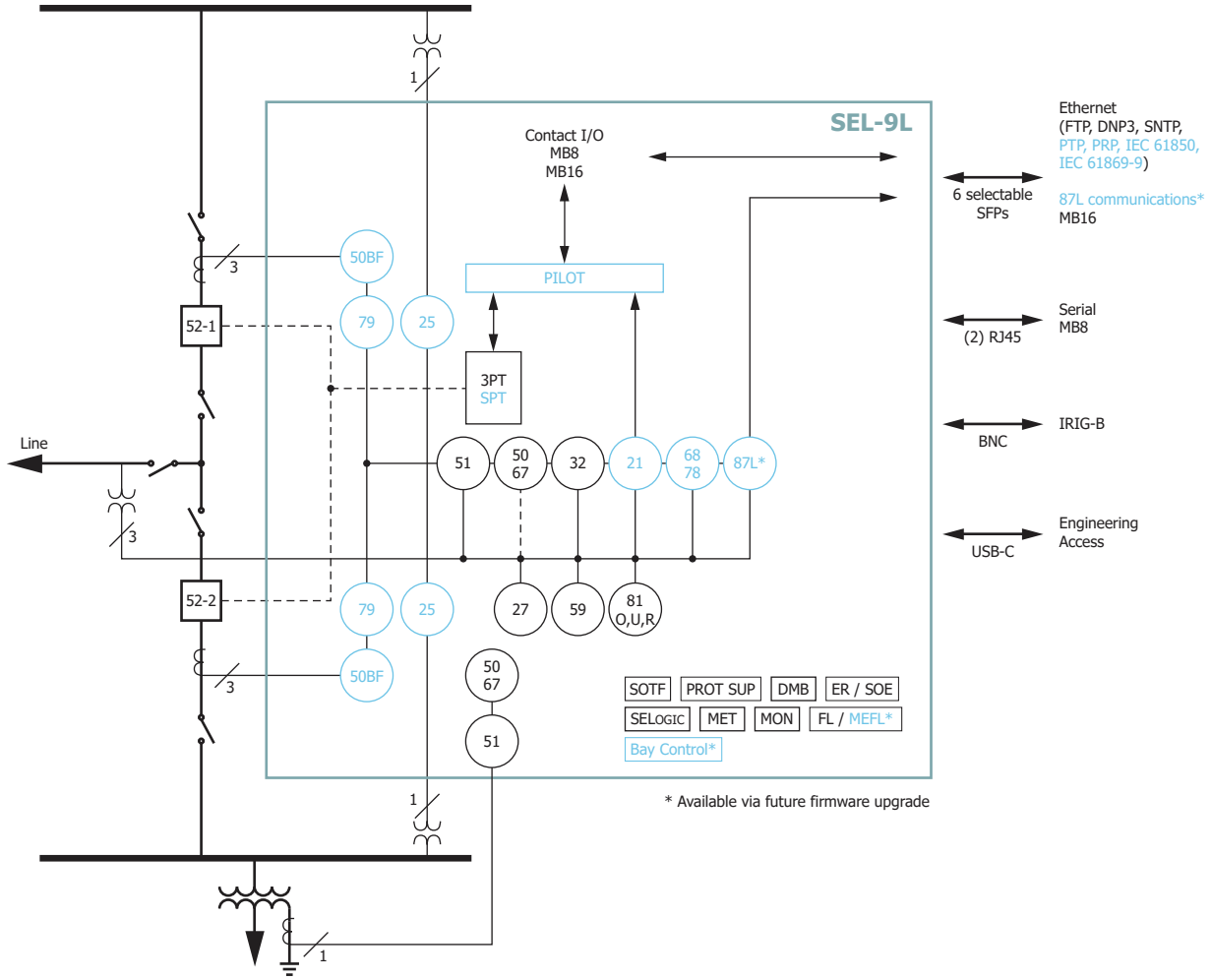

Figure 3 Feature Overview

Table 3 Descriptions of Base and Optional Features

Feature	Description	Quantity/Notes
Base Package		
27 (PTUV)	Undervoltage	Four phase-to-neutral elements (27P). Two phase-to-phase (27PP), positive-sequence (27Pos), VS1, VS2, and VS3 elements. (See *Undervoltage on page 8*)
32 (PDUP/PDOP)	Directional power	Four three-phase underpower (32Un) and overpower (32Ov) elements. (See *Directional Power on page 8*)
50/67 (PIOC/PDOC)	Instantaneous and definite-time directional overcurrent	Six phase-to-neutral (50P, 67P), negative-sequence (50Neg, 67Neg), residual ground (50Gnd, 67Gnd), and neutral (50N, 67N) instantaneous or definite-time elements with optional directionality. Six phase-to-phase (50PP) nondirectional instantaneous elements. (See *Instantaneous and Definite-Time Directional Overcurrent on page 8*)

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Feature	Description	Quantity/Notes
51 (PTOC)	Inverse-time overcurrent	Five maximum phase (51P), negative-sequence (51Neg), residual ground (51Gnd), and neutral (51N) elements. (See *Inverse-Time Overcurrent on page 9*)
59 (PTOV)	Overvoltage	Four phase-to-neutral (59P) elements. Two phase-to-phase (59PP), positive-sequence (59Pos), negative-sequence (59Neg), residual ground (59Gnd), VS1, VS2, and VS3 elements. (See *Overvoltage on page 9*)
81O, U, R (PTOF, PTUF, PFRC)	Overfrequency, underfrequency, and rate-of-change-of-frequency	Six overfrequency (81Ov), underfrequency (81Un), and rate-of-change-of-frequency (81R) elements. (See *Frequency on page 9*)
SOTF	Switch onto fault	(See *Switch Onto Fault on page 10*)
PROT SUP	Protection supervisory elements	Directional control (DIR) Fault-type identification (FID) Load encroachment (LE) Loss of potential (LOP) Open-pole detection (OPD) (See *Protection Supervision on page 11*)
3PT (PTRC)	Three-pole tripping	(See *Trip and Close Logic on page 12*)
SELOGIC	User-defined custom logic	100 each: SELogic variables, math variables, latch bits, conditioning timers, sequencing timers, and counters. (See *Protection Logic on page 12*)
FL (RFLO)	Single-ended fault locating	(See *Fault Location on page 17*)
MET	Metering	(See *Metering on page 15*)
MON	Monitoring	Station battery monitoring (see *Station Battery Monitoring on page 14*) Trip/close circuit monitoring (see *Trip/Close Circuit Monitoring on page 14*) Analog quantity monitoring (see *Analog Quantity Monitoring on page 15*)
ER/SOE	Event reporting and SOE reports	(See *Reports on page 15*)
DMB	Device mode and behavior	(See *Device Mode and Behavior on page 13*)
Ethernet	1 Gbps and 100 Mbps	Relay includes one 100 Mbps SFP. Additional SFPs can be ordered. Protocols: FTP, DNP3, SNTP. (See *Communications on page 18*)
MB16	MIRRORED BITS 16	Two channels (Ports 5 and 6). (See *MIRRORED BITS Communications on page 19*)
MB8	MIRRORED BITS 8	Two channels (Ports A and B). (See *MIRRORED BITS Communications on page 19*)
IRIG-B	Time protocol	(See *Time Synchronization on page 21*)
Distance (Optional)		
21 (PDIS)	Step distance	Five zones of mho or quad for phase (21P) and ground (21Gnd) elements. Includes coupling capacitor voltage transformer (CCVT) transient detection. (See *Distance on page 8*)
68, 78 (RPSB)	Power-swing blocking Out-of-step tripping	Zero settings. (See *Power-Swing Blocking and Out-of-Step Tripping on page 9*)
Pilot (Optional)		
PILOT (PSCH)	Pilot schemes	POTT, DCB, and DTT. (See *Pilot on page 10*)

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Feature	Description	Quantity/Notes
Line Current Differential (Optional)[a]		
87L (PDIF)	Line current differential	(See *Line Current Differential on page 10*)
MEFL (RFLO)	Multi-ended fault locator	(See *Fault Location on page 17*)
Single-Pole Tripping and Pilot (Optional)		
SPT (PTRC)	Single-pole tripping, reclosing, and pilot schemes	(See *Trip and Close Logic on page 12*)
Breaker Failure (Optional)		
50BF (RBRF)	Breaker failure	One breaker (SEL-9L-1) Two breakers (SEL-9L-2) (See *Breaker Failure on page 9*)
Reclosing and Sync Check (Optional)		
79 (RREC)	Reclosing	As many as four shots of reclosing in three-pole mode and two shots of reclosing in single-pole mode. (See *Reclosing on page 13*)
25 (RSYN)	Synchronism check	Three elements with two levels each. (See *Synchronism Check on page 13*)
Bay Control (Optional)[a]		
Bay Control	Control breakers and disconnects	Control as many as two breakers and ten disconnect switches using a custom one-line diagram on the touchscreen. (See *Bay Control on page 13*)
Individual Protocols (Optional)		
PRP	Parallel Redundancy Protocol	(See *Parallel Redundancy Protocol (PRP) on page 20*)
PTP	Precise Time Protocol	(See *Time Synchronization on page 21*)
IEC 61850	Share analog and digital data with other devices	IEC 61850 GOOSE, IEC 61850 MMS. (See *IEC 61850 Edition 2.1 on page 21*)
IEC 61869-9 SV Publication	Sampled Values	IEC 61850 GOOSE, IEC 61850 MMS, and IEC 61869-9 Sampled Values Publication. (See *IEC 61869-9 Sampled Values on page 21*)

[a] Available via future firmware upgrade.

