SEL-487B Relay

Busbar and Breaker Failure Protection, Automation, and Control System

The SEL-487B Relay provides bus current differential protection, circuit breaker failure protection, and backup overcurrent protection. The relay has 18 analog current inputs and three analog voltage inputs. For buses with no more than six terminals, use one SEL-487B in a single-relay application. For buses with seven to nine terminals, use two SEL-487B relays. For buses with up to 18 terminals, use three SEL-487B relays; each relay provides up to six dedicated zones of protection.

Major Features and Benefits

- Busbar differential protection operates in less than one cycle to increase system stability margins and reduce equipment damage.
- Flexible zone selection and six differential zones provide protection for multiple busbar applications.
- Failed CT detection elements reliably indicate open and shorted CTs for alarming and/or blocking.
- Differential protection accommodates up to 10:1 CT ratio mismatch without auxiliary CTs.
- Differential protection is secure for external faults with minimal CT requirements.
- Breaker failure protection for each terminal integrates bus and breaker failure protection.
- Instantaneous and inverse time-overcurrent elements provide backup protection for each terminal.
- Negative- and zero-sequence over- and undervoltage elements provide for differential element supervision.
- Interconnect with automation systems using IEC 61850 or DNP3 protocols directly or DNP3 through an SEL-2032 or SEL-2030 Communications Processor. Use FTP for high-speed data collection.
- Record a wide range of system events with 15-, 30-, 60-, and 120-cycle event report lengths.
- Use the dedicated check zone to supervise complex bus differential schemes.

Functional Overview

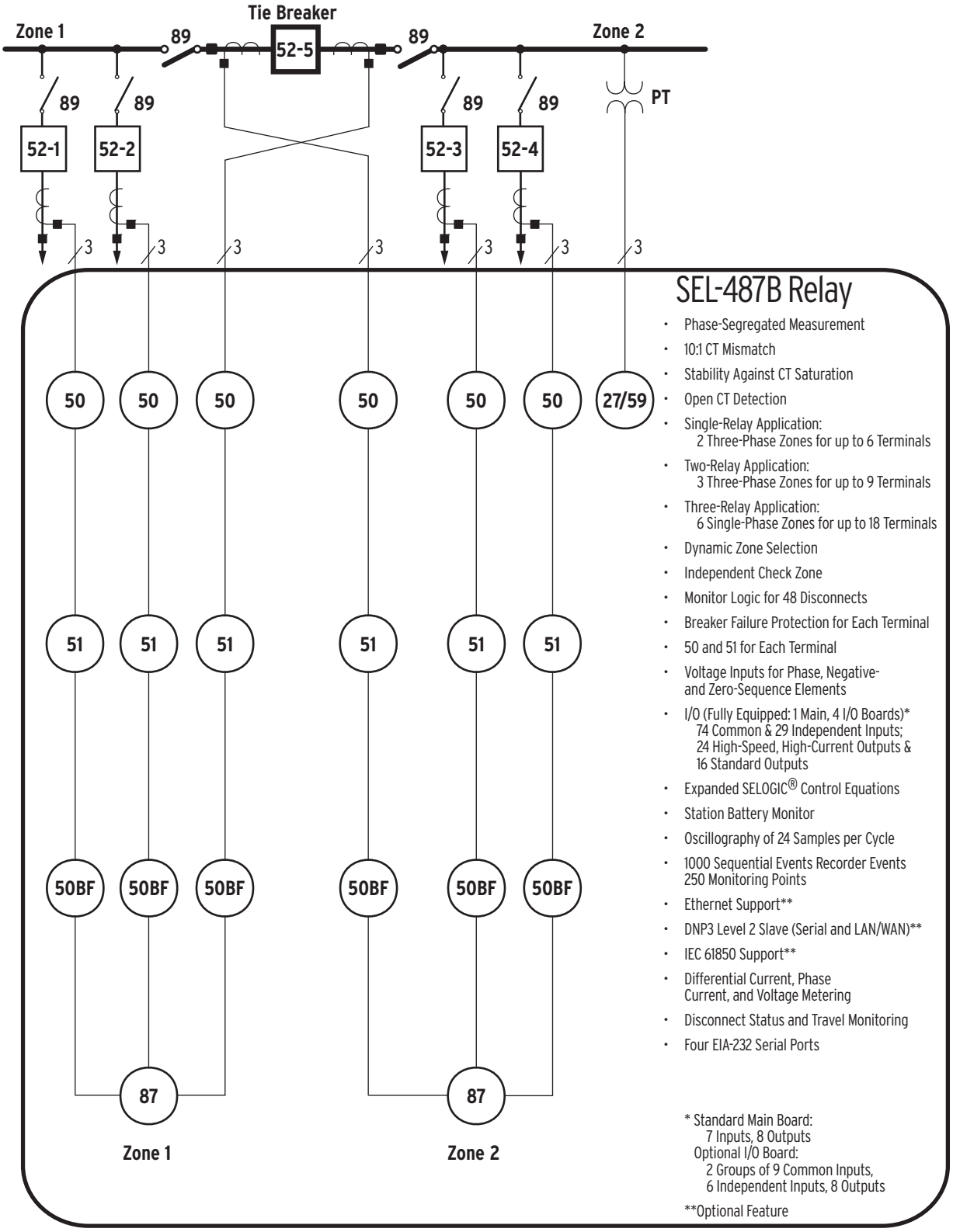


Figure 1 SEL-487B Relay Basic Functions in a Double-Bus Application

Protection Features

Order the 9U chassis version of the SEL-487B to equip the relay with a maximum of four interface boards. With four interface boards, the relay has a total of 103 inputs (72 common inputs and 31 independent inputs) and 40 outputs (24 high speed, high-current interrupting outputs and 16 standard outputs).

Order the 7U chassis version of the SEL-487B to equip the relay with a maximum of two interface boards. With two interface boards, the relay has a total of 55 inputs (36 common inputs and 19 independent inputs) and 24 outputs (12 high speed, high-current interrupting outputs and 12 standard outputs).

The 7U and 9U chassis options for the SEL-487B both contain 18 current inputs and three voltage inputs.

With the flexibility of the expanded SELOGIC control equations, no external auxiliary relays are required to configure the relay for very complex busbar arrangements. The SEL-487B provides station-wide protection using up to six zones of differential protection, advanced zone selection algorithms, and per-terminal breaker failure and overcurrent protection.

Dynamic Zone Configuration

The SEL-487B dynamically assigns the input currents to the correct differential elements without the need for auxiliary relays. Connect the digital inputs from the busbar disconnect auxiliary contacts directly to the relay. SELOGIC control equations and zone selection logic will correctly assign the currents to the differential elements, even for complex bus arrangements as shown in *Figure 2*.

Busbar configuration information, as a function of the disconnect status, is readily available. *Figure 3* depicts the response of the relay to the **ZONE** command, showing the terminals and bus zones assigned to each protection zone.

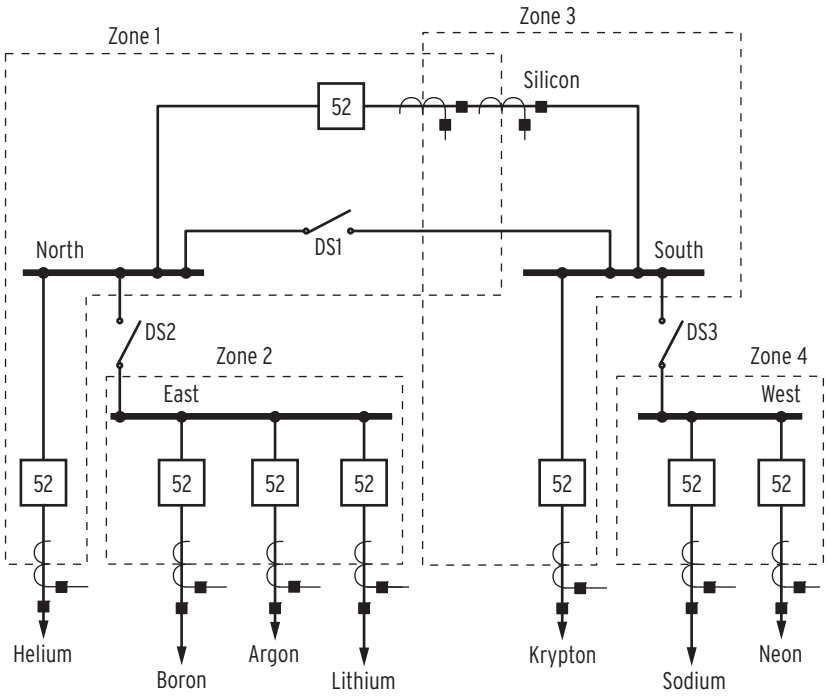


Figure 2 Bus-Zone Protection Based on Disconnect Switch Positions

```
=>>ZONE <Enter>
BUS PROTECTION
Rinadel Station
Terminals in Protection Zone 1
HELIUM         SILICON
Bus-Zones in Protection Zone 1
NORTH
Terminals in Protection Zone 2
BORON        ARGON       LITHIUM
Bus-Zones in Protection Zone 2
EAST
Terminals in Protection Zone 3
SILICON         KRYPTON
Bus-Zones in Protection Zone 3
SOUTH
Terminals in Protection Zone 4
SODIUM         NEON
Bus-Zones in Protection Zone 4
WEST
=>>
```

Figure 3 Result of ZONE Command Indicating the Protection Zone Configuration as Indicated by the Disconnect Switch Positions

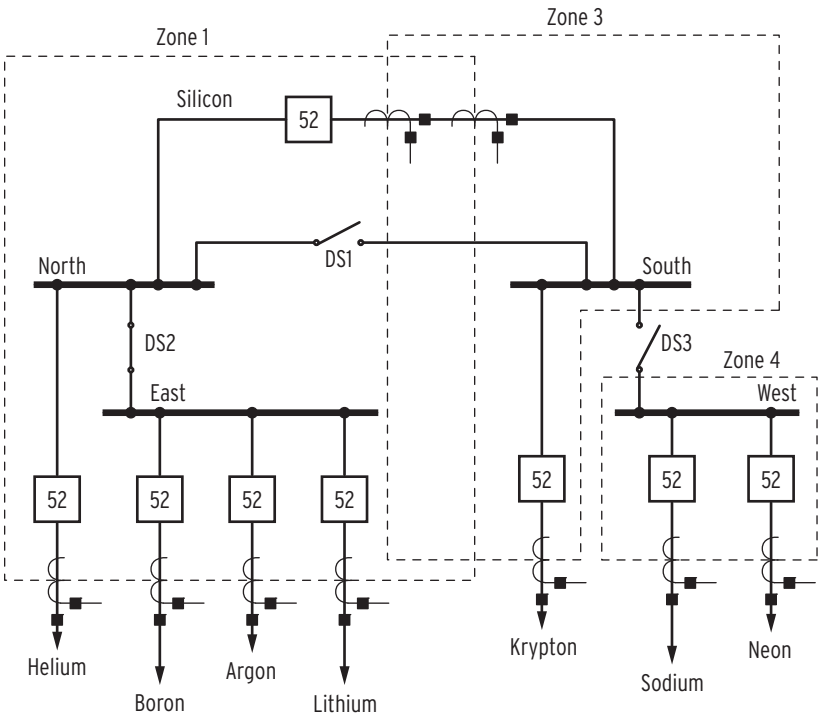


Figure 4 Bus Arrangement With Disconnect DS2 Closed; the New Zone 1 That Includes Bus Zones North and East

```
=>>ZONE <Enter>
BUS PROTECTION
Rinadel Station
Terminals in Protection Zone 1
HELIUM         SILICON       BORON      ARGON       LITHIUM
Bus-Zones in Protection Zone 1
NORTH          EAST
Terminals in Protection Zone 3
SILICON         KRYPTON
Bus-Zones in Protection Zone 3
SOUTH
Terminals in Protection Zone 4
SODIUM         NEON
Bus-Zones in Protection Zone 4
WEST
=>>
```

Figure 5 Result of ZONE Command, Showing the Protection Zone Configuration After Zone 1 Merges With Zone 2

Closing disconnect DS2 combines Zone 1 and Zone 2, forming a single zone. The new protection zone configuration is shown in *Figure 4*. In this combination, Zone 1 includes North and East bus zones. *Figure 5* shows the new Zone 1 that includes bus zones North and East.

