SEL-167

Phase and Ground Directional Overcurrent Relay With Recloser and Fault Locator

Instruction Manual

19930510

SEL SCHWEITZER ENGINEERING LABORATORIES, INC.

⚠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.

⚠WARNING

Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠WARNING

Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.

⚠DANGER

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

⚠DANGER

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

⚠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.

⚠AVERTISSEMENT

Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.

⚠AVERTISSEMENT

L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.

⚠DANGER

Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.

⚠DANGER

Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessuers ou la mort.

PM167-01

This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Cet équipement est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accès non-autorisé à l'équipement pourrait être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès non-autorisé.

20001120

Standard Product Warranty – Ten Years

Definition of Terms

Product: All items manufactured by SEL that are sold to a customer.

New Product: A product manufactured by SEL that is sold for the first time.

Customer: An end-user of the product.

New Product Warranty

All new products sold to customers are warranted against defects in design, materials, and workmanship for a period of ten (10) years from the date of first retail delivery to a customer. If it is determined that the new product defect is covered under this warranty, SEL will repair, replace, or substitute an identical unit at its own discretion to the customer at no charge.

SEL may, at its own discretion, require the customer to ship the unit back to the factory for diagnosis before making a determination as to whether it is covered by this warranty. In such event, SEL may, at its own discretion, decide to provide the customer with a substitute unit which may be sent to the customer either from the SEL factory or from an authorized representative or distributor from their inventory.

All expenses related to the shipment of defective units back to SEL or the provision of a substitute unit to the customer are the responsibility of the customer. This expense may include, but is not limited to, freight, insurance, Customs clearance, and duties. All expenses related to the shipment of repaired units back to customers (or the provision of a new unit to the customer) will be borne by SEL.

Product Upgrade Policy

From time to time, SEL makes product upgrades to add to or enhance the performance of the products. Customers of a particular product being issued an upgrade will be notified either by SEL directly or through its authorized representatives or distributors.

Customers who have purchased an annual upgrade policy will receive all upgrades during the calendar year free of charge. Customers who did not purchase the annual upgrade policy may purchase each unit upgrade individually. The annual upgrade policy can be purchased at any time. Regardless of whether the upgrade policy is purchased, SEL will make reasonable efforts to notify all customers of all available upgrades.

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EQUIPMENT REPAIR AND WARRANTY

Repair costs of products not covered under this warranty are paid for by customers. Customers are responsible for the cost of shipping the products to SEL located at: 2350 NE Hopkins Court, Pullman, Washington 99163 USA.

All products repaired by SEL will be warranted against defects in material and workmanship for a period of one year from the date the equipment is returned to the customer or the remainder of the new product warranty, whichever is longer.

LIMITATIONS

SEL's warranty does not extend to (A) SEL's products subject to (i) improper installation, connection, operation, maintenance, or storage; (ii) accident, damage, abuse, or misuse; (iii) abnormal or unusual operating conditions or applications outside the specifications for the product; (iv) a purpose or application in any way different from that for which the products were designed; or (v) repairs conducted by persons other than SEL employees or an authorized representative or distributor; (B) Equipment and products not manufactured by SEL. Such equipment and products may be covered by a warranty issued by the respective manufacturer.

This warranty is in lieu of any other warranties, express or implied, including without limitation, any warranty of merchantability or fitness for a particular purpose, and is in lieu of any and all other obligations or liability of SEL. Under no circumstances shall SEL be liable for any accidental or consequential damages or for any other loss, injury, damage, or expense of any kind including loss of profits arising hereunder.

To the extent any court, arbitration panel, or other governmental body of competent jurisdiction shall declare any provision of this warranty invalid or unenforceable by reason of a rule of law or public policy, all the other provisions hereof shall remain in full force and effect.

SEL-167 INSTRUCTION MANUAL ADDENDUM

KILOMETER OPTION

The SEL-167 relay instruction manual is written for fault locations in terms of miles. If your SEL-167 relay is ordered with the kilometer line length option, references made in the instruction manual to miles should be substituted with kilometers.

One exception to the straight substitution of kilometers for miles is the reference in the instruction manual to the effect of shunt capacitance on the fault location calculation. The line length equation and associated paragraphs, corrected for a 100-kilometer line, should read:

> Shunt capacitance of the transmission line is not taken into account. The capacitance causes the fault location to appear less remote by, approximately, a factor of 1/cos(bL), where bL is the line length in radians at 60Hz. One wavelength at 60 Hz is 4989 kilometers. For example, the line length of a 100-kilometer line in radians, is:
>
> $$(100/4989) * 2 * 3.14159 = 0.1260 \text{ radians}$$

The indication neglecting capacitance is about cos (0.1260) = 0.992 times the actual fault location, or about 0.8 kilometers short for a fault at the remote end of a 100-kilometer line.

SEL RELAY INSTRUCTION MANUAL ADDENDUM

ACB PHASE ROTATION OPTION

The SEL relay instruction manuals are written for standard ABC phase rotation applications. If your SEL relay is ordered with the ACB phase rotation option, references made in the instruction manual to voltage and current phase angle should be noted accordingly. The firmware identification number (FID) may be used to verify whether your relay was ordered with ABC or ACB rotation.

All current and voltage inputs are connected to the SEL relay rear panel as shown in the instruction manual.

SECTION 1: SEL-100 SERIES ADDENDUM

The SEL-100 series relay logic inputs have been improved to prevent operation of the logic input due to the conditions described in SELUPDATE 94.10. If you would like a copy of SELUPDATE 94.10, please contact the SEL factory.

The new interface board also provides field selectable input voltage selection. The operating voltages and jumper selection for each logic input are shown in the table below.

Control Voltage	Relay Terminals											
	39/40		41/42		43/44		45/46		47/48		49/50	
	JMP11	JMP12	JMP9	JMP10	JMP7	JMP8	JMP5	JMP6	JMP3	JMP4	JMP1	JMP2
250 V												
125 V		●—●		●—●		●—●		●—●		●—●		●—●
48 V	●—●	●—●	●—●	●—●	●—●	●—●	●—●	●—●	●—●	●—●	●—●	●—●

CONTROL INPUT OPERATING RANGES

Control Voltage	Operating Range
250 Vdc	150 - 300 Vdc
125 Vdc	80 - 150 Vdc
48 Vdc	30 - 60 Vdc

Changing the input voltage jumpers requires that you disassemble the relay. The following information describes the procedure for changing the input voltage selection jumpers:

1. Remove power from relay.
2. Place relay in a static-safe work area.
3. Remove top and bottom chassis covers (eight screws total).
4. Remove the four screws securing the front panel.
5. Carefully allow the top edge of the front panel to come forward and down (exposing relay main board/power supply/interface tray assembly).
6. From the bottom of the relay, locate and remove the two 4-40 hex jack screws that secure the tray assembly to the chassis. These jack screws are located at the front corners of the draw-out tray and require a long 3/16-inch nut driver or extended socket.