Popular Models

To simplify configuration, popular models of the SEL-9L are available to order with preconfigured features for the most common applications, such as retrofitting SEL-311C Transmission Protection Systems or SEL-311L Line Current Differential Protection and Automation Systems.

Settings Groups

Using settings groups in the SEL-9L is not required. For simple applications, only one group of protection and logic settings can be enabled. For more advanced applications, as many as six settings groups can be enabled. These groups can be used to adapt protection to changing system conditions, such as seasonal operations, station maintenance, or emergency contingencies. Select the active settings group using a contact input, front-panel pushbutton, or other programmable conditions.

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Protection

Distance

The SEL-9L provides five phase and ground distance element zones. The phase and ground distance element of each zone can each be configured with either a mho or quadrilateral characteristic. Zones 1–4 are directional zones, which are set to reach in the forward or reverse direction. The zone direction setting applies to both the phase and ground distance elements of that zone. Zone 5 is nondirectional (offset), with separate reach settings for forward and reverse.

Each ground zone uses its own zero-sequence compensation (ZSC) factor. The ZSC factors can be set automatically by the relay using the line impedance settings or they can be set individually for each zone based on short-circuit studies.

Each distance element is supervised by LOP logic (see *Loss of Potential (LOP) on page 11*) as well as an associated torque-control equation that can be used to enable or disable the element based on system conditions.

When CCVTs are being used to measure voltage, the automatic CCVT transient security logic controls the Zone 1 phase and ground distance elements to avoid overreaching without any settings necessary.

Undervoltage

The SEL-9L includes four levels of undervoltage elements that operate on phase-to-neutral voltages, two levels that operate on phase-to-phase voltages, and two levels that operate on positive-sequence voltage. In addition, there are two levels of undervoltage elements that operate on each phase of the second set of relay voltage inputs (VS1, VS2, and VS3). Each element includes a torque-control equation to enable or block the element based on system conditions as well as an optional definite-time delay.

Directional Power

The SEL-9L includes eight directional power elements: four underpower and four overpower. Each group of four elements can be set to operate on three-phase or single-phase power, and each individual element can be set to operate on watts or vars in the forward or reverse direction.

Instantaneous and Definite-Time Directional Overcurrent

The SEL-9L includes six levels of maximum phase, negative-sequence, and residual-ground overcurrent elements. Forward or reverse directionality can be added to each of the six levels. There are also six levels of neutral overcurrent elements for each of the neutral current inputs on the relay (as many as two). All the phase, negative-sequence, ground, and neutral overcurrent elements can be applied as instantaneous elements or definite-time elements and include torque-control logic.

In addition, the relay includes six levels of phase-to-phase nondirectional instantaneous overcurrent elements.

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Breaker Failure

The SEL-9L detects single- and multi-phase failures and issues retrips for as many as two breakers. High-speed open-pole detection logic (see *Protection Supervision on page 11*) supervises the breaker failure element, allowing its current pickup to be set below minimum load. Due to the speed of the logic, an open breaker can be detected quickly even when trapped flux in the CT delays the current zero-crossings measured by the relay. This allows for faster breaker failure coordination times and improves stability.

Inverse-Time Overcurrent

The SEL-9L includes five levels of maximum phase, negative-sequence, residual-ground, and neutral inverse-time overcurrent elements. These elements support all the customary parameters, such as torque control, curve type (US U1–U5, IEC C1–C5, IEEE E1–E3), and reset time.

Overvoltage

The SEL-9L includes four levels of overvoltage elements that operate on phase-to-neutral voltages and two levels of overvoltage elements that operate on phase-to-phase, positive-sequence, negative-sequence, and residual ground voltages. In addition, there are two levels of overvoltage elements that operate on each phase of the second set of relay voltage inputs (VS1, VS2, and VS3). Each element includes a torque-control equation to enable or block the element based on system conditions as well as an optional definite-time delay.

Power-Swing Blocking and Out-of-Step Tripping

The SEL-9L includes settings-free power-swing blocking (PSB) and out-of-step tripping (OOST) logic based on the impedance-rate-of-change operating principle. When the change in impedance over time is moving at a speed consistent with a power swing and in a constant direction, the relay declares a stable power swing and blocks the distance element from operating. If the change in impedance over time changes to being inconsistent with a power swing, the distance element is unblocked.

The PSB logic can be enabled for each distance zone individually. In addition, the relay implements the PSB logic independently for each phase and ground distance element, allowing it to reliably perform PSB on healthy phases while detecting faults and selectively unblocking the faulted phases.

The OOST logic in the SEL-9L is used to trip for unstable power swings. For security, it follows the trip-on-the-way-out principle—meaning it only operates when an unstable power swing has already passed through the protected line and the system has slipped a pole. The OOST logic also provides delayed tripping to avoid overvoltage conditions across the circuit breaker.

Frequency

The SEL-9L includes six underfrequency (81U), six overfrequency (81O), and six rate-of-change-of-frequency (81R) elements. Each element includes a torque-control equation to enable or block the element based on system conditions as well as a settable definite-time delay.

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Line Current Differential

The SEL-9L will include line current differential protection for as many as three terminals in a future firmware upgrade. The element will use a percent-restrained characteristic with built-in channel asymmetry detection and include line-charging current compensation to enhance the sensitivity of the 87L elements for protection of long high-voltage lines or cables. It will also include in-line transformer protection and stub bus protection. Communication between relays for the 87L element will be done via Port 5 or 6 via a direct fiber connection (up to 120 km) or an IEEE C37.94 multiplexed connection. See *Table 8* for a list of SFPs that can be used for the 87L communications channel.

Pilot

The SEL-9L includes preconfigured pilot schemes for permissive overreaching transfer trip (POTT), directional comparison blocking (DCB), and direct transfer trip (DTT). The pilot schemes can accept permissive and blocking signals via contact I/O, MIRRORED BITS, or a combination of the two. The pilot schemes can be applied to lines with any number of terminals by using SELOGIC control equations to AND permissive trip signals and OR blocking signals from all remote relays. In addition, SELOGIC control equations and programmable I/O or MIRRORED BITS can be used to implement other types of pilot protection schemes, such as directional comparison unblocking (DCUB).

The preconfigured POTT scheme includes weak-infeed logic and open-breaker echo logic to add dependability during specific system conditions. Weak-infeed logic initiates permissive echo keying when the relay detects an abnormal voltage condition and does not see a reverse fault. Open-breaker echo logic initiates permissive echo keying when one or more line terminals are open or out of service.

When configuring pilot schemes, distance or overcurrent elements in Zone/Level 2 must be set as forward-looking overreaching elements, and elements in Zone/Level 3, 4, or 5 must be set as reverse-looking elements. Built-in current reversal logic uses the same type of elements that were selected (distance or overcurrent) to detect faults in the reverse direction, improving coordination for POTT and DCB schemes.

Switch Onto Fault

When a line is energized, it takes a short amount of time for the relay to measure voltages from the line-side VTs. During this time, any protection elements that depend on voltage for polarization (such as distance and directional overcurrent elements) may not operate. Switch-onto-fault (SOTF) protection fills that gap by temporarily enabling nondirectional elements to detect faults that either exist when the line is energized or appear shortly after line energization. The SOTF logic can be set to enable based on breaker status and disable automatically when the voltage stabilizes.

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Protection Supervision

Directional Control (DIR)

The SEL-9L uses directional control logic to determine if faults are in the forward or reverse direction. This logic includes three directional elements: phase, zero-sequence, and negative-sequence. All three elements operate independently from each other.

The phase directional element is used to determine the direction of balanced three-phase faults. It can be used to directionalize the instantaneous, definite-time, and inverse-time phase overcurrent elements. The element is operational during single-pole tripping and reclosing and allows for detecting the direction of high-current faults during a single-pole open condition.

The zero-sequence directional element is used to determine the direction of unbalanced faults that include ground (phase-to-ground, phase-to-phase, and phase-to-phase-to-ground). It can be used to directionalize the instantaneous, definite-time, and inverse-time ground overcurrent elements.

The negative-sequence directional element is used to determine the direction of any unbalanced fault. It can be used to directionalize the instantaneous, definite-time, and inverse-time ground and negative-sequence overcurrent elements.

Fault-Type Identification Selection (FIDS)

FIDS logic identifies the faulted phases for all fault types, with no settings required. The method used will automatically vary depending on system conditions.

Load Encroachment (LE)

LE logic prevents load conditions from causing phase protection to operate. This allows you to set the phase distance and phase overcurrent elements independent of load. LE logic can detect load in both directions (export or import) and has separate pickup thresholds for each direction for both phase and ground. Blocking angle settings are used for both phase and ground to define the leading and lagging power factor requirements. Settings can be used to block specific distance zones and overcurrent elements during load conditions.