Zone Selection Logic

Busbar protection requires assigning the correct current values to the appropriate differential elements as a function of user-defined conditions. To achieve this, the SEL-487B employs a two-step process:

- Evaluates the user-defined conditions.
- Assigns the currents to the differential element of the appropriate zone.

Current assignment conditions vary from simple to complex. A simple condition would be a statement such as "always include this terminal in the differential calculations." A more complex condition statement could be "when Disconnect 2 is closed, and the transfer disconnect is open."

SELOGIC control equations provide the mechanism by which the user enters the conditions for assigning the currents to the differential elements when these conditions are met. When a SELOGIC control equation becomes true (e.g., the disconnect is closed), the relay dynamically assigns the current to the differential elements. Conversely, when the SELOGIC control equation is false (the disconnect is open), the relay dynamically removes the currents from the differential elements. This is also true for the trip output, when the SELOGIC control equation of a terminal is false, no trip signal is issued to that terminal. *Table 1* shows a simple case where the disconnect status is the only condition considered.

Table 1 Conditions for Automatic Terminal Assignment

Example of Condition	SELOGIC Control Equation Result	Consider Terminal in Protection Calculations?	Issue Trip?
Disconnect is open	False	No	No
Disconnect is closed	True	Yes	Yes

End-Zone Protection

To illustrate the flexibility of the user-defined conditions using SELOGIC control equations, consider the ease of achieving end-zone protection with the SEL-487B.

Figure 6 shows fault F1 between an open circuit breaker and CT of a feeder at a substation. This area is a "dead" zone because neither busbar protection nor local line protection can clear this fault; the remote end of the feeder must clear this fault. Because the feeder circuit breaker is already open, operation of the busbar protection serves no purpose; indeed, the busbar protection must not operate for this fault.

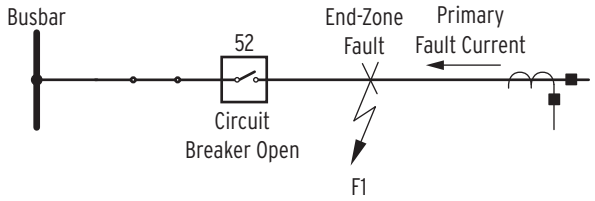


Figure 6 Fault Between Breaker and CT

By including the circuit breaker auxiliary contact in one of the SELOGIC control equations (*Figure 7*), the value of the SELOGIC control equation is false when the circuit breaker is open, removing the current from the differential element calculations. This capability ensures stability of the busbar protection. By configuring the protection system using SELOGIC control equations and normal communications channels, the relay sends a trip signal to the remote end of the feeder.

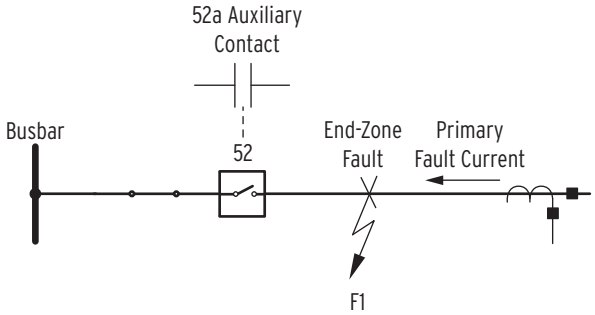


Figure 7 Bus Protection Is Not Affected by Fault, F1; Use Transfer Trip to Clear the Fault

Check Zone

The SEL-487B provides a completely independent check zone with its own adaptive differential element. Supervise zone differential elements by using the independent check zone to monitor all incoming sources and outgoing feeders on the bus. During an internal fault, the check zone differential element will assert. During an external fault the check zone element will remain deasserted.

Differential Protection

The SEL-487B includes six independent current differential elements. Operating time for internal faults is less than one cycle, including high-speed output contact closure. *Figure 8* shows an example of an internal fault and differential element operation.

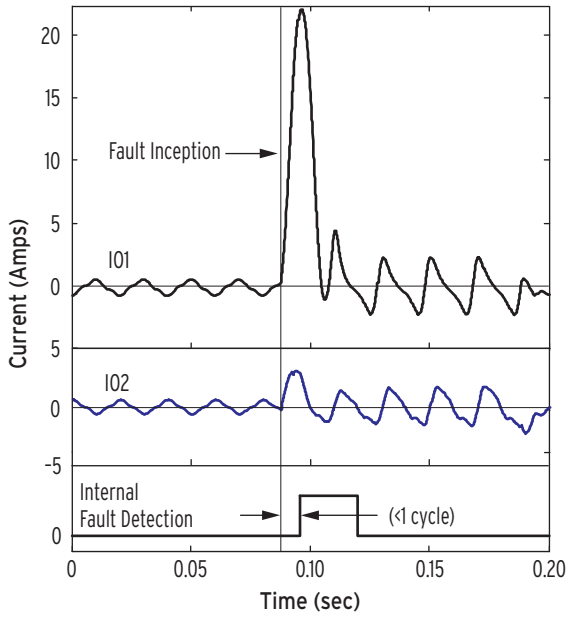


Figure 8 Differential Element Operation in Less Than One Cycle for Internal Faults

Each of the differential elements provides the following:

- Fast operating times for all busbar faults
- Security for external faults with heavy CT saturation
- Security with subsidence current present
- High sensitivity for busbar faults
- Minimum delay for faults evolving from external to internal faults

Figure 9 shows a block diagram of one of the six differential protection elements.

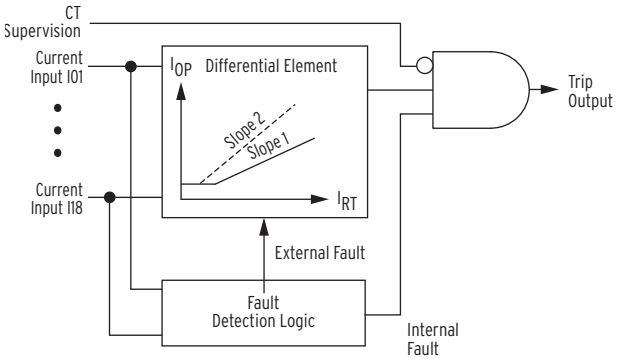


Figure 9 External Fault Detection Logic Increases Differential Element Security

CT saturation is one of the main factors to address when considering relay security. Because of the high sampling rate, the fault detection logic detects external faults in less than 2 ms by comparing the rate of change of the restraint and operating currents. Following the detection of an external fault, the relay enters a high-security mode, during which it dynamically selects a higher slope for the differential elements (see *Figure 9*). *Figure 10* shows an external fault with heavy CT saturation, without differential element operation.

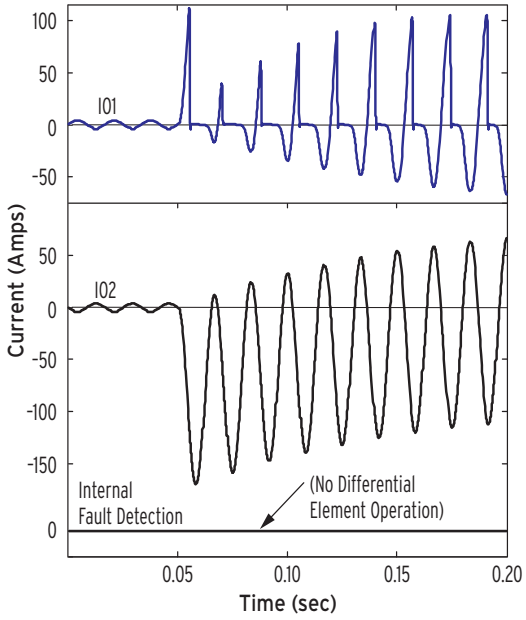


Figure 10 Differential Element Does Not Operate for External Fault With Heavy CT Saturation

CT Supervision

Open or shorted current transformers produce equal and opposite changes in restraint and operate current. The advanced CT supervision in the SEL-487B monitors differential zone restraint and operating current for these changes to provide rapid and dependable detection of open or shorted CT conditions. Use the CT supervision logic in zone trip equations.

Voltage Elements

Voltage elements consist of two levels of phase undervoltage (27) and overvoltage (59) elements and two levels of negative- (59Q) and zero-sequence (59N) overvoltage elements, based on one set of three analog voltage quantities. *Table 2* provides a summary of the voltage elements.

Table 2 Voltage Elements

Element	Quantity	Levels
Undervoltage	Phase	Two levels
Overvoltage	Phase, negative-, and zero-sequence	Two levels

Breaker Failure Protection

The SEL-487B includes complete breaker failure protection, including retrip, for each of the 18 terminals. Because some applications require external breaker failure protection, set the SEL-487B to external breaker fail and connect the input from any external breaker failure relay to the SEL-487B; any terminal can be set to either internal or external breaker failure protection.

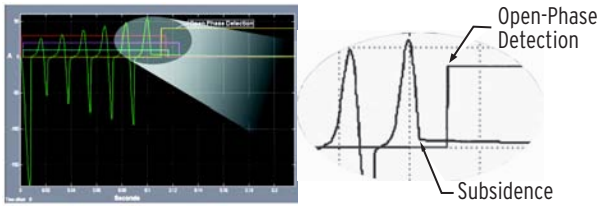


Figure 11 Open-Phase Detection Reduces Breaker Failure Coordination Time

High-speed open-pole detection logic detects open-pole conditions in less than 0.75 cycle to reduce breaker failure coordination times as shown in *Figure 11*.

Overcurrent Elements

Choose from 10 time-overcurrent curves (*Table 3*) for each of the 18 current inputs. Each torque-controlled time-overcurrent element has two reset characteristics. One choice resets the elements if current drops below pickup for one cycle, while the other choice emulates the reset characteristic of an electromechanical induction disk relay.

Each terminal also includes instantaneous and definite-time overcurrent elements. These overcurrent elements are summarized in *Table 4*.

Table 3 Time-Overcurrent Curves

U.S.	IEC
Moderately Inverse	Standard Inverse
Inverse	Very Inverse
Very Inverse	Extremely Inverse
Extremely Inverse	Long-Time Inverse
Short-Time Inverse	Short-Time Inverse

Table 4 Overcurrent Elements per Terminal

Element	Quantity	Levels
Instantaneous Overcurrent	Phase	One level
Definite-Time Overcurrent	Phase	One level

Disconnect Status Monitor

Figure 12 shows the disconnect open and close contact relationship. During the open-to-close operation, the 89b contact must open (disconnect is CLOSED) during the transition zone before the main contact arcing starts. The 89a contact must close in this transition zone.

During the close-to-open operation, the 89b contact must close during the transition zone after the main contact arcing is extinguished (disconnect is OPEN), as shown in *Figure 12*. The 89a contact must open in this transition zone.

Table 5 shows the four possible disconnect auxiliary contact combinations and how the relay interprets each combination.