7. Carefully remove the ribbon cable from the front panel LED display. The power switch/fuse assembly will remain attached to the relay and front panel.

8. Carefully remove the ribbon cable from the main board P104 connector.

9. Pull forward on the draw-out tray using the two standoffs located on the bottom of the tray. Removing the draw-out tray will require a good amount of force.

10. With the main board facing up, rotate the draw-out tray so that the back is facing you. The input jumpers are now exposed on the inside of the interface board (board below draw-out tray).

11. Make the correct jumper selection for the desired input voltages per the jumper selection table.

12. Turn board so that the main board is facing up and reinstall into relay chassis. Note guide hole alignment at the back of the draw-out tray and make sure interface pins located on the back plane board are aligned with the draw-out tray before "seating" the draw-out assembly. Inserting the draw-out tray will require a good amount of force.

13. Reattach ribbon cable to main board P104 connector.

14. Reattach ribbon cable to front panel LED assembly.

15. Replace the 4-40 hex jack screws (two only) so that the draw-out tray is secure.

16. Lift the edge of the front panel up into normal position and replace the four front panel screws. (Make sure switch/fuse cable and ribbon cables are free from any "pinch" points.)

17. Make sure power switch/fuse cable assembly is seated on the back panel connector. (During the normal removal process, it is possible to have partially or completely disconnected this cable.)

18. Carefully replace top and bottom chassis covers and screws (eight screws total).

SEL-167 INSTRUCTION MANUAL ADDENDUM

This addendum details SEL-167 relay protection and security logic which differs from that described in the SEL-167 Instruction Manual. The following summary provides an overview of the single addition and three revisions to the SEL-167 relay. A detailed description of the addition and revisions follows the summary. Please note: an addition is logic added to the relay, while a revision is a change to existing SEL-167 relay logic.

SEL-167 Relay Logic Revisions and Additions

Revision 1. TRIP unlatch logic has been modified to coincide with the loss of current following a trip instead of 52A input deassertion.

Revision 2. Minimum duration the TRIP contacts remain closed is now settable. This time was previously fixed at 60 msec.

Revision 3. The Relay Word now includes separate bits to indicate pickup of the phase time overcurrent (51PP) and residual time overcurrent (51NP) elements. Previously, pickup of both elements was combined in the TOCP (Time OverCurrent Pickup) bit in the Relay Word. The TOCP bit has been retained in the Relay Word.

Addition 1. If a trip condition exists, front panel targets do not clear when the TARGET RESET button is depressed.

Revision 1. TRIP Unlatch Logic Modification
Revision 2. Minimum Trip Duration Logic Modification

Unlatching the TRIP output contacts previously depended on two criteria: 1) 60 msec. minimum trip duration timer expiration, and 2) 52A input deasserted at the expiration of this 60 msec. timer or when the trip conditions no longer existed. Previous SEL-167 relay open TRIP contact logic was as follows:

Open TRIP contact = NOT(TRIP) * [NOT(52A) + TARGET RESET button pushed]
* (60 msec. minimum TRIP duration timer expired)

The new open TRIP contact logic replaces the fixed 60 msec. timer and 52A status criteria with two new criteria: 1) dropout of all elements in Relay Word row 1, and 2) expiration of a settable trip duration timer (TDUR). This new logic is as follows:

Open TRIP contact: NOT(TRIP) * [NOT(Any element in Relay Word row 1 picked up) + TARGET RESET button pushed] * (Trip Duration timer expired (TDUR))

Where:

TRIP ≡ Any condition resulting in TRIP output contact closure (determined by relay and logic settings)

TDUR ≡ Minimum Trip Duration timer (settable)

Row 1 ≡ 51NP + 50N1 + 50N2 + 50N3 + 51PP + 50P1 + 50P2 + 50P3 (please see Revision 3 for a description of Relay Word bits)

The Revision 1 logic change removed TRIP unlatch dependence on 52A input status. The SEL-167 relay logic now requires measured currents to drop below the pickup threshold of any element in the first row of the Relay Word. Requiring all elements in Relay Word row 1 to drop out before unlatching the TRIP contact assures that all three poles of the line breaker have opened. Once the line breaker is open (as judged by the loss of current flowing in the poles), it is acceptable to open the high speed TRIP output contacts without the possibility of their interrupting full trip coil current.

The Revision 2 logic modification allows you to set the minimum duration that TRIP output contacts are closed. This is accomplished with a settable timer labeled TDUR. This function was previously performed by a fixed 60 msec. timer. The TDUR timer is an edge triggered timer initiated from the rising edge of the TRIP output. To maintain the 60 msec. minimum TRIP duration time, set the TDUR timer to 3.5 cycles (3.5 cycles = 58.3 msec.). Figure 1 illustrates the logic involved in Revisions 1 and 2.

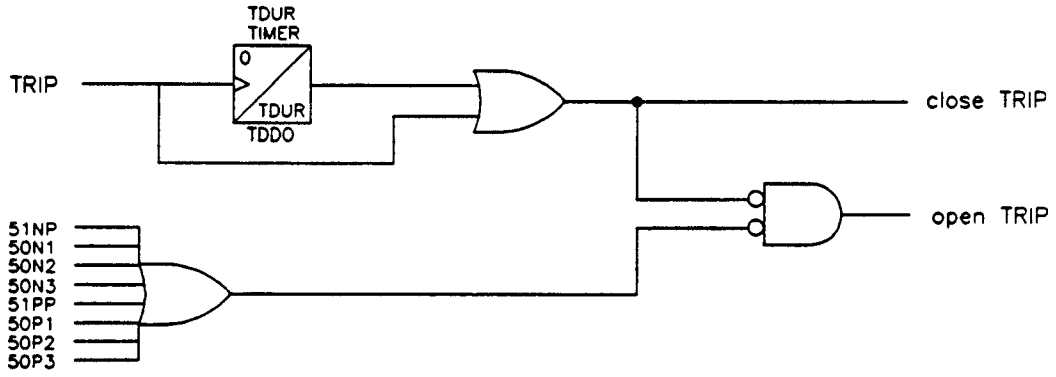

Figure 1: TRIP Unlatch and TDUR Logic Development

Benefit:

The TRIP output contact unlatching operation is not dependent upon the 52A input state. This logic prevents any possible timing mismatch between the 52A input to the relay and the 52A contact in series with the line breaker trip coil. Such a mismatch can result in the TRIP output contacts interrupting full trip coil current.

Revision 3. SEL-167 Relay Word

Table 1 shows the first four rows of the Relay Word for the SEL-167 relay. Relay elements and intermediate logic results are represented in a 32-bit Relay Word (grouped into four 8-bit words). You select bits in this word to perform the desired functions for controlling outputs and initiating or cancelling reclose. Selected bits are stored in masks for each function. You can program the bits in these masks with the LOGIC command.