Loss of Potential (LOP)

Distance and directional elements require proper voltage measurements to operate correctly. When a VT measurement is lost due to a blown fuse or other condition, these elements lose their ability to operate reliably. LOP logic detects a lost voltage condition and blocks affected elements from incorrectly operating. When an LOP condition occurs, distance elements are blocked, directional elements are blocked or set to nondirectional, and an alarm is asserted. The LOP function only needs to be enabled, with no additional settings required.

Open-Pole Detection (OPD)

OPD logic is used to determine if the protected line is connected or disconnected from the local bus. The logic can use current measurements, breaker status, or voltage measurements to operate. OPD logic supervises a wide range of protection elements, including distance and directional elements.

Logic

Protection Logic

Custom logic in the SEL-9L is done through freeform SELOGIC control equations written in SEL Grid Configurator. SELOGIC programming is a powerful tool that can be used to implement almost any custom protection or control scheme. The logic editor in SEL Grid Configurator, shown in *Figure 4*, allows users to control the processing order of their logic as well as create sections of logic for better organization. Users can also document their logic schemes by adding labels to their variables and comments throughout their logic. Automatic variable color-coding and autocomplete while typing makes writing logic more user-friendly than ever.

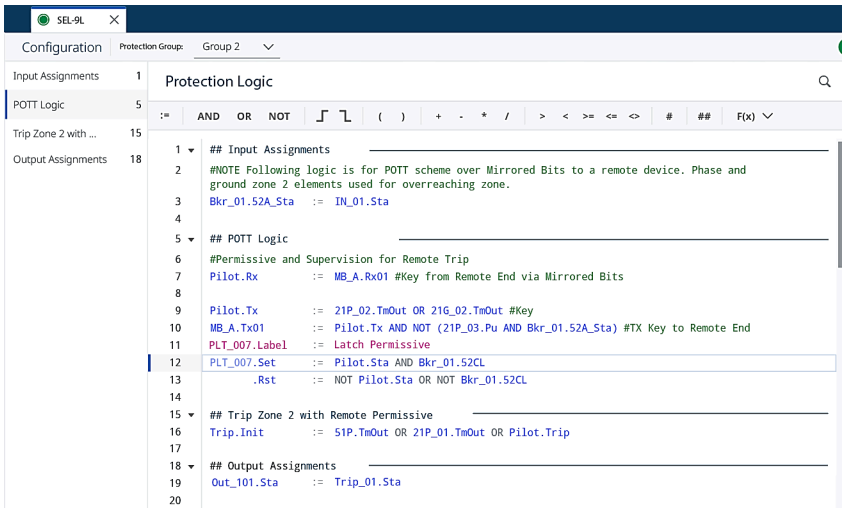

Figure 4 SELOGIC Editor in Grid Configurator

The SELOGIC programming available in the SEL-9L is processed every 1 ms and includes the variety of logic elements shown in *Table 4*.

Table 4 SEL-9L Protection Logic Elements

Protection Logic Elements	Maximum Supported Instances
Logic Variables (PSV)	100
Math Variables (PMV)	100
Latch Bits (PLT)	100
Conditioning Timers (PCT)	100
Sequencing Timers (PST)	100
Counters (PCN)	100

Trip and Close Logic

The SEL-9L can perform three-pole or single-pole tripping and closing.

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Control

Synchronism Check

Synchronism-check elements can be used to block closing across an open breaker when the voltages on either side are not close enough in phase, magnitude, or frequency. The SEL-9L includes three synchronism-check elements that can be programmed for a variety of applications. Each element has two levels of programmable angle thresholds.

Reclosing

The SEL-9L has as many as four shots of reclosing in three-pole mode and two shots of reclosing in single-pole mode. For dual-breaker applications, leader and follower breakers can be set permanently or change dynamically based on system conditions using SELOGIC control equations. Dead-line/dead-bus and zero-closing angle logic is available to minimize system stress when reclosing.

Bay Control

Bay control functionality will be available in a future firmware upgrade. With this feature, the touchscreen of the SEL-9L can be used to display interactive bay control diagrams. The screen can be used to control as many as two breakers and monitor the status of a third. It can also control as many as ten disconnect switches. The bay control diagrams will include the ability to add user-configurable labels for the equipment shown as well as user-definable analog quantities to the screens.

Device Mode and Behavior

When relay testing is being performed or settings are being changed, the contact outputs of the relay are typically isolated from the trip and close coils of the circuit breakers to avoid unnecessary breaker operation. This isolation is typically done using physical switches on the panel.

The SEL-9L supports a method (defined by IEC 61850-7-4) that emulates these isolation functions within the relay itself. At any given time, the relay is in one of the device modes shown in *Table 5*. Each of these modes defines a different type of relay behavior: if the physical contact outputs will operate or not, if communications protocol messages will be sent or received, etc. The mode that the relay is in is reflected by its **ENABLED** LED and is also sent as part of the communications protocol to any other relays with which it is communicating. The remote relays can be programmed to enter a specific device mode based on the device mode of the relay they are communicating with. The ability to remotely block the contact outputs on a remote relay from operating allows more flexibility when designing commissioning procedures, running tests, and performing maintenance.

The SEL-9L supports device modes for the IEC 61850 MMS, IEC 61850 GOOSE, IEC 61869-9 Sampled Values, and MIRRORED BITS 16 protocols. These device modes come standard in the base package of the SEL-9L—purchasing the IEC 61850 protocol package is not necessary to use them.

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Table 5 Device Modes and Behaviors

Device Mode	Relay Enabled	Physical Contacts Operate	Communications Behavior	Notes
On	Yes	Yes	Normal operation	Standard operating mode
On-Blocked	Yes	No	Protocol-dependent	Relay is active, but no physical outputs
Test	Yes	Yes	Test flags sent (protocol-dependent)	Used for testing with full physical outputs
Test/Blocked	Yes	No	Test flags sent (protocol-dependent)	Used for testing without physical outputs
Off	No	No	Disabled	Protection is disabled

Monitoring and Metering

Station Battery Monitoring

The SEL-9L measures and reports the station battery voltage connected to the **+/H** and **–/N** power supply terminals. The measured dc voltage is reported in the meter display via the touchscreen, in the Grid Configurator online HMI, and in the event report. Programmable threshold comparators and associated logic provide alarms for, and control of, the batteries and charger. The event report also provides an oscillography display of the battery voltage for monitoring of station battery voltage drop during tripping, closing, and other control operations. The SEL-9L also provides a method for ground detection on the battery system.

Trip/Close Circuit Monitoring

Contact outputs **OUT101** through **OUT103** are denoted with **CM** (see *Figure 2*), indicating they are Circuit Monitoring (CM) outputs. These high-speed, high-current-interrupting contact outputs include integrated measurements of the dc voltage across the output as well as the dc current flowing through the output, as shown in *Figure 5*. These measurements are provided as analog quantities that are available for use in SELOGIC programming and recorded in the event report for circuit and breaker analytics.

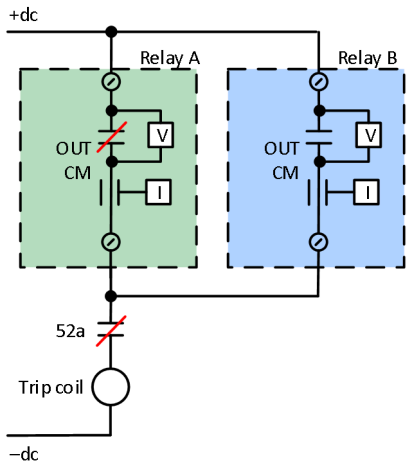

Figure 5 Measurement of Voltage Across and Current Through CM Contact Outputs

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In addition, the built-in voltage measurement across the contact output can take the place of traditional trip circuit monitoring wiring, which requires the voltage across the trip contact to be measured via a separate parallel contact input. This allows trip circuit monitoring functions to be programmed in the relay without any additional wiring.

Analog Quantity Monitoring

The SEL-9L provides a comprehensive set of instantaneous monitoring data that are updated every 1 ms, including the following:

- Phase, neutral, and positive-, negative-, and zero-sequence current magnitudes and angles
- Phase and positive-, negative-, and zero-sequence voltage magnitudes and angles
- Real (kW), reactive (kVAR), and apparent power (kVA)
- Power factor
- Math variables
- Station battery voltage
- Voltage across and current through CM contact outputs
- Voltage across contact inputs

Metering

The SEL-9L provides metering data that are averaged over a 250 ms interval, including the following:

- Phase, neutral, and positive-, negative-, and zero-sequence current magnitudes and angles
- Phase and positive-, negative-, and zero-sequence voltage magnitudes and angles
- Real (kW), reactive (kVAR), and apparent power (kVA)

Reports

Event Reporting

The SEL-9L creates an event report whenever the relay trips or a specified trigger condition occurs. The total length of the event report is configurable, with a range from 0.25 to 5 seconds. Event report files can be downloaded using SEL Grid Configurator or a standard FTP client. Each file contains two versions of the event report, both in COMTRADE IEEE C37.111-2013 format:

- Low-resolution (LR) event report
- High-resolution (HR) event report

The differences between the LR and HR event reports are shown in *Table 6*. For most relay operations, the LR event report provides all the information necessary for analysis. All data in *Table 6* will be available in the event reports without requiring any manual configuration.