Table 5 Disconnect Status as a Function of the Auxiliary Contacts

89a	89b	Relay 89 Status Interpretation
0	0	closed
0	1	open
1	0	closed
1	1	closed

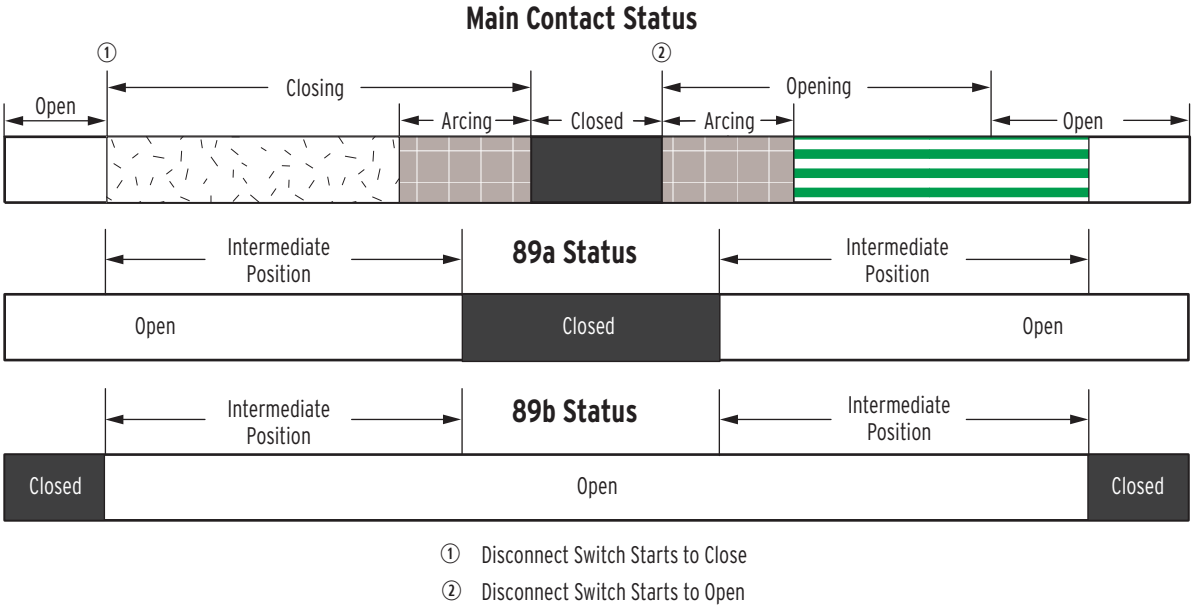


Figure 12 Disconnect Switch Auxiliary Contact Requirements for the Zone Selection Logic; No CT Switching Required

Tie-Breaker Configurations

Figure 13, *Figure 14*, and *Figure 15* show three tie-breaker schemes:

- Two CTs configured in overlap (*Figure 13*)
- A single CT with two cores configured in overlap (*Figure 14*)
- Two CTs configured with a differential element across the breaker (*Figure 15*)

Configure any one of these schemes without using external auxiliary relays. *Figure 13* and *Figure 14* also show the tie breaker closing onto an existing fault, F1. The SEL-487B includes tie-breaker logic to prevent the loss of both zones for this fault.

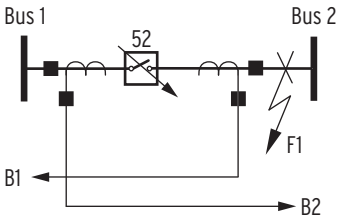


Figure 13 Two CTs Configured in Overlap

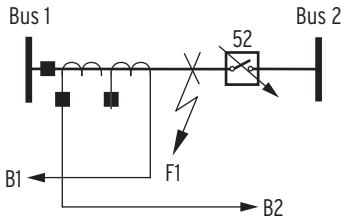


Figure 14 A Single CT With Two CT Cores Configured in Overlap

Configure one of the differential zones as a differential across the tie breaker. This arrangement has the following advantages:

- Both main zones are secure for a fault between the tie breaker and the CT.
- Only one main zone is tripped for a fault between the tie breaker and the CT (as opposed to both main zones with an overlapping tie-breaker arrangement).

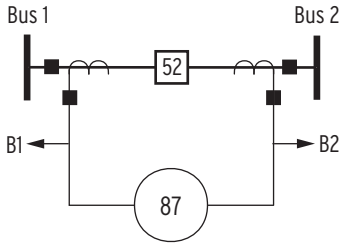


Figure 15 Two CTs Configured With a Differential Element Across the Breaker

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-487B 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, and emergency contingencies.

Applications

Figure 16 shows a station with double bus sections with bus tie breaker. Use a single SEL-487B for this application.

For stations with breaker-and-a-half busbar configuration and six or less connections to either busbar, use an SEL-487B for each busbar as shown in *Figure 17*.

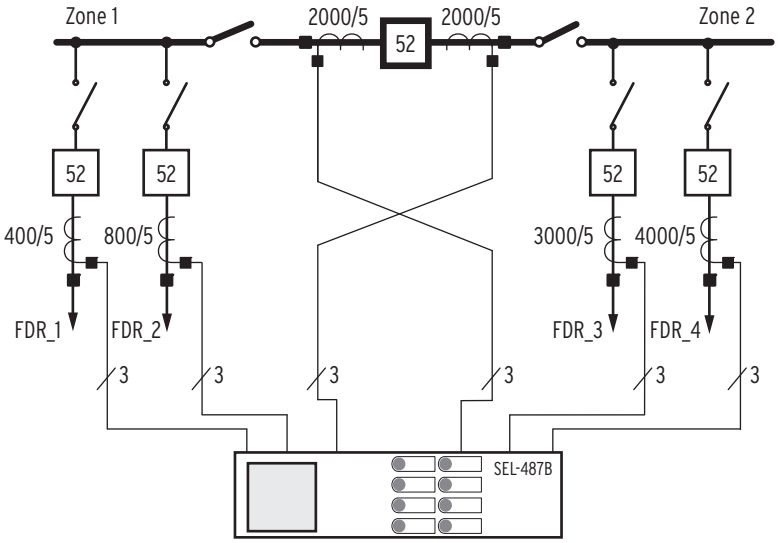


Figure 16 Single SEL-487B Protecting Double Bus Sections With Bus Tie Breaker

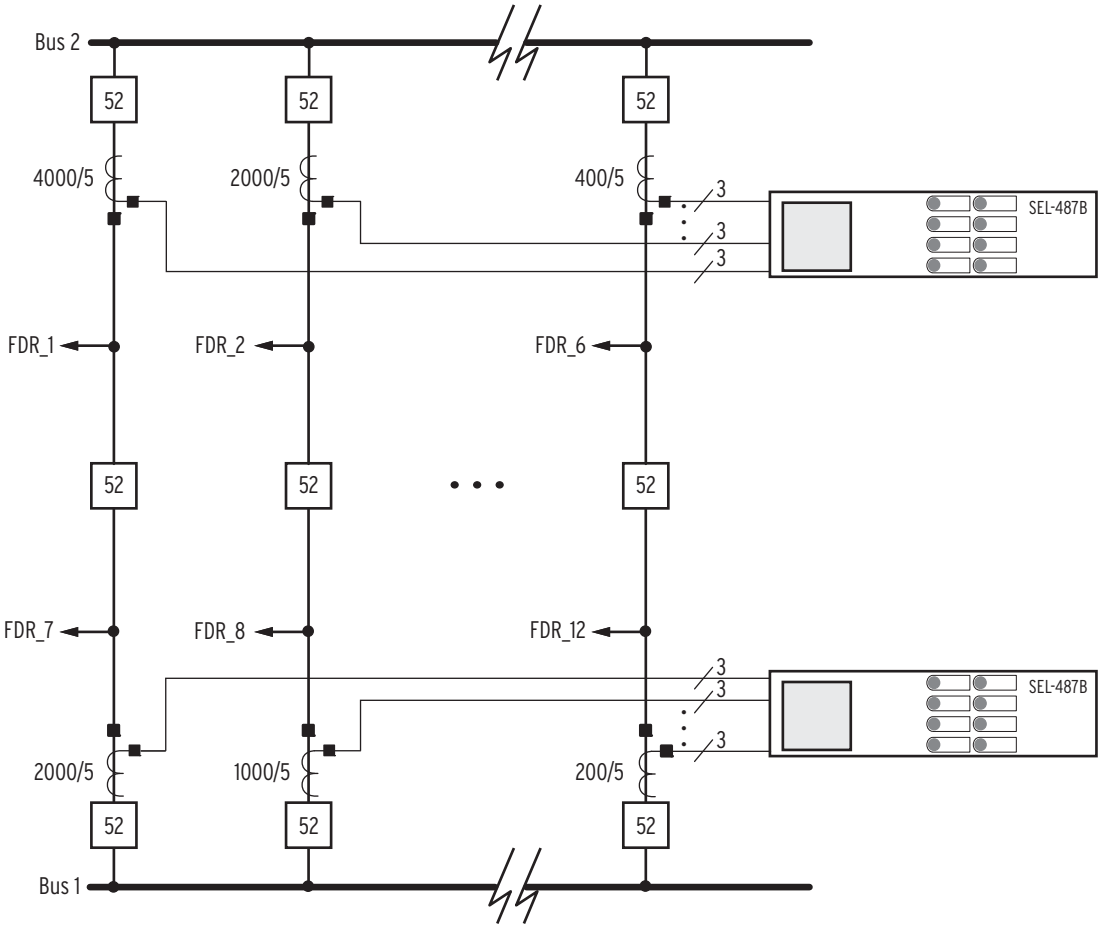


Figure 17 Two Single SEL-487B Relays Protecting the Two Busbars in a Breaker-and-a-Half Busbar Configuration

For stations with seven to 18 terminals (*Figure 18*), use three separate SEL-487B relays and wire analog current inputs from A-, B-, and C-phases separately into each relay. This way, each of the 18 analog current inputs in each relay measures only one phase, with six dedicated zones of protection available. Each relay operates independently; the only communication between relays is MIRRORED BITS® communication and IRIG-B. In this application, the operator has complete flexibility because any disconnect can be closed at any time without compromising the busbar protection. This is possible because the relay dynamically computes the station connection replica by using the patented zone-selection algorithm.

Figure 18 shows a busbar layout consisting of two main busbars and a transfer bus, one busbar coupler, and 17 terminals.

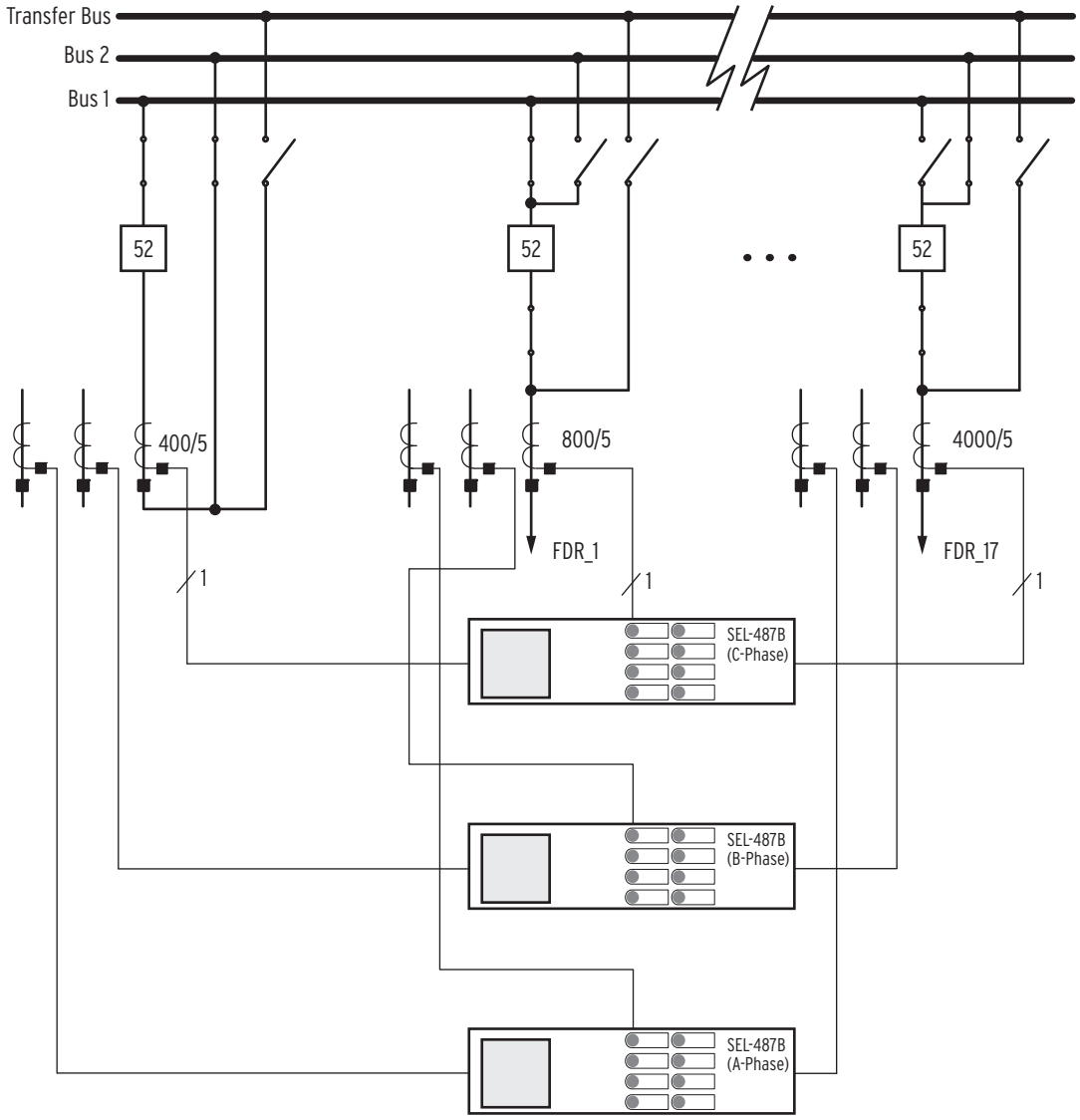


Figure 18 Three SEL-487B Relays Protect Two Main Busbars and a Transfer Busbar, Bus Coupler, and 17 Terminals

Optimize your SEL-487B by protecting both HV and LV busbars with three relays. *Figure 19* shows two HV busbars and two LV busbars. Using four zones for the four busbars (two HV and two LV) still leaves two zones available that can be configured as overall check zones, one for the HV and one for the LV busbars.