Table 1: SEL-167 Relay Word

51NP	50N1	50N2	50N3	51PP	50P1	50P2	50P3
DFP	67N1	67N2	67N3	DFG	67P1	67P2	67P3
51NT	Z1GT	Z2GT	Z3GT	51PT	Z1PT	Z2PT	Z3PT
ALRM	TRIP	TC	DT	52BT	SH1	TOCP	DCTH

The Relay Word Bit Summary Table on the following page explains the meaning of each bit in the first four rows of the Relay Word.

Addition 1. Front Panel Target Update Logic

The previous SEL-167 relay logic allowed clearing of the front panel targets whenever a user pressed the TARGET RESET button, regardless of TRIP output status. Pressing TARGET RESET also unlatched the TRIP output contact. When you press TARGET RESET, the new logic checks to make sure no trip condition is present before clearing the front panel targets. Pressing TARGET RESET still unlatches the TRIP output contacts when no trip condition exists.

Benefit:

When restoring the SEL-167 relay to service following testing, always press the TARGET RESET button to ensure that TRIP output contacts are open. The new logic allows technicians to determine whether a trip condition still persists prior to closing in the trip cutout switch. If relay targets do not clear after you press the front panel TARGET RESET button, a trip condition is present and the trip cutout switch should not be closed.

Table 2: Relay Word Bit Summary Table

51NP	Residual time-overcurrent pickup (directional as enabled)
50N1	Zone 1 residual instantaneous O/C pickup (nondirectional)
50N2	Zone 2 residual instantaneous O/C pickup (nondirectional)
50N3	Zone 3 residual instantaneous O/C pickup (nondirectional)
51PP	Phase time-overcurrent pickup (directional as enabled)
50P1	Zone 1 phase instantaneous O/C pickup (nondirectional)
50P2	Zone 2 phase instantaneous O/C pickup (nondirectional)
50P3	Zone 3 phase instantaneous O/C pickup (nondirectional)
DFP	Direction forward - phase faults
67N1	Zone 1 residual directional instantaneous O/C pickup
67N2	Zone 2 residual directional instantaneous O/C pickup
67N3	Zone 3 residual directional instantaneous O/C pickup
DFG	Direction forward - ground faults
67P1	Zone 1 phase directional instantaneous O/C pickup
67P2	Zone 2 phase directional instantaneous O/C pickup
67P3	Zone 3 phase directional instantaneous O/C pickup
51NT	Residual time-overcurrent trip
Z1GT	Zone 1 residual time-out (67N1 plus Z1DG time delay)
Z2GT	Zone 2 residual time-out (67N2 plus Z2DG time delay)
Z3GT	Zone 3 residual time-out (67N3 plus Z3DG time delay)
51PT	Phase time-overcurrent trip
Z1PT	Zone 1 phase time-out (67P1 plus Z1DP time delay)
Z2PT	Zone 2 phase time-out (67P2 plus Z2DP time delay)
Z3PT	Zone 3 phase time-out (67P3 plus Z3DP time delay)
ALRM	System alarm
TRIP	Trip output (this bit follows the TRIP output contacts)
TC	Trip (OPEN) command
DT	Direct Trip input asserted
52BT	Time delayed inverse of the 52A input
SH1	Shot 1 reclosing indicator
TOCP	Time-overcurrent pickup indicator (51PP + 51NP)
DCTH	Demand current threshold exceeded

The Relay Word and programmable masks provide application flexibility without rewiring panels or changing jumpers on circuit boards.

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Command and Event Report Summary

INTRODUCTION

OVERVIEW

The SEL-167 relay PHASE AND GROUND DIRECTIONAL OVERCURRENT RELAY WITH FAULT LOCATOR may be applied to protect transmission, subtransmission and distribution lines.

The features of the SEL-167 relay include:

- Directional Overcurrent Protection for Phase and Ground Faults
- Versatile User-Programmable Logic
- Three-Shot Reclosing with Fuse Saving Capability
- Fault Locating
- Event Recording
- Automatic Self Testing
- Metering, Including Demand
- Target Indicators for Faults and Testing
- Time Code Input
- Communication Ports for Local and Remote Access
- Compact and Economical

GENERAL INFORMATION

This introduction provides specifications for the SEL-167 relay and describes its theory of operation. Although you should be familiar with this information before applying the relay, you may wish to complete the INITIAL CHECKOUT procedure in the next section before reading the specifications.

Communications functions provide remote and local examination of a wide range of data, including the voltages and currents presented to the instrument, relay settings, and a history of the twelve most recent events. Relay settings may be entered and modified remotely. The relay also allows circuit breaker control via the communica-

tions channels. A secure two-level password access scheme protects settings and circuit breaker control. An alarm contact output monitors the relay to prevent unauthorized access.

The SEL-167 relay includes a fault locator which uses fault type, prefault, and fault conditions to provide an accurate estimate of fault location without the need for communications channels, special instrument transformers, or source impedances, even during conditions of substantial load flow and fault resistance.

The relay generates a detailed event report after every fault. This report includes all data needed to quantitatively examine the prefault, fault, and postfault voltages and currents. Parameters such as fault current sensed by the relay, relay response time, and total fault clearing time can easily be determined. The event report includes the distance to the fault, fault type, and the state of all relay units during the event. Each event is time-tagged by a self-contained clock. In addition to the automatic generation of this report for faults, operators may generate a report upon command, or by asserting one of several control inputs to the instrument. This allows users to trigger the report from other equipment, such as oscillographic starting units or other relaying systems. The SEL-167 relay retains the twelve most recent event reports. A user may recall any of these reports on command.

Phasor diagrams of the voltages and currents showing prefault, fault, and postfault conditions can be constructed from the fault report. This accurate information is useful in verifying short-circuit and load-flow calculations, verifying transmission line constants, and measuring voltage and current unbalance. It can also be used to check the input connections for proper phase-sequence rotation and polarity.

This instrument is designed to provide long-term accuracy and availability. Amplitude-dependent measurements are made with respect to an internal voltage reference which is stable and precise. Extensive self testing functions monitor the voltage reference. Long-term phase stability is guaranteed, since all phase-shifting operations are performed by precise time delays controlled from a quartz crystal oscillator.

SPECIFICATIONS

Relay Functions

Directional overcurrent protection for phase faults
- Nine phase overcurrent elements in three groups
- Three timers, one per group
- Polyphase time-overcurrent element with selectable curve shapes
- Phase directional element operates from negative-sequence and positive-sequence quantities. The negative-sequence voltamperes are weighted four times the positive-sequence voltamperes.

Directional residual-overcurrent protection for ground faults
- Three definite-time elements
- One time-overcurrent element with selectable curve shapes
- Negative- and zero-sequence directional elements for ground faults. Zero-sequence element is dual polarized.