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Table 6 Differences Between Event Reports

Item	Low-Resolution (LR) Event Reports	High-Resolution (HR) Event Reports
Sample rate	1 kHz	10 kHz
Local currents and voltages at the terminals (oscillography)	Included as filtered data (only nominal frequency of 50 or 60 Hz) and raw data (all frequencies)	Included as raw data only (all frequencies)
Derived analog quantities (e.g., sequence components or calculated line current for dual-breaker applications)	Included	Not included
Relay element status (Relay Word bits)	Included	Not included
Contact input status	Included	Included
Contact input voltage	Included (raw)	Not included
Contact output status	Included	Not included
Received IEC 61850 GOOSE messages	Included	Not included
Received IEC 61869-9 Sampled Values messages	Not included	Included (via future firmware upgrade)
Relay settings at time of event trigger	Included (all groups)	Not included
Applications	Use the filtered data to analyze operations of relay elements that use phasor quantities. Use the raw data to analyze power system activity at off-nominal frequencies (e.g., CT saturation or transformer inrush) as well as analyze operations of relay elements that use raw 1 kHz quantities.	Analyze high-resolution power system activity and operations of relay elements that use raw 10 kHz quantities.

Each time the relay generates an event report, it also generates a corresponding event summary. This concise description of the event includes information such as the relay name, date and time of the event, measured voltages and currents, type of event, and relay targets that asserted during the fault.

Sequence of Events (SOE)

The SEL-9L includes an SOE report, which helps users track relay element operation and status over a long period of time. The SOE report contains records of events such as settings changes and relay restarts. In addition, it includes the status of the bits that are configured in the relay's Sequential Events Recorder (SER). The SER can be populated with as many as 250 digital elements that the user would like to monitor, such as the status of specific relay elements or contact I/O. Any time one of those elements asserts or deasserts, an entry is recorded in the SOE report. Each entry includes a date and time stamp, as well as the status of the element that changed. The SOE report stores as many as 4,096 records, which are retained even when the relay is powered off.

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Diagnostics Report

In the rare case that the relay detects a failure or other diagnostic condition, it will trigger the creation of a diagnostic ZIP file. This file can be downloaded with a single click in Grid Configurator and contains everything needed to send to SEL for diagnosis, including error logs, event reports, settings files, and more.

Fault Location

The SEL-9L calculates the fault location for each event report using a single-ended impedance-based method. Multi-terminal fault location will be available in a future firmware upgrade.

Front Panel and Display

Touchscreen

The SEL-9L comes with a 7-inch color touchscreen that makes viewing settings and metering data as well as operating controls quick and efficient. *Figure 6* shows some of the folders and applications that can be used to access information from the touchscreen.

Figure 6 Folders and Applications on the Touchscreen

These applications allow you to perform the following:

- View relay settings, relay status, and firmware version
- View metering and monitoring data
- View event history, summary data, and SOE reports
- Control breaker operations
- Enable the rotating display
- View and control bay screens (available via future firmware upgrade)

Status and Trip Target LEDs

The SEL-9L includes 38 tricolor LEDs on the front panel, as shown in *Figure 7*. By default, the LEDs on the left side reflect the status of protection elements inside the relay. Most of these LEDs function as targets that assert after a relay trip to let personnel know what elements caused the trip. The LEDs on the right side (next to each pushbutton) reflect the status of control functions that are operated by pushing the associated buttons. You can reprogram and relabel all of the LEDs (except **ENABLED** and **TRIP**) for any application.

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Figure 7 Status and Trip Target LEDs

Pushbuttons

The ten pushbuttons in *Figure 7* come preprogrammed to perform the default functions described on the labels. These pushbuttons can be changed through settings to perform any desired function.

Configurable Labels

Configurable labels allow users to easily relabel targets, pushbuttons, and pushbutton LEDs when they are reprogrammed for custom applications. Each relay comes with a blank sheet of labels that can be used with a Microsoft Word template (available online at selinc.com) and a standard printer. It is also possible to write directly on the labels. The small label underneath the **TARGET RESET** button can be used to display the relay name or identifier.

Communications

Ports

In addition to the front USB-C port (Port F), there are eight communication ports on the back of the SEL-9L, as shown in *Figure 8*. The RJ45 serial ports labeled **PORT_A** and **PORT_B** are used to communicate MIRRORED BITS 8 protocol. The remainder of the ports (**PORT_1**–**PORT_6**) are software-configurable SFP fiber-optic LC ports that can be used for a variety of applications, as shown in *Table 7*.

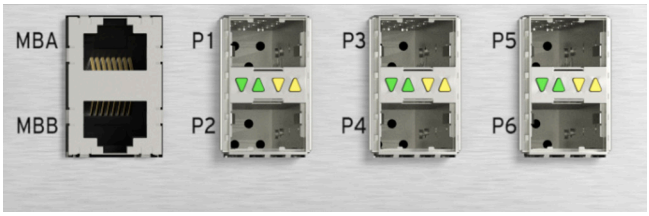

Figure 8 Rear Port Layout

Table 7 Software-Configurable Port Allocation

Communication Protocol	Ports Available
1 Gbps Ethernet	1, 2
100 Mbps Ethernet	1, 2, 3, 4, 5, 6

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Communication Protocol	Ports Available
MIRRORED BITS 16[a]	5, 6
Line Differential[a, b]	5, 6
MIRRORED BITS	A, B

[a] Supports IEEE C37.94 and/or direct fiber over distances as far as 120 km.
[b] This feature will be available in a future release.

Due to the flexible nature of the SFP ports, it is necessary to order the required SFPs based on the desired application. A list of available SFPs is given in *Table 8*. The relay comes standard with one 100 Mbps Ethernet SFP (SEL Part Number 8109-01).

Table 8 Available SFPs

Application	SEL Part Number	Standard	Max. Distance	Wavelength	Mode	Power per SFP
100 Mbps Ethernet	8109-01	100BASE-FX	2 km	1310 nm	MM	–17 dBm
1 Gbps Ethernet	8131-01	1000BASE-SX	0.3 km	850 nm	MM	–2.5 dBm
MB16/87L Direct Fiber	8104-01	100BASE-LX	20 km	1310 nm	SM	–8 dBm
MB16/87L Direct Fiber	8104-02	100BASE-LX	50 km	1310 nm	SM	0 dBm
MB16/87L Direct Fiber	8104-03	100BASE-ZX	80 km	1550 nm	SM	0 dBm
MB16/87L Direct Fiber	8104-04	100BASE-ZX	120 km	1550 nm	SM	5 dBm
MB16/87L C37.94 MM	8141-01	C37.94 MM	2 km	850 nm	MM	–11 dBm
MB16/87L C37.94 SM	8141-02	C37.94 SM	20 km	1310 nm	SM	–8 dBm

To ensure optimal performance and reliability, it is critical to not use third-party SFPs in SEL devices. The SFPs in *Table 8* have been signed by SEL, indicating that they have undergone rigorous testing and will operate reliably across the same environmental ranges as the relay.

MIRRORED BITS Communications

MIRRORED BITS communications is a proprietary SEL protocol that provides bidirectional relay-to-relay digital communications at protection speeds. The protocol sends a set of user-defined bits to another SEL device while at the same time receiving a set of user-defined bits from that device. Each bit represents the state of a binary piece of information in the relay.

MIRRORED BITS communications is often used to exchange information such as transfer trip signals, breaker status, or element status between relays. Permissive keying for POTT schemes and blocking signals for DCB schemes are often sent between relays using MIRRORED BITS. MIRRORED BITS communications is significantly faster than using contact outputs wired to contact inputs to transmit these signals. MIRRORED BITS communications is also easy to set up and has addressing and error detection built in.

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The SEL-9L supports two types of MIRRORED BITS communications:

- **MIRRORED BITS 8 (MB8)** exchanges a set of 8 bits between devices. Two channels of MB8 are supported (**PORT_A** and **PORT_B**). MB8 operates over a direct serial communication channel between devices using the EIA-232 standard.
- **MIRRORED BITS 16 (MB16)** exchanges a set of 16 bits between devices. Two channels of MB16 are supported (**PORT_5** and **PORT_6**). MB16 is encapsulated in an Ethernet packet and can operate over direct fiber at 100 Mbps or an IEEE C37.94 multiplexed channel at 64 kbps, and depending on the SFP being used, can go a longer distance than MB8. MB16 also includes the device mode and behavior status as part of the signal (see *Device Mode and Behavior on page 13*).

The SEL-9L can support two channels of MB8 and two channels of MB16. The MB8 and MB16 protocols are not compatible with each other.

Networking and Ethernet

The SEL-9L provides Ethernet communications capabilities using Ethernet SFPs that transfer data at high speeds (100 Mbps or 1 Gbps) for fast file uploads and data flow.