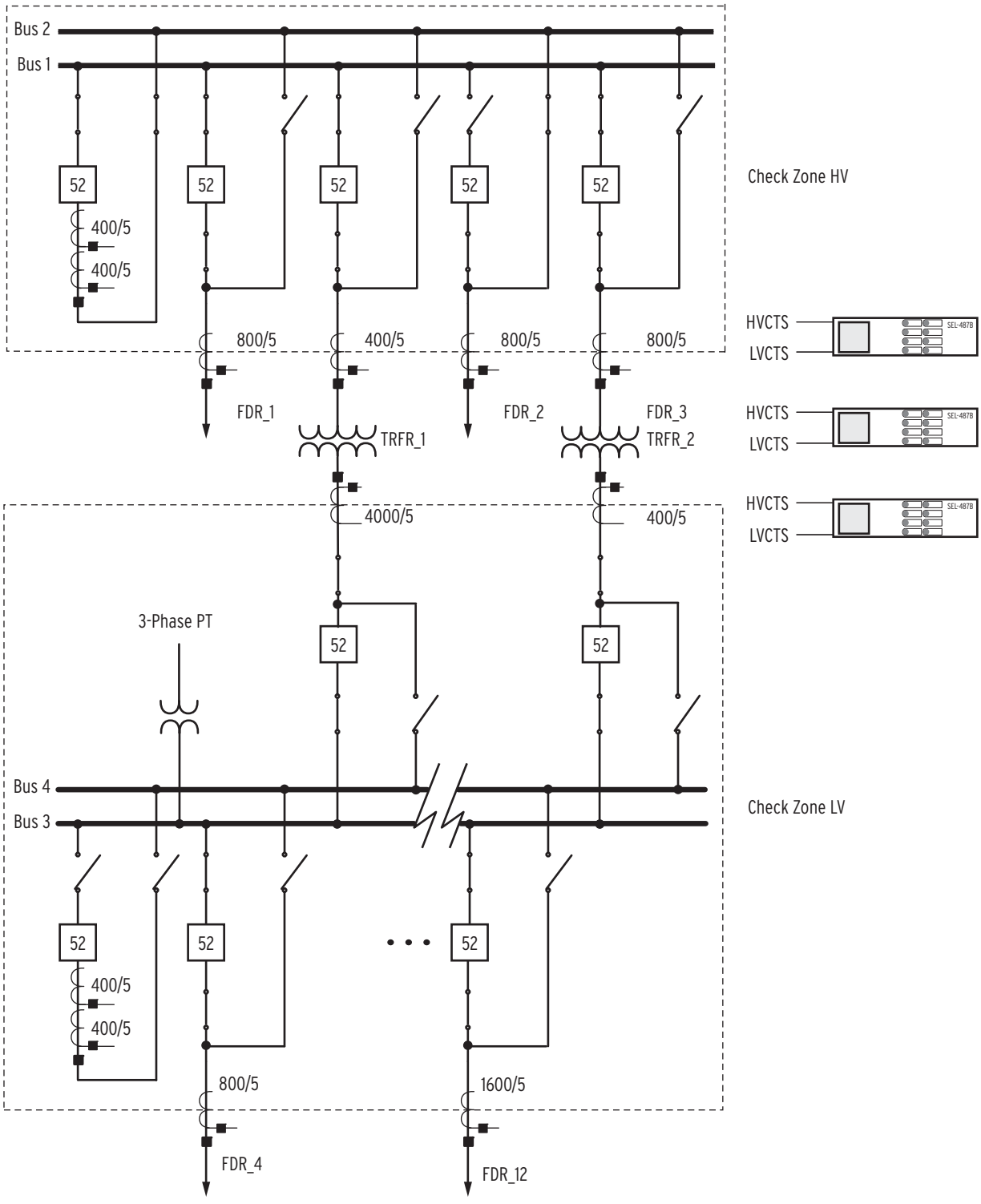


Figure 19 Three SEL-487B Relays Protect Both HV and LV Busbars

Time Synchronization, Automation, and Communication

Time Synchronization

To synchronize the relays in a three-relay application, use the unique **IN** and **OUT** IRIG-B connectors installed on each relay for the IRIG-B signal. Referring to the External Source connections in *Figure 20*, connect the IRIG-B signal to the **IN** connector of Relay A to update the time. Connect the **OUT** connector of Relay A to the IN connector of Relay B to update the time in Relay B. A similar connection between Relay B and Relay C updates the time in Relay C. In the absence of an external IRIG-B signal, connect the relays as shown by the Internal Source connections in *Figure 20*. Connected this way, Relay B and Relay C synchronize to the internal clock of Relay A. Event reports generated in the different relays are time stamped to within 10 µs of each other.

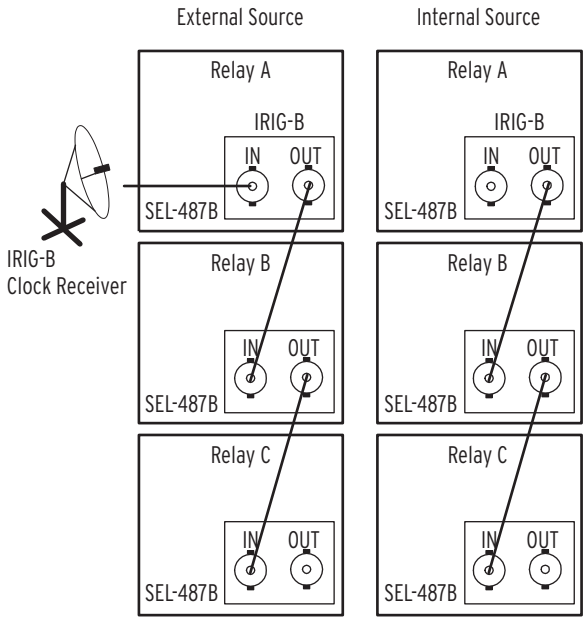


Figure 20 Time Synchronize SEL-487B Relays With or Without External Clock Source

Automation

Flexible Control Logic and Integration Features

Use the SEL-487B control logic to replace the following:

- ➤ Traditional panel control switches
- ➤ RTU-to-relay wiring
- ➤ Traditional latching relays
- ➤ Traditional indicating panel lights

Eliminate traditional panel control switches with 32 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 same local control points for functions such as taking a terminal out of service for testing.

Eliminate RTU-to-relay wiring with 96 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 (e.g., trip, 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 relay retains the states of the latch control points after powering up following a power interruption.

Replace traditional indicating panel lights and switches with either the standard HMI that provides 16 latching target LEDs and eight programmable pushbuttons with LEDs or with the expanded HMI option that provides 24 tricolor latching target LEDs and 12 programmable pushbuttons. Define custom messages to report analog and Boolean power system or relay conditions on the large format LCD. Control displayed messages via SELOGIC control equations by driving the LCD display via any logic point in the relay. Use any of the dozens of measured or calculated analog values in the relay to create display messages for system metering on the front-panel LCD.

SELOGIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations (*Table 6*) 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. Any of the relay internal variables (Relay Word bits) can be used in these equations. For complex or unique applications, these expanded SELOGIC control equation functions allow superior flexibility. Add programmable control functions to your protection and automation systems. New functions and capabilities enable you to use analog values in conditional logic statements. 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 using 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)

ACSELERATOR QuickSet SEL-5030 Software

Use the ACSELERATOR® QuickSet SEL-5030 Software to develop settings and busbar configurations offline. The system automatically checks interrelated settings and highlights out-of-range settings. Settings created offline can be transferred by using a PC communications link with the SEL-487B. The relay converts event reports to oscillograms with time-coordinated element assertion and phasor diagrams. The ACSELERATOR QuickSet interface supports Windows® 95, 98, 2000, XP, ME, and Windows NT® operating systems.

MIRRORED BITS Communications

The SEL patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication. *Figure 21* shows two SEL-487B relays with MIRRORED BITS communications using SEL-2815 Fiber-Optic Transceivers. In the SEL-487B, MIRRORED BITS communications can operate simultaneously on any two serial ports. This bidirectional digital communication creates additional outputs (transmitted MIRRORED BITS) and additional inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS communications mode.

Communicated information can include digital, analog, and virtual terminal data. Virtual terminal allows operator access to remote relays through the local relay. This MIRRORED BITS protocol can be used to transfer information between stations to enhance coordination and achieve faster tripping.

Table 6 Expanded SELOGIC Control Equation Operators

Operator Type	Operators	Comments
Edge Trigger	R_TRIG, F_TRIG	Operates at the change of state of an internal function.
Math Functions	SQRT, LN, EXP, COS, SIN, ABS, ACOS, ASIN, CEIL, FLOOR, LOG	Combine these to calculate other trigonometric functions, i.e., TAN: = SIN(THETA)/COS(THETA).
Arithmetic	*, /, +, -	Uses traditional math functions for analog quantities in an easily programmable equation.
Comparison	<, >, <=, >=,=, <>	Compares the values of analog quantities against predefined thresholds or against each other.
Boolean	AND, OR, NOT	Combines variables, and inverts the status of variables.
Precedence Control	( )	Allows up to 14 sets of parentheses.
Comment	#	Provides for easy documentation of control and protection logic.

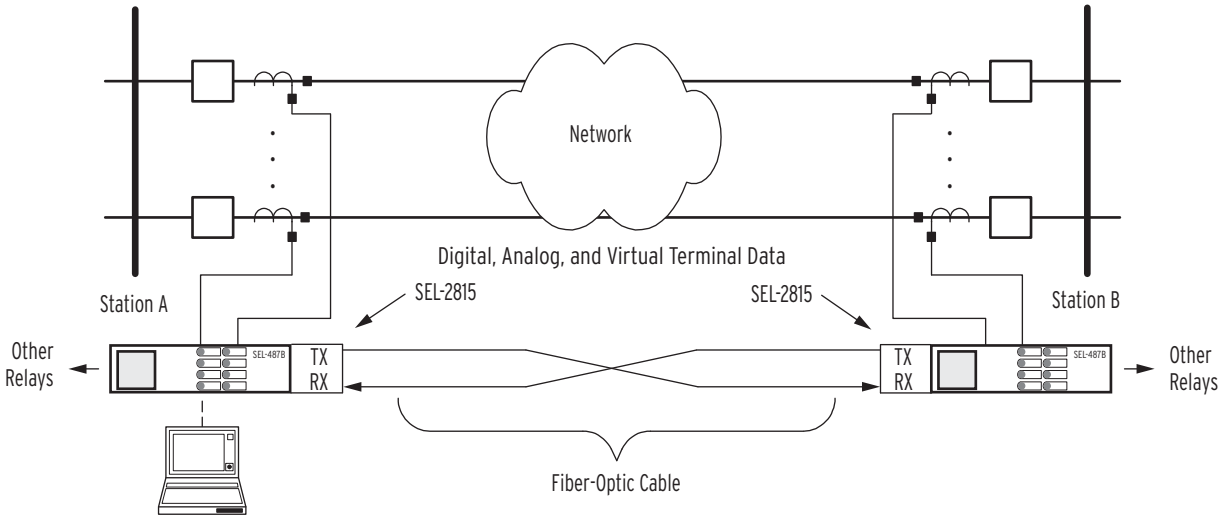


Figure 21 Integral Communication Provides Secure Protection, Monitoring, and Control as Well as Terminal Access to Both Relays Through One Connection

Communications Features

The SEL-487B offers the following communication features:

- Four independent EIA-232 serial ports
- Full access to event history, relay status, and meter information from the communications ports
- Settings and group switching password control
- SCADA interface capability including FTP, IEC 61850, and DNP3 LAN/WAN (via optional internally mounted Ethernet card), and DNP3 Level 2 Slave (via serial port)

The relay 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 7* provides a synopsis of the communications protocols in the SEL-487B.