Automatic reclosing for selectable fault types (3 shots).

51P Phase time-overcurrent element.
Selectable curve shape (4 curves).
Time Dial: 0.50 to 15.00 in steps of 0.01
Pickup: 1 to 12.6 A, ±0.05A ± 2% of setting.

50A1, 50B1, 50C1 Zone 1 phase overcurrent elements (50P1).
50A2, 50B2, 50C2 Zone 2 phase overcurrent elements (50P2).
50A3, 50B3, 50C3 Zone 3 phase overcurrent elements (50P3).
Pickup: 1 A to 25 times 51P pickup
Timers are provided for each zone:
Zone 1 Timer: 0-60 cycles in 0.25 cycle steps
Zone 2 Timer: 0-2000 cycles in 0.25 cycle steps
Zone 3 Timer: 0-2000 cycles in 0.25 cycle steps

Ground Overcurrent (secondary values)
51N Residual time-overcurrent element.
Selectable curve shape (4 curves)
Time dial: 0.50 to 15.00 in steps of 0.01
Pickup: 0.25 to 6.3 A, ±0.05 A ±2% of setting.
50N1, 50N2, 50N3 residual-overcurrent elements.
Pickup: 0.2 to 47 times 51N pickup
Timers are provided for 50N1, 50N2, and 50N3:
Zone 1 Timer: 0-60 cycles in 0.25 cycle steps
Zone 2 Timer: 0-2000 cycles in 0.25 cycle steps
Zone 3 Timer: 0-2000 cycles in 0.25 cycle steps

Demand Overcurrent
DCTH Phase demand overcurrent element.
Pickup: 51PP ≤ 4.0 A, secondary; 0.7 to 60.2 A, secondary
51PP > 4.0 A, secondary; 0.2 to 14.9 times 51PP setting
Where 51PP is the phase-time overcurrent element pickup setting. See Meter function description.

Directional Elements
Phase directional element:
Angle: MTA (maximum torque angle) setting (47 - 90 degrees in 1 degree steps).
Sensitivity: 1 VA of positive-sequence and 0.25 VA of negative-sequence at MTA
Memory: Eight cycles
Negative-sequence directional element:
Angle: MTA setting (47-90 degrees in 1 degree steps).
Sensitivity: Proportional to 51P pickup for 4A < 51PP < 12.6A:
0.35VA at 12.6 A pickup at MTA
0.11VA at 4.0A pickup and below at MTA

Zero-sequence directional element

Voltage polarization:

Angle: MTA setting (47-90 degrees in 1 degree steps).

Sensitivity:(0.125 volts) X (51N pickup setting) at MTA in units of zero-sequence volts times residual amps, and V0 > 0.17V.

Current polarization:

Angle: Zero degrees

Sensitivity: (0.5 amps) X (51N pickup setting), at zero degrees, in units of residual amps squared, and Ipol > 0.5 amps.

Note: The MTA setting is common to all three directional elements.

Three-shot reclosing relay:

79OI1 open interval 1,
79OI2 open interval 2, and
79OI3 open interval 3:

Timer ranges: 0 - 8,000 cycles in 1/4 cycle steps.

A setting of 0 disables that shot and successive shots.

79RS reset interval:

Timer range: 60 - 10,000 cycles in 1/4 cycle steps

Fault Location

Fault location is computed using event reports stored following each fault. The algorithm compensates for prefault current, improving accuracy for high-resistance faults.

Metering

All metered quantities are displayed in primary units.

Voltage: Phase-neutral voltages are measured, scaled to primary and displayed upon command. Calculated phase-to-phase voltages are also displayed.

Current: Each phase current is measured, scaled to primary and displayed on command. Calculated phase-to-phase currents are also displayed.

Demand: Current demand is computed with a 5 to 60 minute time constant. To see the current demand issue a METER command. Peak demand is determined and stored, and is resettable by command. A demand threshold setting is provided. When the demand exceeds the setting, the DCTH bit in the Relay Word is set. It can be used for tripping, annunciation, alarm, etc.

Power: MW and MVAR are determined by a three-phase, four-wire calculation.

Event Reporting

The relay retains a data record with current, voltage, relay element, and input/output contact information for each of the 12 most recent faults. The report may also be triggered by command or contact closure. When tripping occurs after the end of the event report, a second report is triggered at tripping.

Self Testing	Analog ac channel offset errors Stall timer monitors processor Power supply voltage checks Setting checks RAM, ROM, and A/D converter tests
Rated Input Voltage	115 volts phase-to-phase, 3-phase 4-wire connection
Rated Input Current	5 amps per phase nominal 15 amps per phase continuous 500 amps for one second thermal rating
Output Contact Ratings	30 amp make per IEEE C37-90 para 6.6.2 6 amp carry continuously MOV protection provided
Logic Input Ratings	48 Vdc: 25 - 60 Vdc 125 Vdc: 60 - 200 Vdc 250 Vdc: 200 - 280 Vdc Input current: 6 mA at nominal voltage
Power Supply	48 Volt: 20 - 60 Vdc; 12 watts 125 Volt: 85 - 200 Vac or Vdc; 12 watts 250 Volt: 85 - 280 Vdc or 85 - 200 Vac; 12 watts
Dielectric Strength	Routine tested: V, I inputs: 2500 Vac for 10 seconds Other: 3000 Vdc for 10 seconds (excludes RS-232-C and time code input)
Interference Tests	IEEE C37-90 SWC test (type tested) IEC 255-6 interference test (type tested)
Impulse Tests	IEC 255-5 0.5 joule 5000 volt test (type tested)
RFI Tests	Type-tested in field from a ¼-wave antenna driven by 20 watts at 150 MHz and 450 MHz, randomly keyed on and off at a distance of 1 meter from relay.
Dimensions	5¼" x 19" x 13". Mounts in standard 19" relay rack.
Unit Weight	21 pounds
Shipping Weight	32 pounds, including two instruction manuals
Operating Temp.	-20 deg C to +55 deg C
Burn-in Temp.	Each SEL-167 relay is burned in at 60 deg C for 100 hours

BASIC PROTECTIVE CAPABILITIES

The SEL-167 relay provides complete directional overcurrent protection for faults of all types. The demand ammeter, with its programmable threshold and time constant, offers overload protection and alarm functions.

The SEL-167 Relay Function Block Diagram illustrates the basic configuration of the protective capabilities (the FUNCTIONAL DESCRIPTION section of this manual provides exact descriptions of the logic).

Analog inputs from current and voltage transformers are delivered to the protective relaying elements and saved for additional features, such as metering and fault locating.

The relay elements process the analog data. Some intermediate logic is performed, including directional supervision of overcurrent elements and grouping of certain elements.

The states of the intermediate results and other data are recorded in the Relay Word.