Each relay can have as many as three different IP addresses on the rear Ethernet ports, with the possibility of setting up failover or PRP schemes for redundancy. *Figure 9* shows two examples of how relays can be set up for various network configurations.

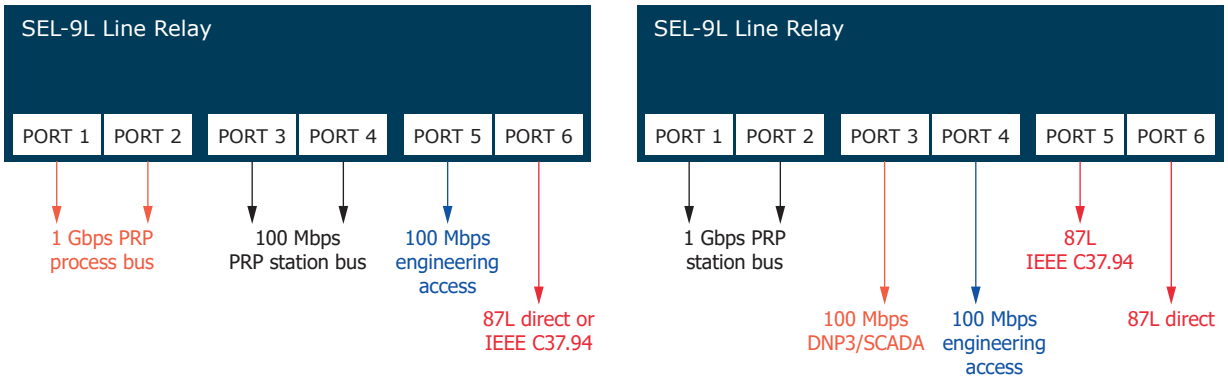

Figure 9 Network Configuration Examples

Parallel Redundancy Protocol (PRP)

PRP is used to provide seamless recovery from any single Ethernet network failure in accordance with IEC 62439-3. When PRP is used, two ports share an IP address and operate on two duplicate parallel networks for redundancy.

File Transfer Protocol (FTP)

FTP is used to transfer event reports, SOE records, settings files, and firmware to and from the relay via the Ethernet ports or the front-panel USB-C port.

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DNP3

DNP3 LAN/WAN provides the SEL-9L with DNP3 Level 2 Outstation functionality over Ethernet. As many as six DNP3 sessions can be configured with as many as six custom DNP3 data maps. The relay supports as many as ten unique IP addresses per session.

IEC 61850 Edition 2.1

The IEC 61850 Edition 2.1 Ethernet protocol can be used for sharing analog and digital data with other devices at protection speeds.

MMS

The SEL-9L is equipped with an embedded IEC 61850 data server that supports as many as 12 simultaneous client associations and MMS file transfer. All relay files that can be transferred via FTP can also be transferred via MMS file services.

GOOSE

The SEL-9L can support as many as 16 IEC 61850 GOOSE publications.

The SEL-9L can support as many as 128 IEC 61850 GOOSE subscriptions and map the data to the following:

- 128 measured values (analog values)
- 256 single-point status values (binary status)
- 32 double-point status values (breaker or switch status)
- 32 integer-status values (mode and behavior status; see *Device Mode and Behavior on page 13*)

All of the above quantities received over GOOSE can be used in SELOGIC control equations and are recorded in event reports.

IEC 61869-9 Sampled Values

The SEL-9L supports IEC 61869-9:2016 Sampled Values (SV) publication of as many as 4 SV streams, compatible with sample rates of 4,800 Hz with 1 or 2 ASDUs, and 4,000 Hz with 1 ASDU. The capability to subscribe to IEC 61869-9 SV streams will be available in a future firmware upgrade.

Time Synchronization

The SEL-9L can receive an IRIG-B signal through the BNC port on the back of the relay for high-accuracy timekeeping. It can also receive a time signal via SNTP over an Ethernet network. For higher-accuracy timing over Ethernet, the relay can use IEEE 1588 Precision Time Protocol version 2 (PTPv2). When connected directly to a time transmitter clock providing PTP at one-second synchronization intervals, the relay can be synchronized to an accuracy of ±100 ns. The relay can receive as many as 32 sync messages per second.

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Cybersecurity

The SEL-9L will provide robust security features, including the following:

- Secure booting of signed firmware
- Role-based access control (RBAC)
- Encrypted communication using Transport Layer Security (TLS)[a]
- Comprehensive device audit logging via Sequence of Events (SOE) and Syslog[a]
- File Transfer Protocol Secure (FTPS)[a]

[a] Available via future firmware upgrade.

SEL Grid Configurator

SEL Grid Configurator software is required for configuring and operating the SEL-9L and is available as a free download from selinc.com. The software allows users to do the following:

- Create a settings file for the relay.
- Connect to the relay locally or remotely.
- Read, send, and change relay settings.
- Create SELOGIC control equations with a user-friendly editor (see *Protection Logic on page 12*).
- Download event data.
- Create a directory of networked relays.
- Keep track of settings changes using versions.
- Upgrade relay firmware.
- Collect relay support and diagnostic information.

Online HMI

The online HMI in Grid Configurator provides users with a powerful, fast, and intuitive interface with the relay. Users can create a dashboard of as many as four different HMI views on one screen as shown in *Figure 10*. Once configured, the dashboard can be saved to reuse with other relays.

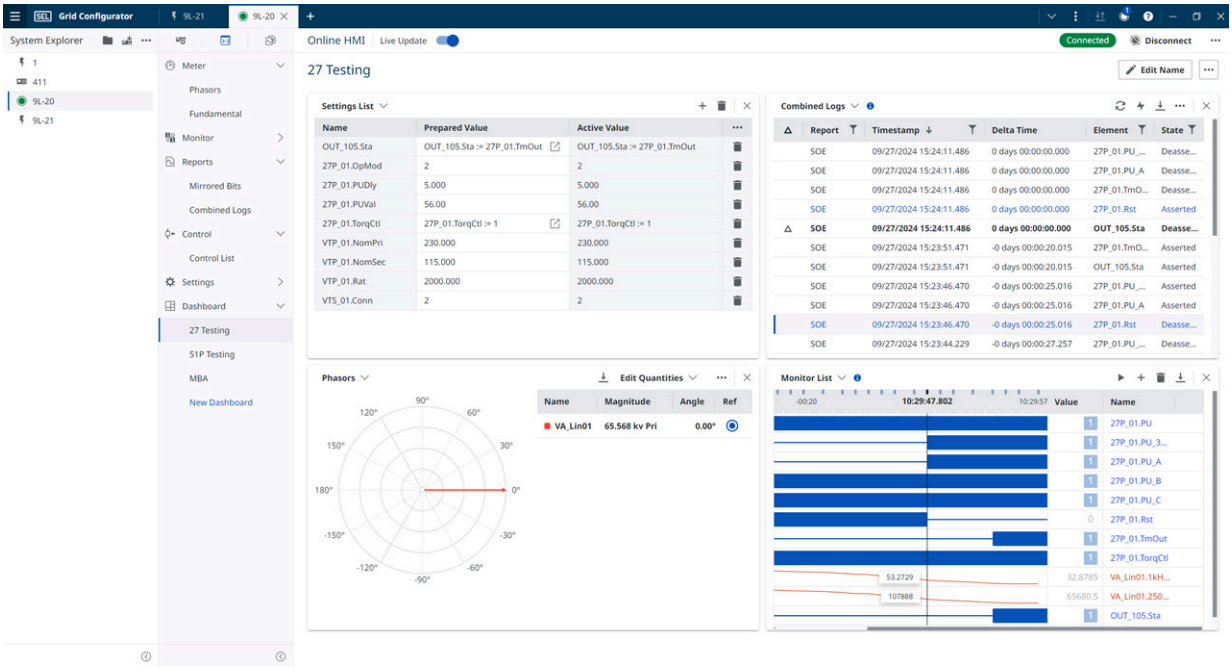

Figure 10 Grid HMI Dashboard

The HMI screens shown on the dashboard in *Figure 10* are Settings List, Combined Logs Report, Meter Phasors, and Monitor List. The following is a complete list of available HMI screens:

- **Device Status:** View information about the connected relay.
- **Device Test Mode:** View or change the device test mode and behavior.
- **Device Configuration:** View information about how the connected relay is configured.
- **Meter Phasors:** View a live phasor plot of currents and voltages measured by the relay.
- **Meter Fundamental:** View line currents, individual breaker currents, and voltages.
- **Monitor List:** Poll the status of any available binary or analog value in the relay. The live view can be paused at any time, and the list keeps a 30-second history of recent data.
- **Mirrored Bits Report:** View information about the MIRRORED BITS channels.
- **Combined Logs Report:** See all event reports and SOE data in the same view. Set a reference and calculate the time between different events. Filter, export, and download event reports and SOE data.
- **PTP Report:** View information about PTP connections.
- **IEC 61850 GOOSE Report:** View GOOSE publications and subscriptions.
- **Port Statistics:** View information about the six SFP ports on the relay.
- **Control List:** Set, clear, or pulse contact outputs and remote bits. Reset event report history and clear SOE reports.
- **Test DB:** Force analog quantities and Relay Word bits to specific values to easily test communications protocols.
- **Settings List:** View, filter, and change the settings in the relay.