Ethernet Card

The SEL-487B provides Ethernet communication capabilities with the optional Ethernet card. This card mounts directly in the relay. Use Telnet applications for easy terminal communication with SEL relays and other devices. Transfer data at high speeds (10 Mbps or 100 Mbps) for fast file uploads. The Ethernet card communicates using FTP applications for easy and fast file transfers. Choose Ethernet connection media options for primary and stand-by connections:

- 10/100BASE-T Twisted Pair Network
- 100BASE-FX Fiber-Optic Network

Communicate using IEC 61850 Logical Nodes and GOOSE Messages, or DNP3 LAN/WAN.

The DNP3 LAN/WAN option provides the SEL-487B with DNP3 Level 2 slave functionality over Ethernet. Custom DNP3 data maps can be configured for use with specific DNP3 masters.

IEC 61850 Ethernet Communications

IEC 61850 Ethernet-based communications provide interoperability between intelligent devices within the substation. Logical nodes using IEC 61850 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 with IEC 61850. Eliminate system RTUs by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

The SEL-487B can be ordered with embedded IEC 61850 protocol operating on 100 Mbps Ethernet. Use the IEC 61850 Ethernet protocol for relay monitoring and control functions, including the following.

- As many as 24 incoming GOOSE messages. The incoming GOOSE messages can be used to control up to 128 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. Outgoing GOOSE messages 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 Data Server. The SEL-487B equipped with embedded IEC 61850 Ethernet protocol, provides data according to pre-defined logical node objects. As many as six 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 IEC 61850 data server provided in the relay.

Use the ACSELERATOR Architect SEL-5032 software to manage the logical node data for all IEC 68150 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 using IEC 61850 compliant CID (Configured IED Description) files. CID files are used by the ACSELERATOR Architect to describe the data that will be provided by the IEC 61850 logical node within each relay.

Telnet and FTP

Order the SEL-487B with Ethernet communications and use the built-in Telnet and FTP (File Transfer Protocol) that come standard with Ethernet to enhance relay communication 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 via the high-speed Ethernet port using FTP.

Table 7 Open Communications Protocol

Type	Description
ASCII	Plain-language commands for human and simple machine communication. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports allow external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended SEL Fast Meter, SEL Fast Operate, and SEL Fast SER	Binary protocol for machine-to-machine communication. Quickly updates SEL 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.
Ymodem	Support for reading event, settings, and oscillography files.
Optional DNP3 Level 2 Slave	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.
MIRRORED BITS	SEL protocol for exchanging digital and analog information between SEL relays and for use as low-speed terminal connection.
Optional FTP and Telnet	Available with the optional Ethernet card. Use Telnet to establish a terminal-to-relay connection over Ethernet. Use FTP to move files in and out of the relay over Ethernet.
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation.

Additional Features

Front-Panel Display

Close-up views of the standard SEL-487B front panel are shown in *Figure 22* and *Figure 23*. The standard front panel includes a 128 x 128 pixel (76.2 mm x 76.2 mm or 3 in x 3 in) LCD screen; 18 LED target indicators; and eight direct-action control pushbuttons with indicating LEDs for local control functions. Target and pushbutton identification can be custom configured with easily changed slide-in labels. *Figure 24* shows the expanded SEL-487B front panel. The optional expanded SEL-487B front panel provides the same LCD screen with more latching target LEDs and programmable pushbuttons. When ordered with the optional front panel, the SEL-487B provides 24 tricolor LEDs and 12 programmable pushbuttons with indicating LEDs. Use the capabilities of the expanded SEL-487B front panel to integrate a wide range of control and system annunciation functions.

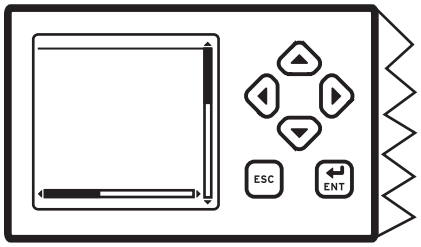


Figure 22 Front-Panel Display and Pushbuttons

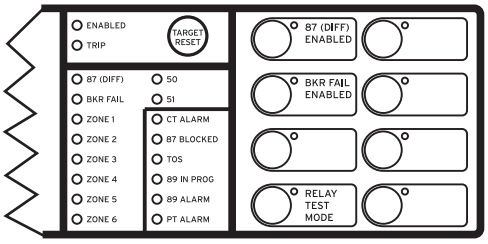


Figure 23 Standard Front-Panel Configurable Labels, Programmable Targets and Controls for Customized Applications

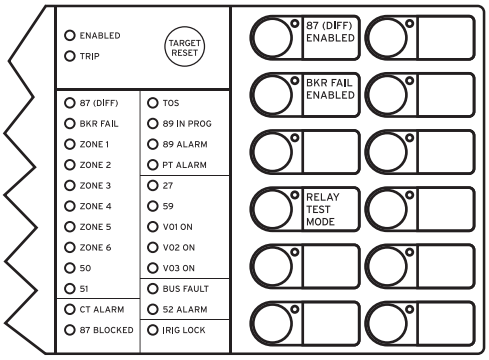


Figure 24 Optional Front Panel With 24 Tricolor Target LEDs and 12 Pushbuttons

The LCD shows event, metering, setting, and relay self-test status information. The LCD is controlled by the navigation pushbuttons (*Figure 22*), automatic messages the relay generates, and user-programmable display points. The rotating display scrolls through any active, nonblank display points. If none are active, the relay scrolls through displays of the differential operating and restraint quantities, the terminals in each enabled zone, and the primary current and voltage values. Each display remains for five seconds before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.

Status and Trip Target LEDs

The SEL-487B standard front panel includes 16 programmable status and trip target LEDs as well as eight programmable direct-action control pushbuttons on the front panel. The optional SEL-487B expanded front panel provides 24 programmable tricolor LED indicators and 12 direct action control pushbuttons. These targets are shown in *Figure 23* and *Figure 24* and explained in *Table 8*.

Table 8 Description of Factory Default Target LEDs—Standard Front Panel

Target LED	Function
87 (DIFF)	Differential element trip
BKR FAIL	Breaker failure protection trip
ZONE 1	Fault was in Zone 1
ZONE 2	Fault was in Zone 2
ZONE 3	Fault was in Zone 3
ZONE 4	Fault was in Zone 4
ZONE 5	Fault was in Zone 5
Standard Front-Panel LED Functions	
ZONE 6	Fault was in Zone 6
50	Instantaneous overcurrent element trip
51	Time-overcurrent element trip
CT ALARM	Current transformer alarm
87 BLOCKED	Differential element blocked
TOS	Any terminal out of service
89 IN PROG	Disconnect operation in progress
89 ALARM	Disconnect failed to complete operation
PT ALARM	Potential transformer alarm
Expanded Front-Panel LED Functions	
27	Phase Undervoltage
59	Phase Overvoltage
V01 ON	Phase Voltage V01 Present
V02 ON	Phase Voltage V02 Present
V03 ON	Phase Voltage V03 Present
BUS FAULT	Any Bus Zone Internal Fault
52 ALARM	Any System Breaker Failure Alarm
IRIG LOCK	IRIG Clock Input Lock

Configurable Front-Panel Labels

Customize the SEL-487B front panel 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 pushbutton LEDs. The blank slide-in label set is included with the SEL-487B. Functions are simple to configure using ACSELERATOR QuickSet software. Label sets can be printed from a laser printer using templates supplied with the relay or handwritten on blank labels supplied with the relay.

Control Inputs and Outputs

The basic SEL-487B (main board only) includes five independent and two common inputs, and five Form A and three Form C standard outputs, as depicted in *Figure 25*.

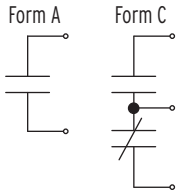


Figure 25 Form A and Form C Output Contacts

Add as many as four interface boards with the following additional input/output (I/O) per interface board:

- six independent inputs
- 18 common inputs (in two groups of nine)
- six high-speed, high-interrupting Form A outputs
- two standard Form A output contacts

The relay is available in either 9U or 7U chassis heights. The 9U chassis supports up to four INT4 interface boards, the 7U chassis option supports up to two INT4 interface boards. Assign the control inputs for disconnect auxiliary contact status and breaker auxiliary contact status. Set the input debounce time independently for each input or as a group. Each control output is programmable using SELOGIC control equations.

Monitoring and Metering

Access a range of useful information in the relay with the metering function. Metered quantities include fundamental primary and secondary current and voltage magnitudes and angles for each terminal. Secondary quantities also include the PT ratio and CT ratio of each terminal. Zone information displays primary current and voltage magnitudes and angles for each terminal and also includes the polarity of each CT and the bus zones in each of the protective zones at the station. The same information is available in secondary quantities and includes both the CT ratio and polarity. Differential metering shows the operating and restraint currents for each zone as well as the reference current.

Table 9 Flexible Metering Capabilities and Large Screen Display Eliminate Need for Panel Instruments

Capabilities	Description
V01, V02, V03	Fundamental phase voltage magnitude and angle in primary and secondary values
I01, I02, . . ., I18	Fundamental phase current magnitude and angle in primary and secondary values
IOP, IRT, IREF	Operating and restraint currents for each zone and the reference current
Bus Zones in Protection Zone *n*	Names of the bus zones in Protection Zone *n* (where *n* = 1 to 6)
PTR, CTR	PT ratio and CT ratio for each Terminal
POL	Polarity of each CT

Event Reporting and Sequential Events Recorder (SER)

Event Reports and Sequential Events Recorder 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 relay settings and protection schemes.

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 relay, scheme, and system performance for every fault. The relay stores 480 cycles of information at 24 samples per cycle. The relay supports 15-, 30-, 60-, and 120-cycle event report lengths. Reports are stored in nonvolatile memory. Relay settings operational in the relay at the time of the event are appended to each event report.

Each SEL-487B provides event reports for analysis with software such as the SEL-5601 Analytic Assistant. For stations with more than six terminals, the busbar protection requires three SEL-487B relays. For multiphase faults in a three-relay application, we need event reports from different relays for postfault analysis. With the SEL-5601, you can display events from as many as three different relays in one window to make the fault analysis easier and more meaningful. Because the different relays time stamp the events with values from their individual clocks, be sure to time synchronize the three SEL-487B relays (see *Figure 20*). *Figure 26* shows the SEL-5601 software screen with three events selected.

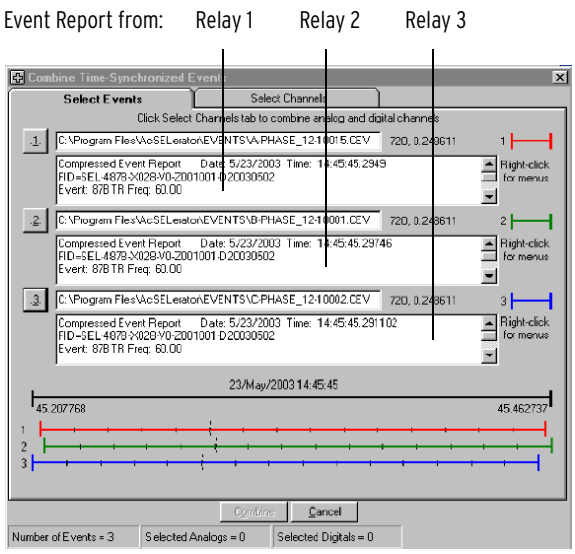


Figure 26 Software Screen After Reading an Event From Three Different Relays

Select from each event the information of interest and combine this selection into a single window. *Figure 27* shows the combination of the tie-breaker A-phase current (Relay 1), B-phase current (Relay 2), and C-phase current (Relay 3) in one window.