Logic for tripping, closing, and other purposes uses the Relay Word data. Most of that logic is programmable by logic masks.

Phase and Three-Phase Faults

Phase fault protection consists of three instantaneous phase overcurrent elements and a time-overcurrent element. The three overcurrent elements are directionally supervised by the phase directional element for both three-phase and phase-phase faults. To securely discriminate between forward and reverse-direction faults, the torque threshold of the phase directional element must be exceeded for faults in either direction before fault direction is declared.

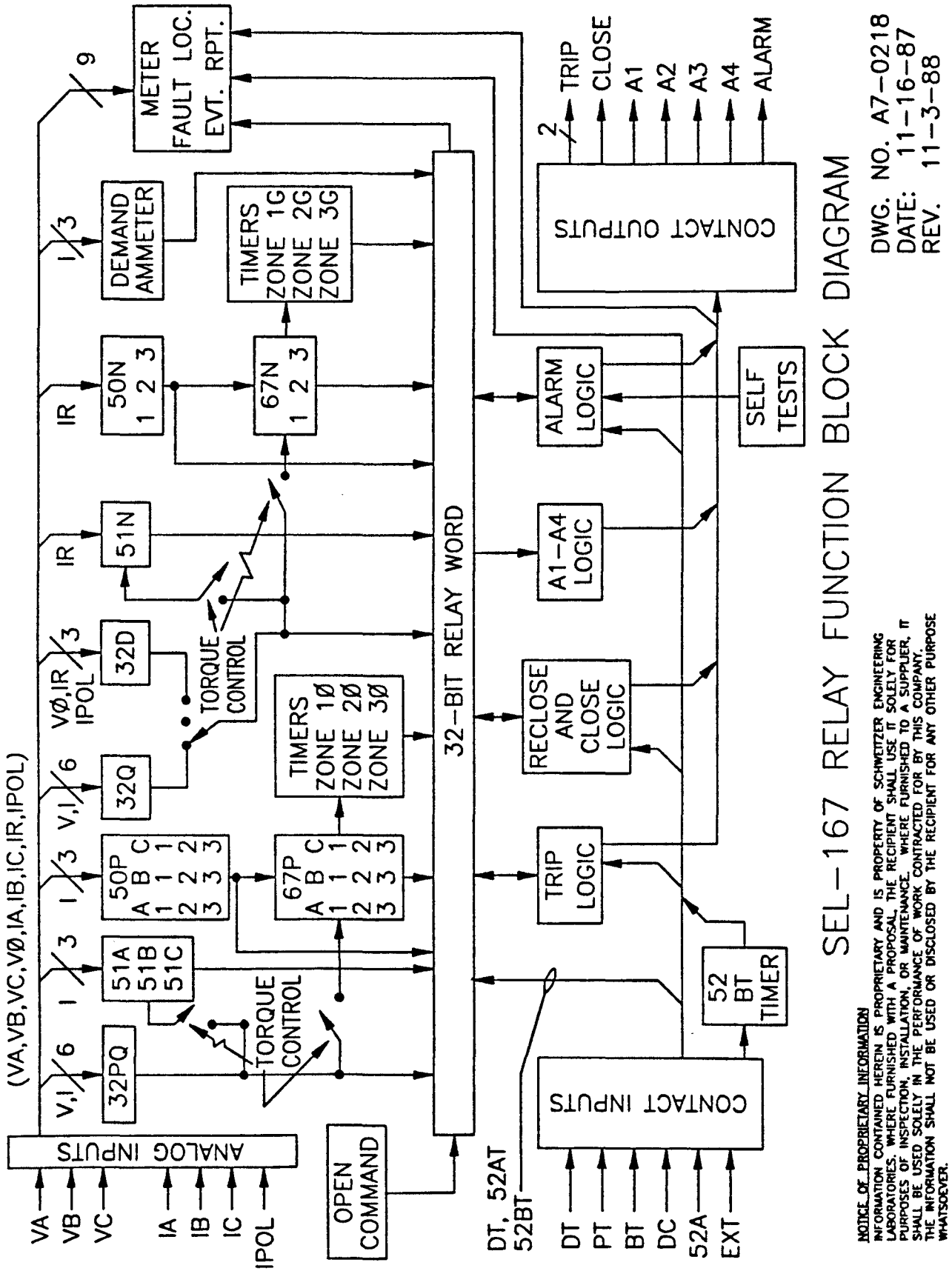
Each of the directionally-supervised outputs of the overcurrent elements drive timers. The Relay Word contains the instantaneous nondirectional outputs (50P1, 50P2, 50P3), the instantaneous directional outputs (67P1, 67P2, 67P3), and the definite-time delayed outputs (Z1PT, Z2PT, Z3PT). The direction of 67P3/Z3PT may be reversed. The directionality for all three elements may also be disabled (67NE=N, 67PE=N).

A time-overcurrent element (51P) with selectable curve shapes is provided. It may be directionally supervised if desired.

Ground Faults

Ground fault protection consists of three instantaneous residual-overcurrent elements (50N1, 50N2, 50N3) and a residual time-overcurrent element (51N).

Direction is determined by either a negative-sequence directional element or a dual-polarized zero-sequence element. Settings are provided to select either negative-sequence polarization or zero-sequence polarization of the ground overcurrent elements. To securely discriminate between forward and reverse-direction faults, the directional elements have a torque threshold which must be exceeded in either direction before the fault direction



SEL-167 RELAY FUNCTION BLOCK DIAGRAM

DWG. NO. A7-0218
DATE: 11-16-87
REV. 11-3-88

is declared. The directionally-supervised instantaneous elements are designated 67N1, 67N2, and 67N3. They drive timers whose outputs are Z1GT, Z2GT, and Z3GT.

The direction of 67N3/Z3GT may be reversed to assist in blocking schemes, weak-infeed schemes, and local bus protection for looped or double-feed circuits. Directionality may also be disabled for all three elements.

The curve shape of the time-overcurrent element is user-selectable. This element is either non-directional or forward-reaching, as enabled.

Overload Alarm or Protection

The demand ammeter feature of the SEL-167 relay has a programmable time constant and a settable threshold. When demand (maximum of the three phases) reaches the setpoint, a bit (DCTH) in the Relay Word is set. By programming a mask, this bit may be routed to one of the programmable outputs for an alarm to initiate tripping, or perform any other desired function. Since the demand interval (time constant) is settable, it may be programmed to match the time constant of a protected piece of apparatus, e.g. transformer, reactor or line.