Diagrams and Dimensions

The SEL-9L is the same size and has a very similar rear-panel layout as the SEL-311C and SEL-311L, making it an easy direct replacement.

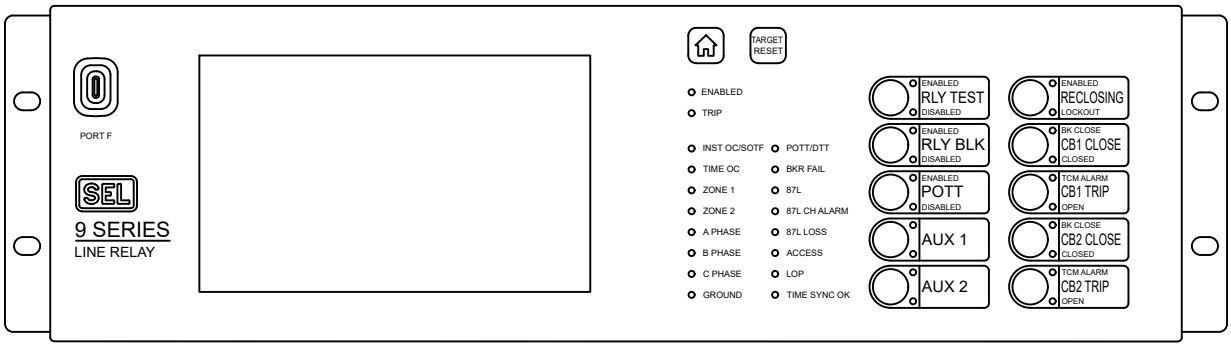

Figure 11 SEL-9L Front Panel

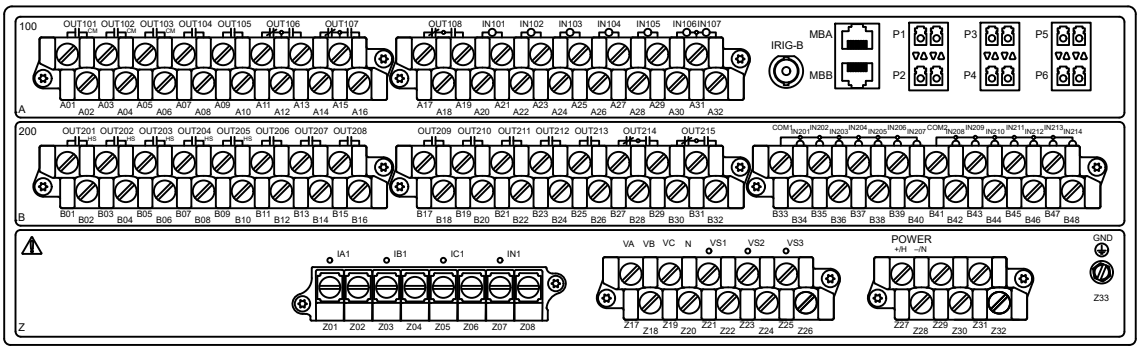

Figure 12 SEL-9L-1 Rear Panel

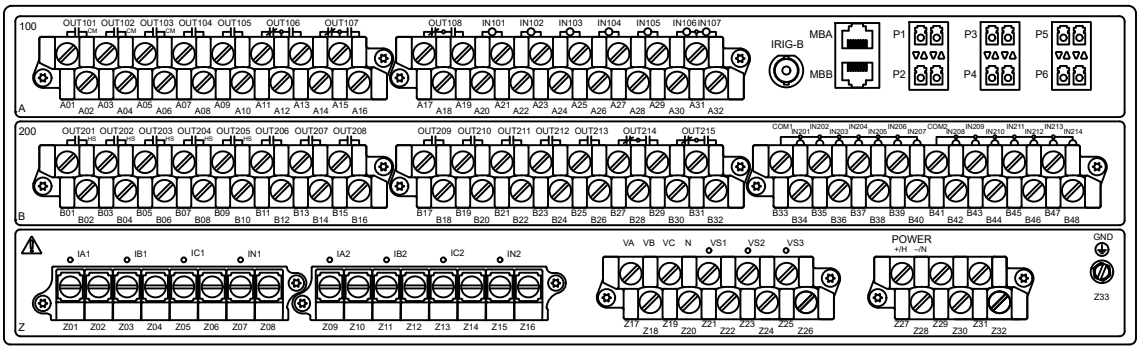

Figure 13 SEL-9L-2 Rear Panel

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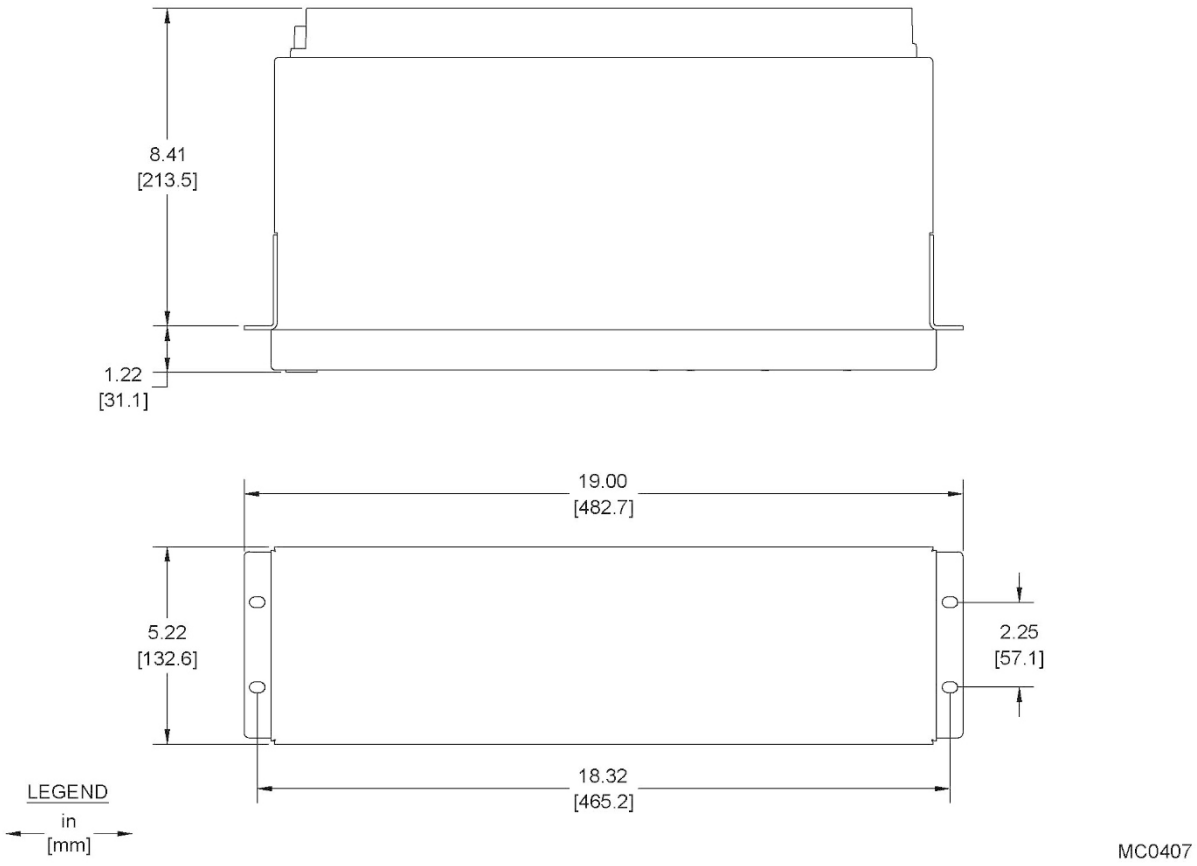

Figure 14 SEL-9L Rack-Mount Dimensions (All Models)

Specifications

AC Analog Inputs

General

Sampling Rate:	10 kHz
Rated Frequency:	50/60 Hz
Operational Frequency Range:	40–70 Hz

AC Current Inputs

CT input accuracy ranges from 0.05 to 4 • INOM for both 1 A and 5 A CTs.

Rated Current (I_{NOM}):	1 A or 5 A (software-selectable)
Continuous Thermal Rating:	20 A rms
One-Second Thermal Rating:	500 A rms
Burden Rating:	≤0.1 VA at 1 A rms at rated frequency
ADC Current Limit:	≥350 A peak

AC Voltage Inputs

Rated Voltage Range (V_{NOM}):	57.7–250 V rms line-to-neutral
Operational Voltage Range:	0–300 V rms line-to-neutral

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Ten-Second Thermal Rating:	600 V rms
Burden Rating:	≤0.1 VA at 120 V rms at rated frequency

Contact Inputs

All contact inputs include reinforced isolation.