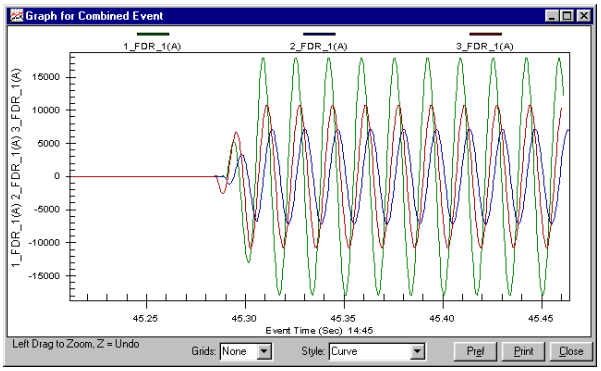


Figure 27 Information From Three Relays Combined Into a Single Window

Event Summary

Each time the relay 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:

- Relay/terminal identification
- Event date and time
- Event type
- Event number
- Time source
- Active settings group
- Targets asserted during the fault
- Current magnitudes and angles for each terminal
- Voltage magnitudes and angles
- Terminals tripped for this fault
- Bus zones in Protection Zone *n* (*n* = 1–6)

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

Sequential Events Recorder (SER)

Use this feature to gain a broad perspective of relay element operation. Items that trigger an SER entry are selectable and can include as many as 250 monitoring points such as input/output change of state, element pickup/dropout. The relay SER stores the latest 1000 events.

Substation Battery Monitor for DC Quality Assurance

The SEL-487B measures and reports the substation battery voltage for one battery system. The relay provides alarm, control, and dual ground detection for one battery and charger. The battery monitor includes warning and alarm thresholds that can be monitored with the SEL-2030 Communications Processor and trigger messages, telephone calls, or other actions. The measured dc voltage is reported in the METER display via serial port communications, on the LCD, and in the Event Report. Use the event report data to see an oscillographic display of the battery voltage. Monitor the substation battery voltage drops during trip, close, and other control operations.

Guideform Specification

The microprocessor-based relay shall provide protection, monitoring, control, and automation. Relay self-checking functions shall be included. Specific requirements are as follows:

- **Differential Protection**. The relay shall include six low-impedance current differential elements.
- **Directional Element**. The relay shall include phase-comparator directional elements for each zone.
- **Check Zone**. The relay shall include a single, dedicated check zone with its own adaptive differential element and settings.
- **Analog Inputs**. The relay shall accept 18 current and three voltage inputs.
- **Current Transformer Inputs**. The relay shall accept CTs from different classes and a ratio mismatch of 10:1. Measuring quantities shall be on a phase-segregated basis and not from summation CTs.
- **Minimum CT Requirement**. The relay requires primary CTs that shall reproduce the primary current without saturation for at least 2 ms after external fault inception.
- **Current Transformer Alarm**. The relay shall include an element in each zone to detect CT open or short circuit conditions.
- **Digital Inputs**. With all optional interface boards installed, the relay shall accept a total of 103 inputs and provide 40 output contacts.
- **Outputs**. The relay shall include 40 outputs of which 18 must be high-current interrupting outputs.
- **Breaker Failure Protection**. The relay shall include internal breaker failure protection with retrip functions for each of the terminals, but be selectable to also accept external breaker failure protection.
- **Overcurrent Fault Protection**. The relay shall include both instantaneous and time-overcurrent elements for each of the 18 current inputs. Torque control capability shall be provided for the inverse-time overcurrent elements.
- **Voltage Elements**. The relay shall include three phase over- and undervoltage elements as well as negative- and zero-sequence overvoltage elements.
- **End-Zone Protection**. The relay shall include the capability to provide protection for a fault between the open circuit breaker and the CT.
- **External Faults**. The relay shall detect an external fault and enter into a high-security mode but not block the differential protection at any time.
- **Dynamic Busbar Replica**. The relay shall, without auxiliary relays, use the disconnect contacts to create a replica of the busbar linking in order to assign the terminal currents to the correct differential elements.
- **Current Transformer Switching**. No CT switching shall be permitted.
- **Disconnect Monitor**. The relay shall include logic to monitor the open/close operations of up to 48 disconnects (isolators) and provide individual alarms for each disconnect.
- **Tie-Breaker Security Logic**. The relay shall include logic to ensure security of the healthy zone when the tie breaker is closed onto a fault.
- **Tie-Breaker Configuration**. The relay shall, without any additional wiring, allow the coupler to be configured in any one of the following configurations: a CT on one side in overlap, CTs on either side in overlap, or CTs on either side in a separate breaker differential configuration.
- **Auxiliary Relays**. The relay shall not need auxiliary relays. All configuration and logic shall be realized in the relay software.
- **Event Reporting**. The relay shall store 480 cycles of event report data recorded at 24 samples per cycle in nonvolatile memory. The relay shall support 15-, 30-, 60-, and 120-cycle event report lengths.
- **Sequential Events Recorder.** The relay shall include an SER (Sequential Events Recorder) report that stores the latest 1000 entries of at least 250 monitored points.
- **Substation Battery Monitor**. The relay shall measure and record the substation battery voltage and provide dual ground detection. Two sets of selectable threshold parameters shall be provided for alarm and control purposes.
- **Digital Relay-to-Relay Communications**. The relay shall include send and receive logic elements and provide analog and virtual terminal service in each of two communications ports for dedicated relay-to-relay communication.
- **IEC 61850 Ethernet Communications.** The relay shall provide IEC 61850-compliant communications. The IEC 61850 capability shall include GOOSE messaging and defined logical node data points.
- **Automation**. The relay shall include 32 local control switches, 96 remote control switches, 32 latching switches, and programmable display messages in conjunction with a local display panel in the relay. The relay shall be capable of displaying custom messages.
- **Relay Logic**. The relay shall include programmable logic functions for a wide range of user-configurable protection, monitoring, and control schemes. Logic shall have the ability to use relay elements, math functions, comparison functions, and Boolean logic functions.
- **Terminal Communication**. The relay shall allow communication from any ASCII terminal without proprietary software.

- **IRIG-B**. The relay shall include an interface port for a demodulated IRIG-B time synchronization input signal. The relays shall generate a time synchronizing signal to provide a synchronizing signal to other relays.
- **Environment**. The relay shall be suitable for continuous operation over a temperature range of –40° to +85°C.
- **Reliability**. The vendor shall supply the actual measured Mean-Time Between Failures (MTBF) for the device upon request.
- **Service**. The device shall include no-charge technical support for the life of the product.
- **Manufacturer**. The device shall be manufactured in the United States.
- **Warranty Return**. The vendor shall support a 72-hour turn-around on all warranty repairs.
- **Warranty**. The device shall include a ten-year, no-questions-asked warranty for all material and workmanship defects. In addition, the warranty shall cover accidental customer-induced damage.

Front- and Rear-Panel Diagrams

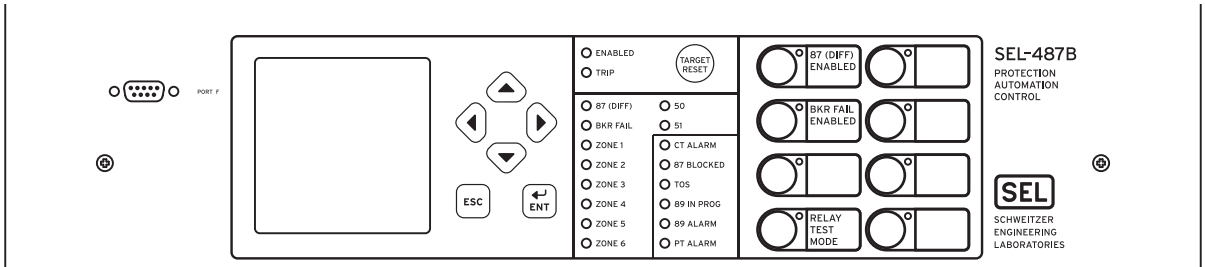


Figure 28 Standard Front-Panel Diagram, Showing the Front Panel With LCD, Navigation Pushbuttons, 16 Target LEDs, Reset, and Eight Programmable Pushbuttons

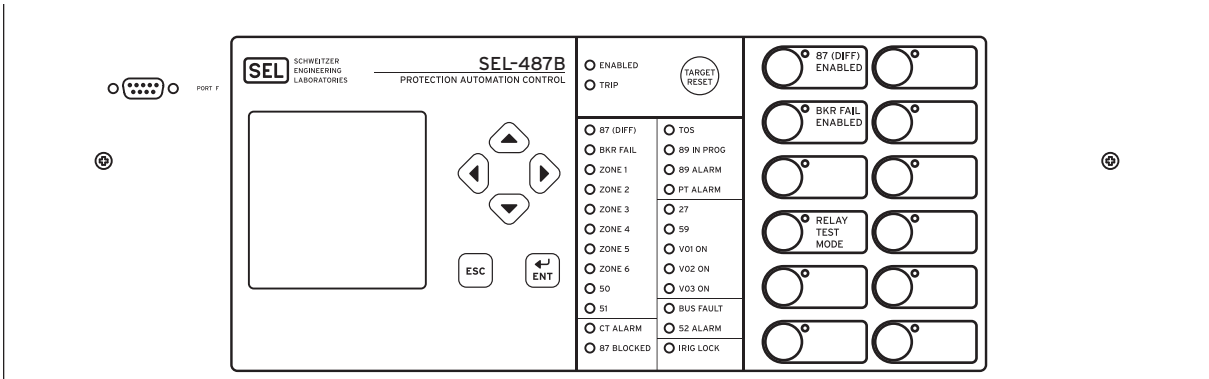


Figure 29 Expanded Front-Panel Diagram, Showing Extended Front-Panel HMI With LCD, Navigation Pushbuttons, 24 Tricolor LEDs, Reset, and 12 Programmable Pushbuttons