Reclosing

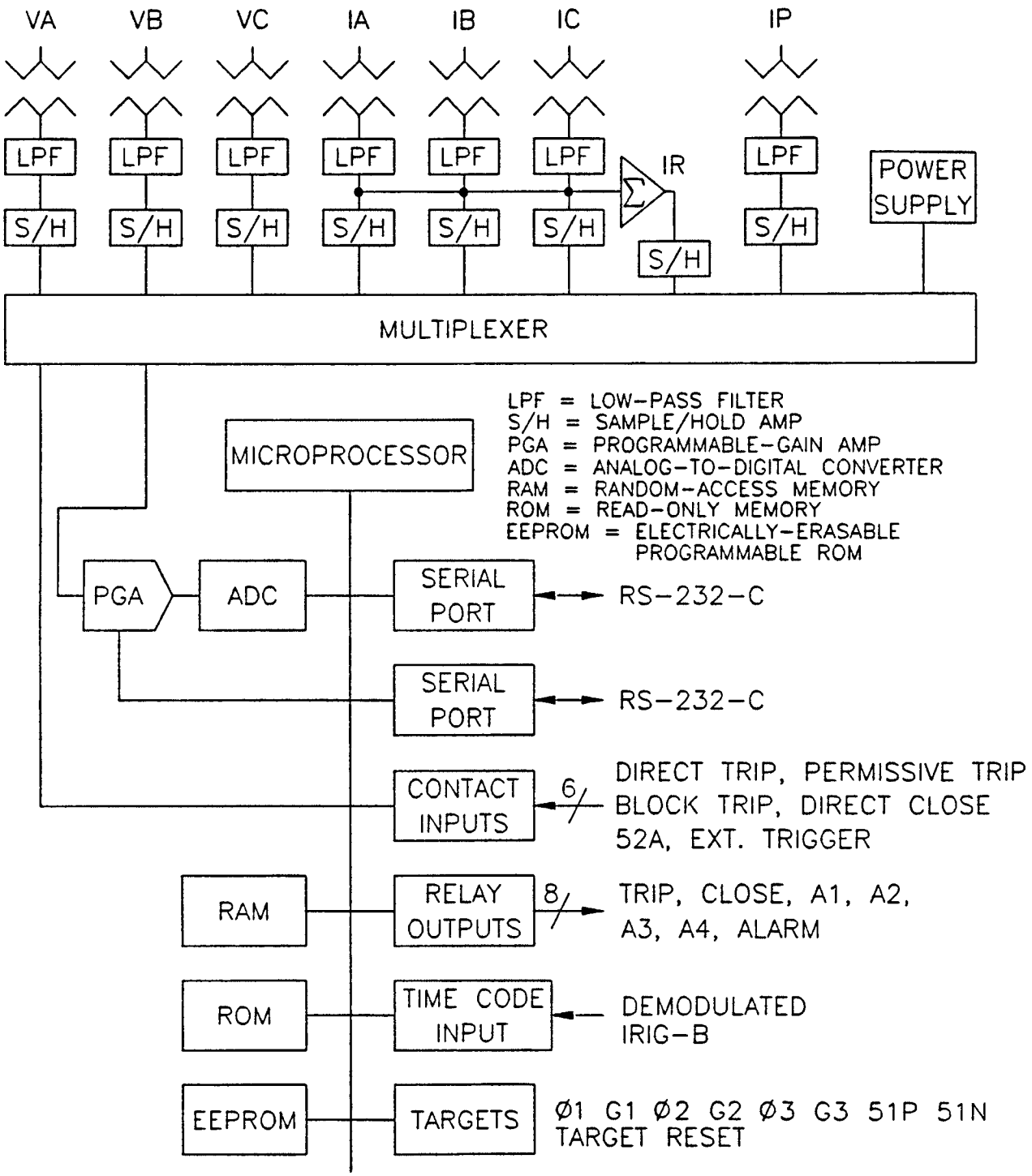
A three-shot reclosing relay is provided. Reclosing may be initiated or cancelled for any conditions recorded in the Relay Word and is accomplished by programming the Reclose Initiate and Reclose Cancel masks.

The Shot 1 (SH1) bit is included in the Relay Word for fuse saving schemes. The SH1 bit sets after the first reclose in a reclose sequence and remains asserted during the following reclose shots. You may program one of the four programmable output contacts with the SH1 bit. This programmable output may then be used to energize the Block Trip (BT) input of the SEL-167 relay. The elements in the SEL-167 MTB mask can then be programmed to be blocked from tripping during the next reclose attempts thus creating a fuse saving scheme.

HARDWARE DESCRIPTION

The SEL-167 HARDWARE BLOCK DIAGRAM illustrates the major parts of the relay. Current and voltage inputs are isolated by magnetic input transformers. The signals are low-pass filtered, sampled by sample/hold amplifiers, and multiplexed to a programmable-gain amplifier. Its output drives an analog-to-digital converter. This analog-input network gives the microcomputer measurements of the measurands four times per power-system cycle.

The microcomputer consists of an eight-bit microprocessor, ROM (read-only memory) for program storage, RAM (random-access memory) for data storage, and EEPROM (electrically-erasable programmable ROM) for storing the relay settings. The EEPROM saves settings even during power loss. Input/output (I/O) devices connected to the microcomputer bus provide for the control of the output relays, targets, and monitor inputs such as the state of the breaker 52A contact. Other I/O devices provide communications for setting, reporting fault



SEL-167 HARDWARE BLOCK DIAGRAM

DWG. NO. A7-0275
DATE: 04-22-88
REV: 05-16-90

location, and other purposes. The relay includes an input for time code which allows users to synchronize the internal time clock with an external source of time code.

Mechanical Features

The majority of the SEL-167 relay components are contained on a drawout assembly. This includes the main circuit board, the interface circuit board, and the switching power supply. The only components remaining in the relay housing are the rear panel board, which has only passive components, the transformer subchassis which mounts the transformers, and the transformer termination board.

SIGNAL PROCESSING

Phasor representations of the input quantities are desired, i.e., each input signal is represented by a Cartesian coordinate pair of numbers updated every one-fourth power system cycle. The phasor quantities are processed by relaying and fault-locating algorithms.

Digital Filters

The requirements for the digital filters include eliminating dc offsets introduced by the analog electronics, reducing the decaying exponential offset present on the current data following a fault, and passing the power system frequency information. The digital filters are simple, placing a minimum burden of computation on the microprocessor.

The relay employs a very simple and effective digital filter with the properties of a double-differentiator smoother. It requires only addition and subtraction of data samples. Let the latest four samples from one channel of information be X1, X2, X3, and X4. The filter is then defined by:

$$P = X1 - X2 - X3 + X4.$$

This filter has the desired property of eliminating dc offsets. You may verify this by setting all the samples to the same value and noting that the filter output is zero. The filter also eliminates ramps, as can be seen by setting the samples equal to 1, 2, 3, 4. Again, the output is zero.

A new value of P for each input is computed every one-fourth cycle. The latest value of P and the value of P one-fourth cycle earlier (renamed Q) form a Cartesian-coordinate pair representing the input signal as a phasor (P, Q). These representations are processed in the relay and fault-locating algorithms. They are also available as part of the system output in response to an event. This information can be used to construct phasor diagrams of the voltages and currents.