Sampling Rate:	10 kHz
Operational Polarity:	Bipolar dc; ac
Rated Voltages:	24/48/110/125/220/250 Vdc; 120/240 Vac rms, 50/60 Hz (software-selectable)
Operational Voltage Range:	0–300 Vdc; 0–288 Vac rms
Steady-State Current Draw:	1–4 mA (at rated voltages)
Burden (Max. Steady-State Power Consumption):	≤0.6 W (at dc rated voltages) ≤0.6 VA (at ac rated voltages)

Contact Outputs

General

All contact outputs include reinforced isolation.

Update Rate:	≤1 ms
Operational Polarity:	Bipolar dc ac (applies to standard Form A and Form C contacts only)
Continuous Contact Current:	5 A at 70°C (158°F) 4 A at 85°C (185°F)
Breaking Current:	All breaking capacities are given in watts. To calculate breaking current, divide the given rating in watts by the applied voltage.

Standard Form A and Form C Contact Outputs (DC or AC)

Rated Voltage Range:	24–250 Vdc; 100–240 Vac rms, 50/60 Hz
Operational Voltage Range:	0–300 Vdc; 0–264 Vac rms
Operating Time:	Pickup: ≤6 ms Dropout: ≤6 ms
Make[a, b] (Short Duration Contact Current):	30 A at 250 Vdc 2,000 operations
AC Limited Making Capacity (Inductive):	1,000 W at 250 Vac rms (PF = 0.4) 2,000 operations
DC Limited Making Capacity (Inductive):	1,000 W at 250 Vdc (L/R = 40 ms) 2,000 operations
DC Limited Breaking Capacity (Resistive):	50 W, Resistive, 10,000 operations for 24–250 Vdc 10 operations in 4 seconds, followed by 2 minutes idle
DC Limited Breaking Capacity (Inductive):	50 W, L/R = 40 ms, 10,000 operations 24–250 Vdc 10 operations in 4 seconds, followed by 2 minutes idle
AC Limited Breaking Capacity (Resistive):	50 W, Resistive, 10,000 operations for 100–240 Vac rms 10 operations in 4 seconds, followed by 2 minutes idle
AC Limited Breaking Capacity (Inductive):	50 W, PF = 0.4, 10,000 operations for 100–240 Vac rms 10 operations in 4 seconds, followed by 2 minutes idle
Short-Time Thermal Withstand:	50 A for 1 s
Leakage Current:	≤30 µA for –40° to +85°C (–40° to +185°F) for ≤300 Vdc ≤100 µA for –40° to +85°C (–40° to +185°F) for ≤264 Vac rms, 50/60 Hz

High-Speed, High-Current-Interrupting Contact Outputs (DC Only)

Rated Voltage Range:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc

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Operating Time (Resistive Load):	Pickup: ≤10 µs Dropout: ≤8 ms
Make[a, b] (Short Duration Contact Current):	30 A at 250 Vdc 2,000 operations
DC Limited Making Capacity Resistive (Inductive):	1,000 W at 250 Vdc (L/R = 40 ms) 2,000 operations
DC Limited Breaking Capacity (Resistive):	1,250 W, Resistive, 10,000 operations for 24–250 Vdc 4 operations in 1 second, followed by 2 minutes idle
DC Limited Breaking Capacity (Inductive):	For 48–250 Vdc: 1,250 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle For 24 Vdc: 625 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle
Short-Time Thermal Withstand:	50 A for 1 s
Leakage Current:	≤100 µA for –40° to +85°C (–40° to +185°F) for ≤300 Vdc

Circuit Monitoring—High-Speed, High-Current-Interrupting Contact Outputs (DC Only)

Rated Voltage Range:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time (Resistive Load):	Pickup: ≤10 µs Dropout: ≤8 ms
Make[a, b] (Short Duration Contact Current):	30 A at 250 Vdc 2,000 operations
DC Limited Making Capacity Resistive (Inductive):	1,000 W at 250 Vdc (L/R = 40 ms) 2,000 operations
DC Limited Breaking Capacity (Resistive):	1,250 W, Resistive, 10,000 operations for 24–250 Vdc 4 operations in 1 second, followed by 2 minutes idle
DC Limited Breaking Capacity (Inductive):	For 48–250 Vdc: 1,250 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle For 24 Vdc: 675 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle
Short-Time Thermal Withstand:	50 A for 1 s
Leakage Current:	≤500 µA for –40° to +85°C (–40° to +185°F) for ≤300 Vdc
Voltage Measurement Range:	(0.4–1.2) • V_{NOM} where V_{NOM} = 24/48/110/125/220/250 Vdc
Accuracy:	±5% of reading, ±2 Vdc
Resolution:	≤0.2 Vdc for V_{NOM} = 24 Vdc ≤0.4 Vdc for V_{NOM} = 48 Vdc ≤1 Vdc for V_{NOM} = 110 Vdc ≤1 Vdc for V_{NOM} = 125 Vdc ≤2 Vdc for V_{NOM} = 220 Vdc ≤2 Vdc for V_{NOM} = 250 Vdc
Current Measurement Range:	±0.2 A to ±20 A
Accuracy:	±5% of reading, ±0.2 A
Resolution:	≤0.1 A

[a] According to IEEE C37.90-2005.
[b] According to IEC 60255-27:2023.

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Power Supply

General

Rated Voltage Range:	48–250 Vdc/100–240 Vac rms
Operational Voltage Range:	38–300 Vdc/80–264 Vac rms
Rated Frequency:	50/60 Hz
Operational Frequency Range:	40–70 Hz
Burden Rating (Max.):	≤40 W/70 VA for rated voltage range
Vdc Input Ripple:	15% of applied rated dc voltage
Interruption/Ride-Through (30 W Burden):	48, 125, 250 Vdc: ≥1 second

Power Supply Battery Monitor

Rated Voltage Range:	48–250 Vdc
Operational Voltage Range:	38–300 Vdc
Accuracy:	±2 Vdc
Resolution:	≤0.1 Vdc

Communication Ports

PORT_1–PORT_6

Connector Type:	Small Form-Factor Pluggable (SFP)
Number of SFP Ports:	6
Protocols Supported:	1 Gbps Ethernet (PORT_1, PORT_2) 100 Mbps Ethernet (PORT_1–PORT_6) PRP (PORT_1–PORT_6) FTP (PORT_1–PORT_6) DNP3 (PORT_1–PORT_6) IEC 61850 Edition 2.1 (PORT_1–PORT_6) IEC 61869-9 Sampled Values (PORT_1–PORT_6) SNTP (PORT_1–PORT_6) PTP (PORT_1–PORT_6) SEL MIRRORED BITS 16 (PORT_5, PORT_6) Line differential over direct fiber and IEEE C37.94 (PORT_5, PORT_6)
Supported SFP Transceivers:	Refer to *Table 8*

PORT_A and PORT_B

Connector Type:	RJ-45 serial
Protocols Supported:	SEL MIRRORED BITS 8
5 Volt:	Pin 2
Serial Data Speed:	9,600 to 115,200 bps

USB Front-Panel Port F

Connector Type:	USB Type C
USB Type:	2.0
Application:	Engineering Access

Time Inputs

IRIG-B Time Input

Connector Type:	BNC
Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc

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Operational Voltage Range:	0–8 Vdc
Logic High Threshold:	≥2.2 Vdc
Logic Low Threshold:	≤0.8 Vdc
Time Accuracy:	100 ns when connected to a high-accuracy clock
Input Impedance:	≥1 kΩ

PTP—Ethernet

Input:	IEEE 1588 PTPv2
Profiles:	Default profile, Power Profile (IEEE Std C37.238-2011 and IEEE Std C37.238-2017), and Profile for Power Utility Automation (IEC/IEEE 61850-9-3)
Synchronization Accuracy:	±100 ns at 1-second synchronization intervals when communicating directly with time transmitter clock

Precise Time Holdover

Drift:	≤100 seconds/year (~4 ppm) at 25°C (77°F) when no external time source is connected

Power-Up Duration

Relay energization time to trip:	≤1 second

Note: Measurement based on 60255-1:2022 (7.3.4.3). Maximum time from energization of relay power supply to the protection being capable of issuing a trip command.

Environmental Operating Parameters

Operating Temperature:	–40° to +85°C (–40° to +185°F) **Note:** The front-panel display is impaired for temperatures below –20°C (–4°F) and above +70°C (+158°F)
Relative Humidity:	5%–95%; noncondensing
Altitude:	≤2,000 m See IEEE C37.90 for derating factors at higher altitudes.
IP Rating:	IP4X for front (with installation of port cover on **PORT F**), top, and sides of chassis IP2X for back (terminals) IP1X for terminal blocks
Pollution Degree:	2
Overvoltage Category:	III
Insulation Class:	I

Size and Weight

Size:	3U 19-inch horizontal rack-mount
Depth:	22.35 cm (8.80 in) (maximum)
Front-Panel Projection:	3.81 cm (1.50 in) (maximum)
Weight:	6.8 kg (15.0 lb) (maximum)

Terminal Connections

CT Input Terminal Blocks

Supported Wire Gauge for CT Connectors:	14 to 10 AWG
Supported Termination for CT Connectors:	Ring terminal (#8 stud size) Maximum width of 9.65 mm (0.380 in)
Tightening Torque for CT Connector Wiring Terminations:	Range: 9 to 18 in-lb Recommended: 12 in-lb
Tightening Torque for Terminal Block Mounting Ears:	Range: 9 to 12 in-lb Recommended: 9 in-lb

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All Other Terminal Blocks (Power, Voltage, and Contact I/O)

Supported Wire Gauge for Screw-Terminal Connectors:	18 to 14 AWG
Supported Termination for Screw-Terminal Connectors:	Ring terminal (#8 stud size) Maximum width of 9.1 mm (0.360 in)
Tightening Torque for Screw-Terminal Connector Wiring Terminations:	Range: 9 to 18 in-lb Recommended: 12 in-lb
Tightening Torque for Terminal Block Mounting Ears:	Range: 9 to 12 in-lb Recommended: 9 in-lb

Note: User terminals and stranded copper wire should have a minimum temperature rating of 105°C (221°F).

Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. Use the following table as a guide for selecting wire sizes. The grounding conductor should be as short as possible and sized equal to or greater than any other conductor connected to the device, unless otherwise required by local or national wiring regulations.

Connection Type	Min. Wire Size	Max. Wire Size
Grounding (Earthing) Connection	14 AWG (2.5 mm^2)	N/A
Current Connection	16 AWG (1.5 mm^2)	10 AWG (6.0 mm^2)
Voltage Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	10 AWG (6.0 mm^2)
Other Connections	18 AWG (0.8 mm^2)	10 AWG (6.0 mm^2)

Measurement Accuracy

AC Current Inputs

Magnitude Accuracy:	(0.05–4.00) • I_{NOM}: ±0.2% ±0.0004 • I_{NOM}
Phase Accuracy:	(0.20–4.00) • I_{NOM}: ±0.2° (0.05–0.20) • I_{NOM}: ±0.4°

Note: Measurement accuracies assume 20°C (68°F) temperature and 1-second averaged data at tracked rated frequency.

AC Voltage Inputs

Magnitude Accuracy:	(0.1–1.2) • V_{NOM}: ±0.2%
Phase Accuracy:	(0.1–1.2) • V_{NOM}: ±0.1°

Note: Measurement accuracies assume 20°C (68°F) temperature and 1-second averaged data at tracked rate frequency.

Total Vector Error

TVE Accuracy	Input Range	Frequency Range
<1%	(0.1–2.0) • I_{NOM} (0.1–1.2) • V_{NOM}	50/60 Hz ± 5 Hz

Reporting Functions

Event Reports

Length:	0.25–5 s (based on LER and SRATE settings)
Volatile Memory Storage:	15 s of back-to-back event reports sampled at 10 kHz
Nonvolatile Memory:	At least 100 event reports of a 5-second duration sampled at 10 kHz

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Protection

Sequence of Events Recorder

Storage:	4,096 entries
Number of Configurable Points:	250
Resolution:	500 µs

Compliance and Type Tests

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B Class A
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.

CAN ICES-001 (A) / NMB-001 (A)
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to ICES-001, Issue 5.

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

CE Mark

Electromagnetic Compatibility (EMC)

Product Standards	**IEC 60255-26:2023 IEEE C37.90-2005**			
Test	**Methodology**	**Level**		
Emissions	CISPR 11/22/32 47 CFR Part 15B Canada ICES-001 (A) / NMB-001 (A) ANSI C63.4	Class A		
Harmonics	IEC 61000-3-2:2018	Meets applicable limits		
Flicker	IEC 61000-3-3:2013	Meets applicable limits		
Radiated RF Immunity	IEC 61000-4-3:2020 IEEE C37.90.2-2024	**Frequency (MHz)**	**Field Strength**	**Modulation**
		80–3,000	20 V/m	AM 80% 1 kHz sine
		380/1,600/1,800/1,850/ 2,150/2,600/3,500/ 3,800/5,000	10 V/m	AM 80% 1 kHz sine
		80/160/450/900	20 V/m	AM 80% 1 kHz sine
		900	20 V/m	Pulse Mod. 50%
Conducted RF Immunity	IEC 61000-4-6:2023	150 kHz–80 MHz, 1 kHz 80% AM 10 V rms Spot Frequencies: 27 MHz and 68 MHz		
Electrostatic Discharge	IEC 61000-4-2:2025 IEEE C37.90.3-2023	Contact Discharge: ±2, 4, 6, 8 kV Air Discharge: ±2, 4, 8, 15 kV		

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Product Standards	IEC 60255-26:2023 IEEE C37.90-2005		
Test	**Methodology**	**Level**	
Electrical Fast Transient Burst	IEC 61000-4-4:2012 IEEE C37.90.1-2024	**Port Type**	**Level**
		Power, Communication, and Functional Earth	±4 kV at 5 kHz
		Input/Output	±4 kV at 5 kHz and 2.5 kHz
Surge Immunity	IEC 61000-4-5:2017	**Port Type**	**Level**
		Power and Input/Output	±0.5, 1, 2 kV line-to-line ±0.5, 1, 2, 4 kV line-to-earth
		Communication	±0.5, 1, 2 kV line-to-line
Damped Oscillatory Wave Immunity	IEC 61000-4-18:2019 IEEE C37.90.1-2024	**Port Type**	**Level**
		Power	±2.5 kV common ±2.5 kV differential
		Communication	±2.5 kV common ±1 kV differential
		Input	±2.5 kV common ±1 kV differential
		Output	±2.5 kV differential
Power Frequency Immunity	IEC 60255-26:2023 IEC 61000-4-16:2015	**Port Type**	**Level**
		Binary Input	300 V rms common 150 V rms differential
Power Frequency Magnetic Field Immunity	IEC 61000-4-8:2009	100 A/m for 60 Seconds 1,000 A/m for 3 Seconds	
Pulse Magnetic Field Immunity	IEC 61000-4-9:2016	1,000 A/m, Level 5	
Damped Oscillatory Magnetic Field Immunity	IEC 61000-4-10:2016	100 A/m, Level 5	
Startup and Shutdown	IEC 60255-26:2023	60 second ramp/5 minute power off	

Environmental

Product Standards	IEC 60255-27:2023		
Test	**Methodology**	**Level**	
Cold	IEC 60255-1:2022 IEC 60068-2-1:2007	**Test Type**	**Level**
		Operational	Test Ad: 16 hours at –40°C
		Storage	Test Ab: 16 hours at –40°C
Dry Heat	IEC 60255-1:2022 IEC 60068-2-2:2007	**Test Type**	**Level**
		Operational	Test Bd: 16 hours at +85°C
		Storage	Test Bb: 16 hours at +85°C

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Product Standards	IEC 60255-27:2023	
Test	**Methodology**	**Level**
Cyclic Temperature	IEC 60255-1:2022 IEC 60068-2-14:2023	Test Db: –40°C to +85°C, 5 cycles
Damp Heat	IEC 60255-1:2022 IEC 60068-2-78:2012 IEC 60068-2-30:2005	**Test Type** / **Level** Steady State: Test Cab: 93% relative humidity, +40°C, 10 days Cyclic: Test Db: +25° to +55°C, 6 cycles, (12+12-hour cycle), 95% relative humidity
Object Penetration	IEC 60529:2013	**Location** / **Level** Front, Top, Sides (Enclosure): IP3X Back (Terminals): IP2X Terminal Block: IP1X
Vibration	IEC 60255-21-1:1988	Class 2 Endurance, Class 2 Response
Shock/Bump	IEC 60255-21-2:1988	**Test Type** / **Level** Shock: Class 1 Withstand, Class 2 Response Bump: Class 1
Seismic	IEC 60255-21-3:1993	Class 2 Quake Response

Safety

Product Standards	IEC 60255-27:2023 IEEE C37.90-2005 UL 61010-1:2024	
Test	**Methodology**	**Level**
Dielectric Strength	IEC 60255-27:2023 IEEE C37.90-2005 UL 61010-1:2024	**Port Type** / **Level** Power: 3.6 kVdc Communication: 1.5 kV rms Input/Output: 3.25 kV rms, 50 or 60 Hz, 1 min
Impulse	IEC 60255-27:2023 IEEE C37.90-2005 UL 61010-1:2024	**Port Type** / **Level** Power: 5 kV Communication: 5 kV Input/Output: 6 kV See IEC 60255-27:2023 Table C.12 - Test site altitude correction factor.
Insulation Resistance	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels
Flammability of Insulating Materials	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels

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Product Standards	IEC 60255-27:2023 IEEE C37.90-2005 UL 61010-1:2024	
Test	**Methodology**	**Level**
Maximum Temperature of Parts and Materials	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels, normal use
Protective Bonding/Continuity	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels
Laser Safety	IEC 60825-1:2014 21 CFR 1040.10 and 1040.11	Meets applicable levels

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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Notes

⚠ WARNING
Operator safety may be impaired if the device is used in a manner not specified by SEL.

⚠ AVERTISSEMENT
La sécurité de l'opérateur peut être compromise si l'appareil est utilisé d'une façon non indiquée par SEL.

⚠ 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.

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