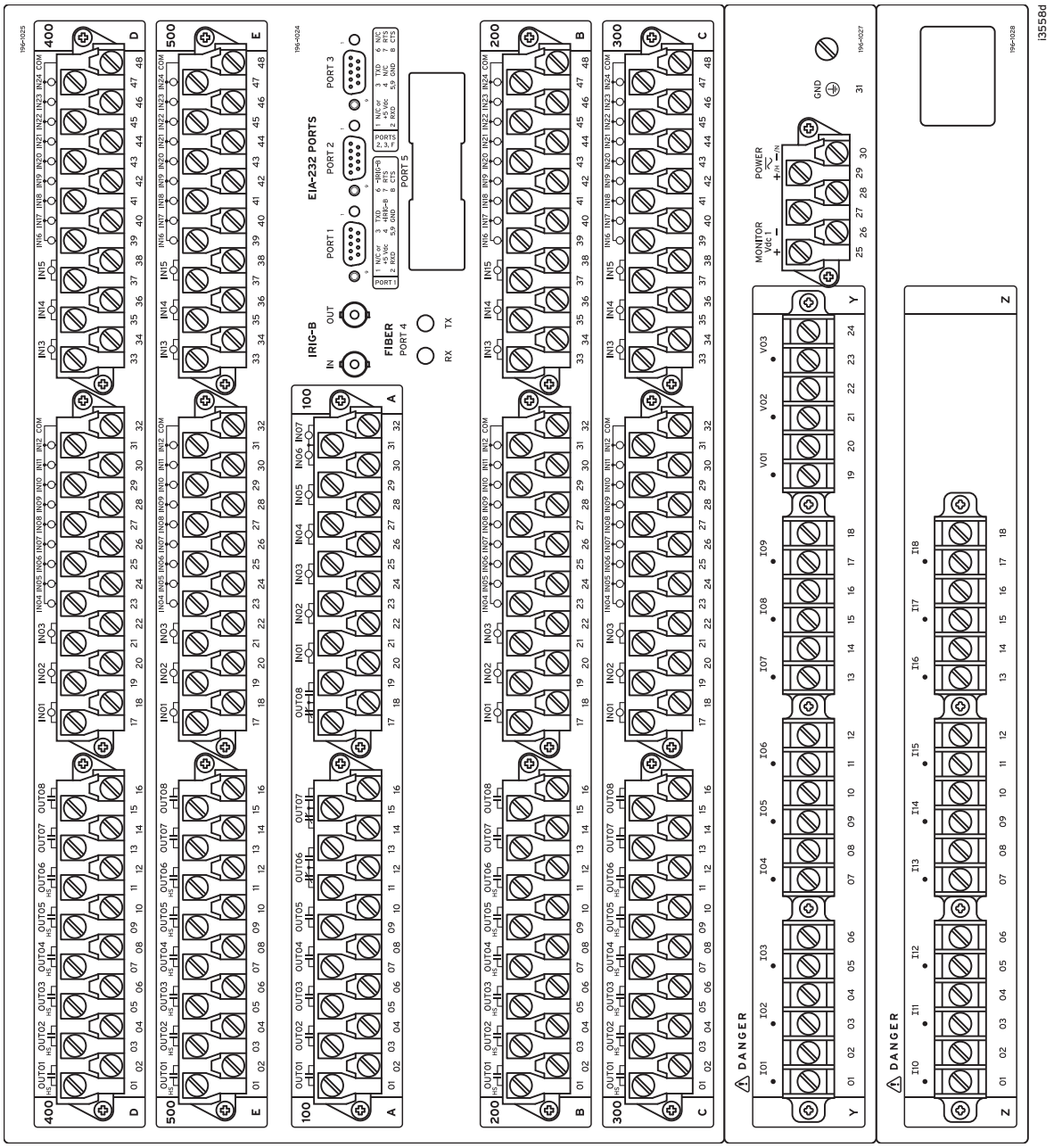


Figure 30 Rear-Panel Diagram of the 9U Chassis Size With Four INT4 Interface Boards

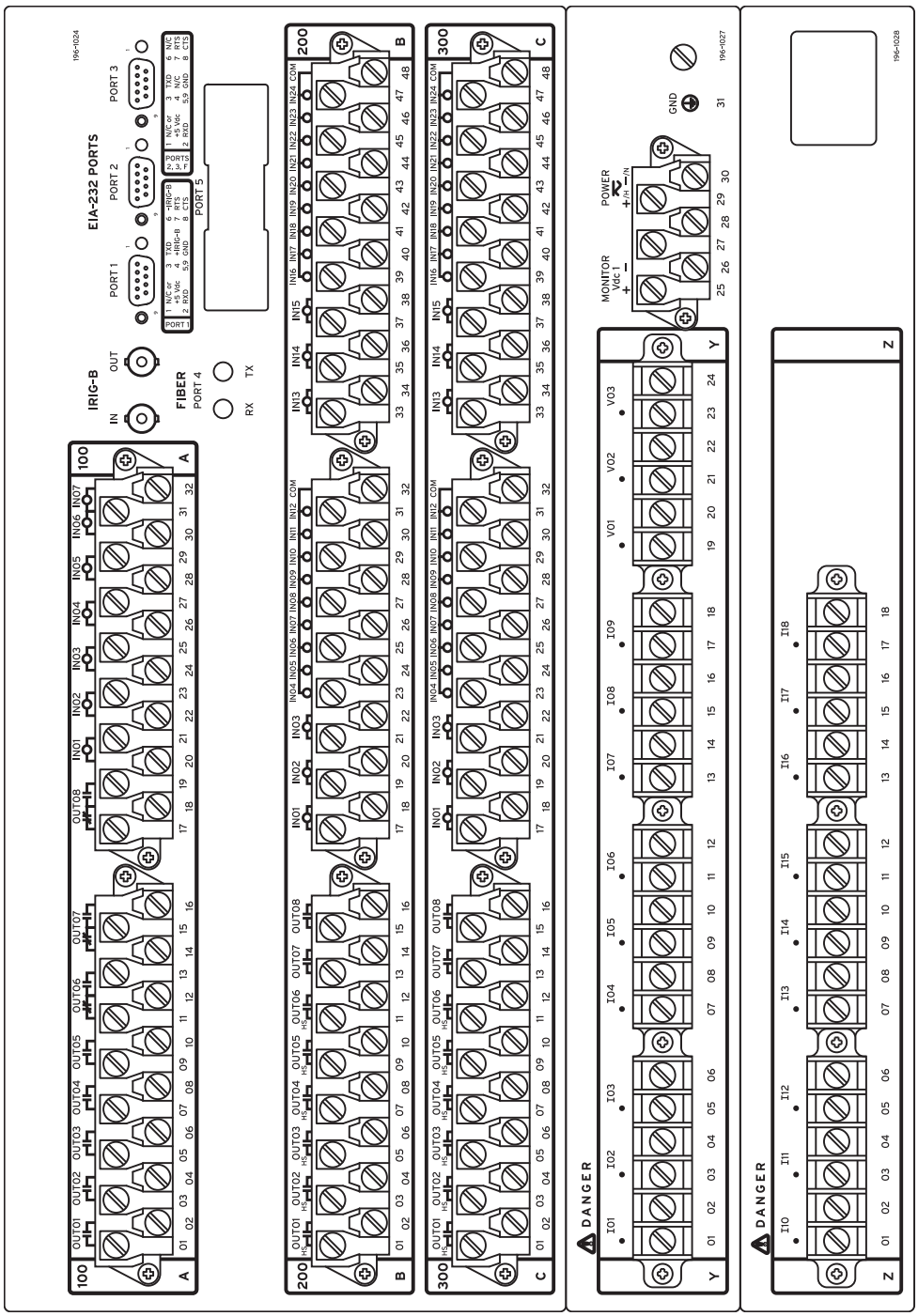
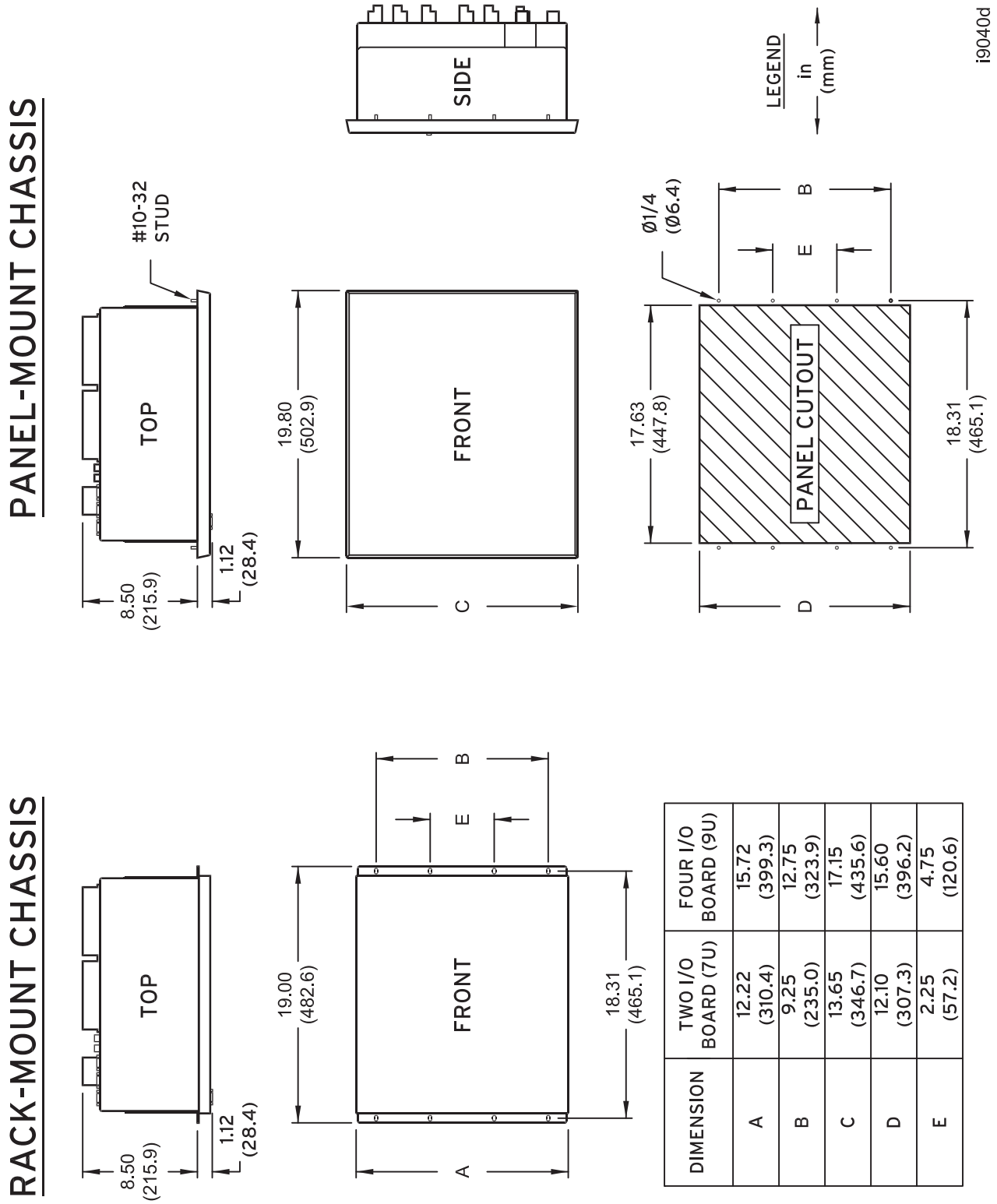


Figure 31 Rear-Panel Diagram of the 7U Chassis Size With Two INT4 Interface Boards

Relay Dimensions



DIMENSION	TWO I/O BOARD (7U)	FOUR I/O BOARD (9U)
A	12.22 (310.4)	15.72 (399.3)
B	9.25 (235.0)	12.75 (323.9)
C	13.65 (346.7)	17.15 (435.6)
D	12.10 (307.3)	15.60 (396.2)
E	2.25 (57.2)	4.75 (120.6)

Figure 32 Dimensions for Rack- and Panel-Mount Models

Specifications

Important: Do not use the following specification information to order an SEL-487B. Refer to the actual ordering information sheets.

General

AC Current Inputs (Secondary Circuits)

Note: Current transformers are Measurement Category II.

Continuous Thermal Rating

5 A nominal:	15 A
1 A nominal:	3 A

Saturation Current (Linear) Rating

5 A nominal:	100 A
1 A nominal:	20 A

One-Second Thermal Rating

5 A nominal:	500 A
1 A nominal:	100 A

One-Cycle Thermal Rating

5 A nominal:	1250 A-peak
1 A nominal:	250 A-peak

Burden Rating

5 A nominal:	0.5 VA at 5 A 2.51 VA at 15 A
1 A nominal:	0.1 VA at 1 A 1.31 VA at 3 A

Minimum A/D Current Limit (peak)

5 A nominal:	247.5 A
1 A nominal:	49.5 A

Sampling Rate:	Analog input signals shall be sampled at a rate of 24 samples per cycle.
Rated Voltage (U_e):	240 Vac
Rated Insulation Voltage (U_i):	300 Vac
Sampling Rate Analog inputs:	24 samples per cycle
Rotation:	ABC, ACB

AC Voltage Inputs

Rated Voltage Range:	0–300 V_{LN}
Ten-Second Thermal Rating:	600 Vac
Burden:	<0.1 VA @ 125 V

Power Supply

125/250 Vdc or 120/240 Vac

Rated Supply Voltage:	120/240 Vac 125/250 Vdc
Absolute Voltage Range:	85–300 Vdc 85–264 Vac
Rated Frequency:	50/60 Hz ± 5 Hz
Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-11:2008
Interruption:	250 ms @ 250 Vdc per IEC 60255-11:2008
Burden:	<35 W

48/125 Vdc or 120 Vac

Rated Supply Voltage:	120 Vac 48/125 Vdc
Absolute Voltage Range:	38–140 Vdc 85–140 Vac
Rated Frequency:	50/60 Hz ± 5 Hz
Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-11:2008
Interruption:	160 ms @ 125 Vdc per IEC 60255-11:2008
Burden:	<35 W

24/48 Vdc

Rated Supply Voltage:	24/48 Vdc
Absolute Voltage Range:	18–60 Vdc
Vdc Input Ripple:	15% per IEC 60255-11:2008
Interruption:	100 ms @ 48 Vdc per IEC 60255-11:2008
Burden:	<25 W

Operating Temperature

SEL-487B Without Ethernet Card:

–40° to +85°C (–40° to +185°F)

SEL-487B With Ethernet Card:

–40° to +75°C (–40° to +167°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)

9U Rack Unit:	19.1 kg (42 lbs)
7U Rack Unit:	16.1 kg (35 lbs)

Control Outputs

Main Board:	5 Form A and 3 Form C
Interface Boards:	High-speed contact option: 2 standard Form A 6 high-speed, high-current interrupting Form A Standard Contact Option: 8 standard Form A contacts

Standard

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (maximum voltage):	250 Vac, 330 Vdc
Pickup/Dropout Time:	6 ms, resistive load
Update Rate:	1/12 cycle

Break Capacity (10000 operations):

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

Cyclic Capacity (2.5 cycle/second):

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

High-Speed High-Current Interrupting

Make: 30 A

Carry: 6 A continuous carry at 70°C
4 A continuous carry at 85°C

1 s Rating: 50 A

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

Pickup Time: 10 µs, resistive load

Dropout Time: 8 ms, resistive load

Update Rate: 1/12 cycle

Break Capacity (10000 operations):

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

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

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

Note: Per IEC 60255-23:1994, using the simplified method of assessment.