INITIAL CHECKOUT

The initial checkout of the SEL-167 relay is intended to familiarize you with the instrument and ensure that all functions are operational.

EQUIPMENT REQUIRED

The following equipment is necessary for initial checkout of the SEL-167 relay.

1. Computer or dumb terminal with RS-232-C serial interface.
2. Interconnecting cable between terminal and SEL-167 relay.
3. Source of control power.
4. Source of three-phase voltages and at least two currents.

CHECKOUT PROCEDURE

In the following procedure, you will use several of the SEL-167 relay commands. The COMMANDS AND SERIAL COMMUNICATIONS section provides full explanations of all commands. However, the following information should allow you to complete the checkout without referring to the detailed descriptions.

1. Inspect the instrument for physical damage such as dents or rattles.

2. Connect a computer terminal to PORT 2 on the rear panel of the SEL-167 relay. The terminal should be configured to 2400 baud, eight data bits, two stop bits, and no parity. Be sure your terminal is compatibly configured. The FUNCTIONAL DESCRIPTION section provides additional details concerning port configuration. Baud rate selection is described in the RS-232-C Jumpers subsection of JUMPER SELECTION in the INSTALLATION chapter.

3. Connect a frame ground to terminal 36 on the rear panel. Connect control power to terminals 37 and 38.

4. Turn on the power and push the target reset button. All eight target LED's should illuminate for a lamp test and to indicate no self test failures. If not, be sure that power is present and check the fuse or fuses.

The following message should appear on the terminal:

```
Example 69 kV Line                    Date: 1/1/90          Time: 01:01:01

SEL-167
=
```

The ALARM relay should pull in, holding its "b" contacts (terminals 27,28) open. If the relay pulls in but no message is received, check the terminal configuration. If neither occurs, turn off the power and refer to the TROUBLESHOOTING guide.

The equal sign is a prompt indicating that communications with the SEL-167 relay are at Access Level 0, the lowest of three access levels to the SEL-167 relay. The only command allowed at this level is ACCESS, which admits you to Access Level 1, as described below.

5. Type the command **ACCESS** and press **<ENTER>**. At the prompt, enter the password **OTTER** and press **<ENTER>**. The prompt = > should appear, indicating that you have established communications at Access Level 1.

6. The SEL-167 relay is shipped with demonstration settings which you may inspect using the SHOWSET command. Type **SHOWSET** and press **<ENTER>** to view these settings. The terminal should display the following:

```
=>SHOWSET

Settings for: Example 69 kV Line

R1    =49.83     X1    =56.32     R0    =56.07     X0    =143.07  LL   =60.00
CTR   =60.00     PTR   =600.00    MTA   =49.00     LOCAT =Y       DATC =15
DCTH  =120.00    79OI1 =40.00     79OI2 =60.00     79OI3 =80.00   79RS =240.00
51PP  =120.00    51PTD =1.00      51PC  =2         51PTC =N
50P1  =1158.00   50P2  =516.00    50P3  =210.00
Z1DP  =0.00      Z2DP  =160.00    Z3DP  =30.00
51NP  =30.00     51NTD =2.00      51NC  =2         51NTC =N
50N1  =1008.00   50N2  =450.00    50N3  =30.00
Z1DG  =0.00      Z2DG  =30.00     Z3DG  =10.00
52BT  =30        ZONE3 =R         67NE  =Y         67PE  =Y
32QE  =N         32VE  =Y         32IE  =Y
TIME1 =5         TIME2 =0         AUTO  =2         RINGS =3

Logic settings:

MTU  MPT  MTB  MTO  MA1  MA2  MA3  MA4  MRI  MRC
44   44   00   77   44   00   00   00   00   00
44   66   00   77   66   00   00   00   44   00
FF   FF   00   FF   FF   00   80   08   00   BB
30   00   00   30   00   01   00   00   00   30
```

A brief line-by-line description of the settings follows:

Line 1: Positive- and zero-sequence impedances of the transmission line (primary ohms) and line length (miles) for which the impedances are given.

Line 2: Current and voltage transformer ratios, maximum torque angle for the directional elements, fault locator enable, and demand ammeter time constant.

Line 3: Demand current threshold, three reclosing open interval delays and one reset delay.

Line 4: Phase time-overcurrent pickup, time dial, curve, and torque control by direction.

Line 5: Pickup settings for the three phase overcurrent elements.

Line 6: Zone 1, 2, and 3 time delays for the phase overcurrent elements.

Line 7: Residual time-overcurrent pickup, time dial, curve, and torque control enable.

Line 8: Zone 1, 2, and 3 residual instantaneous-overcurrent element pickup thresholds.

Line 9: Zone 1, 2, and 3 time delays for ground faults.

Line 10: 52B time delay, Zone 3 direction selection, and the enables for directionality of the ground and phase instantaneous elements.

Line 11: The enables for the negative-sequence directional, voltage polarized zero-sequence directional, and current polarized zero-sequence directional elements.

Line 12: PORT 1 and 2 timeouts, the autoport for automatically transmitted messages, and the number of rings after which the modem automatically answers.

A complete description of the settings appears under the SET command.

The description of the LOGIC command includes a detailed explanation of the logic settings. Each column in the logic settings display shows the masks for the Relay Word as follows:

Row 1, of any column:	DRP	50N1	50N2	50N3	DFP	50P1	50P2	50P3
Row 2, of any column:	DRG	67N1	67N2	67N3	DFG	67P1	67P2	67P3
Row 3, of any column:	51NT	Z1GT	Z2GT	Z3GT	51PT	Z1PT	Z2PT	Z3PT
Row 4, of any column:	ALRM	TRIP	TC	DT	52BT	SH1	TOCP	DCTH

Logic settings are shown in hexadecimal format. The SHOWSET command description in the COMMAND DESCRIPTIONS section includes a table and example of hexadecimal to binary conversion.

7. Turn the power off and connect a source of three-phase voltages to the SEL-167 relay at terminals 29 - 32. Apply 67 volts per phase (line-to-neutral) in positive-sequence. Wye-connect the two current sources to generate balanced positive-sequence currents. Connect A and B current sources to the dotted A and B current input terminals (1 and 2 respectively) of the SEL-167 relay. Connect the undotted A and B current

input terminals (7, 8) both to the undotted C current input terminal (9). Connect the dotted C current input terminal (3) to both the A and B current source returns. Set the A-phase current source to 1 ampere, at the same angle as the A-phase voltage. Set the B-phase current source to 1 ampere, at the same angle as the B-phase voltage.