Note: Make rating per IEEE® C37.90-1989.

Optoisolated Inputs

Main Board: 5 inputs with no shared terminals
2 inputs with shared terminals

INT4 Interface Board: 6 inputs with no shared terminals
18 inputs with shared terminals (2 groups of 9 inputs, with each group sharing one terminal)

Voltage Options: 24 V standard
48, 110, 125, 220, 250 V standard

DC Thresholds

24 Vdc: Pickup 15.0–30.0 Vdc

48 Vdc: Pickup 38.4–60.0 Vdc;
Dropout below 28.8 Vdc

110 Vdc: Pickup 88.0–132.0 Vdc;
Dropout below 66.0 Vdc

125 Vdc: Pickup 105–150 Vdc;
Dropout below 75 Vdc

220 Vdc: Pickup 176–264 Vdc;
Dropout below 132 Vdc

250 Vdc: Pickup 200–300 Vdc;
Dropout below 150 Vdc

AC Thresholds (Ratings met only when recommended control input settings are used—see *Table 2.1 on page 2.9*)

24 Vac: Pickup 12.3–30.0 Vac

48 Vac: Pickup 31.4–60.0 Vac;
Dropout below 20.3 Vac

110 Vac: Pickup 71.9–132.0 Vac;
Dropout below 46.6 Vac

125 Vac: Pickup 85.8–150.0 Vac;
Dropout below 53.0 Vac

220 Vac: Pickup 143.8–264 Vac;
Dropout below 93.2 Vac

250 Vac: Pickup 163.3–300 Vac;
Dropout below 106 Vac

Current Drawn: 5 mA at nominal voltage
8 mA for 110 V option

Sampling Rate: 24 samples per cycle

Frequency and Rotation

System Frequency: 50/60 Hz

Phase Rotation: ABC or ACB

Communications Ports

EIA-232: 1 Front and 3 Rear

Serial Data Speed: 300–57600 bps

Communications Card Slot for Optional Ethernet Card

Fiber Optic (Optional)

Ordering Options: 100BASE-FX

Mode: Multi

Wavelength (nm): 1300

Source: LED

Connector Type: ST

Min. TX Pwr. (dBm): –19

Max. TX Pwr. (dBm): –14

RX Sens. (dBm): –32

Sys. Gain (dB): 13

IRIG Time Input

Demodulated IRIG-B time code

Nominal Voltage: 5 Vdc + 10%

Maximum Voltage: 8 Vdc

Input Impedance: 333 ohms

Distance Between Relays for Cable With Capacitance of 28 pF/ft: 90 m (300 ft)

IRIG Time Output

Capable of driving 300 ohm termination with <200 ns propagation delay

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum: 1.0 Nm (9 in-lb)

Maximum: 2.0 Nm (18 in-lb)

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

Wire Sizes and Insulation

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

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

Type Tests

Electromagnetic Compatibility Emissions

Emissions:	IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity:	IEC 60255-22-6:2001 Severity Level: 10 Vrms IEC 61000-4-6:2008 Severity Level: 10 Vrms
Electrostatic Discharge Immunity:	IEC 60255-22-2:2008 Severity Level: 2, 4, 6, 8 kV contact: 2, 4, 8, 15 kV air IEC 61000-4-2:2008 Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air IEEE C37.90.3-2001 Severity Level: 2, 4, 8 kV contact; 4, 8, 15 kV air
Fast Transient/Burst Immunity:	IEC 60255-22-4:2008 Severity Level: Class A: 4 kV, 5 kHz; 2 kV, 5 kHz on communication ports IEC 61000-4-4:2011 Severity Level: 4 kV, 5 kHz
Magnetic Field Immunity:	IEC 61000-4-8:2009 Severity Level: 900 A/m for 3 seconds, 100 A/m for 1 minute IEC 61000-4-9:2001 Severity Level: 1000 A/m
Power Supply Immunity:	IEC 60255-11:2008 IEC 61000-4-11:2004 IEC 61000-4-29:2000
Radiated Digital Radio Telephone RF Immunity:	ENV 50204:1995 Severity Level: 10 V/m at 900 MHz and 1.89 GHz
Radiated Radio Frequency Immunity:	IEC 60255-22-3:2007 Severity Level: 10 V/m IEC 61000-4-3:2010 Severity Level: 10 V/m IEEE C37.90.2-2004 Severity Level: 35 V/m
Surge Immunity:	IEC 60255-22-5:2008 Severity Level: 1 kV Line to Line, 2 kV Line to Earth IEC 61000-4-5:2005 Severity Level: 1 kV Line to Line, 2 kV Line to Earth
Surge Withstand Capability Immunity:	IEC 60255-22-1:2007 Severity Level: 2.5 kV peak common mode, 1.0 kV peak differential mode IEEE C37.90.1-2002 Severity Level: 2.5 kV oscillatory, 4 kV fast transient waveform

Environmental

Cold:	IEC 60068-2-1:2007, Severity Level: 16 hours at –40° C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity 95%
Dry Heat:	IEC 60068-2-2:2007 Severity Level: 16 hours at +85° C
Vibration:	IEC 60255-21-1:1988 Severity Level: Class 1 Endurance, Class 2 Resonse IEC 60255-21-2:1988 Severity Level: Class 1 – Shock Withstand, Bump, and Class 2 – Shock Response IEC 60255-21-3:1983 Severity Level: Class 2 (Quake Response)

Safety

Dielectric Strength:	IEC 60255-5:2000 Severity Level: 2500 Vac on control inputs, control outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute. IEEE C37.90-2005 Severity Level: 2500 Vac on control inputs, control outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.
Impulse:	IEC 60255-5:2000 Severity Level: 0.5 Joule, 5 kV IEEE C37.90-2005 Severity Level: 0.5 Joule, 5 kV
IP Code:	IEC 60529:2001 + CRGD:2003 Severity Level: IP30

Safety Agency Certifications

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

Certifications

ISO 9001:	This product was designed and manufactured under an ISO 9001 certified quality management system.

Event Reports

Maximum Duration:	16 events at 30 cycles, 32 events at 15 cycles, 8 events at 60 cycles, or 4 events at 120 cycles
Resolution:	4-, 12-, and 24-samples/cycle

Event Summary

Storage:	100 summaries

Sequential Events Recorder

Sequential Events Recorder Storage:	1000 entries
Trigger Elements:	250 monitoring points
Processing Rate:	24 samples per cycle

Processing Specifications

AC Voltage and Current Inputs

24 samples per cycle, 3 dB low-pass analog filter cut-off frequency of 646 Hz, ±5%

Digital Filtering

Full-cycle cosine after low-pass analog filtering

Protection and Control Processing

12 times per power system cycle

Control Points

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

Relay Element Pickup Ranges and Accuracies

Differential Elements

Number of Zones:	6
Number of Terminals:	
Three-relay Application:	18
Single-Relay Application:	6
Slope 1	
Setting Range:	15–90%
Accuracy:	±5% ±0.02 • I_{NOM}
Slope 2	
Setting Range:	50–90%
Accuracy:	±5% ±0.02 • I_{NOM}

Supervising Differential Element

Quantity:	6
Setting range:	0.10–4.00 pu
Accuracy:	±5% ±0.02 • I_{NOM}

Incremental Restraint and Operating Threshold Current Supervision

Setting range:	0.1–10.0 pu
Accuracy:	±5% ±0.02 • I_{NOM}

Sensitive Differential Current Alarm

Quantity:	6
Setting range:	0.05–1.00 pu
Accuracy:	±5% ±0.02 • I_{NOM}
Timer Setting Range:	50–6000 cycles

Instantaneous/Definite-Time Overcurrent Elements

Phase Current Setting 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, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Transient Overreach:	<5% of setting
Timer Setting Range:	0.00–99999.00 cycles, 1/6-cycle steps
Timer Accuracy:	±0.1% of settings ±1/6 cycle
Max. Operating Time:	1.5 cycles

Time-Overcurrent Elements

Pickup Range:	
5 A Model:	0.50–16.00 A secondary, 0.01 A steps
1 A Model:	0.10–3.20 A secondary, 0.01 A steps
Accuracy (Steady State):	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Time Dial Range:	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles, ±4% of curve time (for current between 2 and 30 multiples of pickup)
Reset:	1 power cycle or Electromechanical Reset Emulation time

Under/Overvoltage Elements (27, 59)

Processing Rate:	1/12 cycle
Phase Under/Overvoltage (2 Level/Phase)	
Setting Range:	1.0–200 V_{LN} in 0.1 steps
Accuracy:	±5% of setting, ±0.5 V
Transient Overreach:	<5% of pickup
Maximum Delay:	1.5 cycles
Zero- and Negative-Sequence Overvoltage Elements	
Setting Range:	1.0–200 V in 0.1 steps
Accuracy:	±5% of setting, ±1 V
Transient Overreach:	<5% of setting
Maximum Delay:	1.5 cycles

Breaker Failure Instantaneous Overcurrent

Setting Range:	
5 A Model:	0.50–50 A, 0.01 A steps
1 A Model:	0.10–10.0 A, 0.01 A steps
Accuracy:	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±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, 1/12-cycle steps (BFPU*nn*, RTPU*nn*) 0–1000 cycles, 1/12-cycle steps (BFISP*nn*, BFIDO*nn*)
Time Delay Accuracy:	1/12 cycle, ±0.1% of setting

Disconnect Monitor

Number:	48
Timer Setting Range:	0–99999 cycles, 1 cycle step

Breaker Status Monitor

Number:	18

Coupler Security Logic

Number:	4
Timer Setting Range:	0–1000 cycles, 1/12 cycle step

Control Input Timers

Setting Range:	
Pickup:	0.00–1 cycle
Dropout:	0.00–1 cycle

Station DC Battery System Monitor Specifications

Operating Range:	0–350 Vdc
Input Sampling Rate:	24 samples per cycle
Processing Rate:	1/6 cycle
Maximum Operating Time:	≤1.5 seconds (element DC1R) ≤1.5 cycles (all elements but DC1R)
Setting Range:	
DC Settings:	OFF, 15–300 Vdc, 1 Vdc steps
AC Ripple Setting:	1–300 Vac, 1 Vac steps
Pickup Accuracy:	±10%, ±2 Vdc (DC1RP), ±3%, ±2 Vdc (all elements but DC1RP)

Metering Accuracy

All metering accuracies are based on an ambient temperature of 20°C and nominal frequency.

Instantaneous Differential Metering per Zone (Steady State)

IOP, IRT:	±3.0%, ±0.02 • I_{NOM}

Per-Phase Instantaneous Metering (Steady State)

V01, V02, and V03:	> 30 V ±1%
I01, I02, . . ., I18:	±1.5% ±0.004 • I_{NOM}, ±2.0°

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PDS487B-01