8. Turn the relay power back on, execute the ACCESS command and enter the password **OTTER** again.

9. Use the METER command to measure voltages and currents. With applied voltages of 67 volts per phase and a potential transformer ratio of 600:1, the line to neutral voltages displayed should be 40.2 kV. With applied currents of 1.0 ampere per phase and a current transformer ratio of 60, the currents displayed should be 60 amperes. Further, all line-to-line quantities should be balanced, differing from the line-to-neutral measurements by a factor of 1.73.

10. Test the digital relay/fault locator with the voltages and currents listed in the following chart. They were obtained assuming a source impedance of 0.2 times the total 60-mile line impedance and single-end feed for faults at the indicated locations and types. The appendices provide a BASIC program which you may find helpful when computing test set settings.

LOCATION	TYPE	VA	VB	VC	IA	IB	IC	
9 miles	AG	28.71	76.59	68.45	19.18	0	0	V or A
		0	-124.5	129.3	-58.70			degs
	BC	67.00	41.72	41.72	0	22.05	22.05	V or A
		0	-143.4	143.4		-138.5	41.50	degs
36 miles	AG	50.25	71.14	67.41	8.39	0	0	V or A
		0	-122.1	124.1	-58.70			degs
	BC	67.00	54.92	54.92	0	9.64	9.64	V or A
		0	-127.6	127.6		-138.5	41.50	degs
54 miles	AG	54.80	70.00	67.26	6.10	0	0	V or A
		0	-121.6	123.0	-58.70			degs
	BC	67.00	58.10	58.10	0	7.01	7.01	V or A
		0	-125.2	125.2		-138.5	41.50	degs

The fault listings in the preceding chart should cause certain combinations of output relays to remain closed and front panel LEDs to remain illuminated as long as the fault condition persists. The following table shows the results.

LOCATION	TYPE	OUTPUT RELAYS	TARGET LEDs
9 miles	AG	TRIP, A1, A2, A3, A4	G1
9 miles	BC	TRIP, A1, A2, A4	P1
36 miles	AG	TRIP, A1, A2, A3, A4	51N
36 miles	BC	TRIP, A1, A2, A4	51P
54 miles	AG	TRIP, A1, A2, A3, A4	51N
54 miles	BC	TRIP, A1, A2, A4	51P

The output relay A1 at terminals (19, 20) is set to key permissive trip for any Zone 1 fault, directionally supervised Zone 2 fault, and time delayed trip element. From the table, output relay A1 should close for all of the faults.

The A2 output relay on terminals (21, 22) monitors the demand current threshold. Since the demand current exceeds the demand current threshold, the A2 output relay operates for all of the faults shown in the first table.

The A3 output relay on terminals (23, 24) monitors the residual time-overcurrent trip (51NT). Since the fault condition persists longer than the 51N time delay, the output relay A3 operates for any of the ground faults shown in the first table as determined by the settings.

The output relay A4 at terminals (25, 26) is set to monitor the phase time-overcurrent trip (51PT). The polyphase time-overcurrent relay element operates on the largest phase current magnitude. Therefore, the A4 output asserts for both phase and ground faults as shown in the table.

The LOGIC command section provides a detailed description of the programming of the output relays A1-A4 and six other logic masks (MRC, MRI, etc.).

The Zone 1 ground fault target (G1) illuminated for the ground fault at 9 miles because the Zone 1 ground overcurrent relay element caused the trip (with Z1DG set to zero or instantaneous trip for the example 69kV line). The displayed targets generally disclose the relay element that caused the trip to occur for the fault. The fault targets are automatically cleared by the next fault, before the new fault targets are presented.

Each fault generates a short event report. Type **EVENT 1** and press **<ENTER>** to display a full event report for the last fault. The report provides an eleven cycle record of the currents, voltages, relay element states, and states of all contact inputs and outputs. The twelve newest reports are saved.

This checkout procedure demonstrates only a few of the features of the SEL-167 relay. Study the FUNCTIONAL DESCRIPTION, COMMAND, and EVENT REPORT sections of this manual to obtain a complete understanding of the capabilities of the SEL-167 relay. For additional test procedures, refer to the appendices.

FUNCTIONAL DESCRIPTION

INTRODUCTION

This section describes all SEL-167 relay inputs and outputs, relay elements, and the logic equations which relate them.

It also describes the self tests and how they affect system operation.

INPUTS AND OUTPUTS

All connections to the SEL-167 relay are made on the rear panel. A rear-panel drawing is included in this manual.

Serial Interfaces

Connectors labeled PORT 1 and PORT 2 provide RS-232-C serial-data interfaces. PORT 1 is normally used for remote communications via a modem, while PORT 2 is used for local communications via a terminal.

The following table lists port pin assignments and signal definitions.

PIN	NAME	DESCRIPTION
2	TXD	Transmit data output
3	RTS	The SEL-167 relay asserts this line under normal conditions. When its received-data buffer is full, the line is deasserted, and asserts again when the buffer has sufficient room to receive more data. Connected devices should monitor RTS (usually with their CTS input) and stop transmission whenever the line deasserts. If transmission continues, data may be lost.
4	RXD	Receive data input
5	CTS	The SEL-167 relay monitors CTS, and transmits characters only if CTS is asserted.
6	+ 5 volts	
7	+12 volts	
8	-12 volts	
1,9	GND	Ground for ground wires and shields

Input Power

Terminals (37 and 38) should be connected to a source of control voltage. Polarity of dc power is unimportant. Power requirement is approximately 12 watts. Terminal 35 or 36 connects to the instrument frame, and should be wired to the relay rack ground reference.

Contact Inputs

Six input circuits are provided. They are listed below with terminal numbers in parentheses.

DIRECT TRIP	(39,40)	DIRECT CLOSE	(45,46)
PERMISSIVE TRIP	(41,42)	52A MONITOR	(47,48)
BLOCK TRIP	(43,44)	EXTERNAL TRIGGER	(49,50)

To assert an input, nominal control voltage is applied to the appropriate terminal pair. Polarity is unimportant. The following table shows input parameters.

LOGIC INPUT RATING	CONTACT INPUT RANGE	CURRENT AT NOMINAL VOLTAGE
48 Vdc	25 - 60 Vdc	6 mA
125 Vdc	60 - 200 Vdc	6 mA
250 Vdc	200 - 280 Vdc	6 mA

Input functions are explained below.

Direct Trip (DT):

Assertion of the DT input causes the TRIP output to close immediately and unconditionally if so enabled (see LOGIC MTU command). It also cancels any reclose initiation or reclose sequence if so enabled in the MRC mask (see the LOGIC MRC command) and triggers an event report. The TRIP output remains closed as long as the DT input is asserted and drops out about 0.5 cycle after the DT input deasserts or approximately 60 ms after the TRIP output first closed, whichever is later. Applications include reclose cancel, test trip and Direct Underreaching Transfer Trip (DUTT) schemes. The OPEN command has the same effect as the DT input.

Direct Close (DC):

The DC input causes the CLOSE output to close, as long as no trip condition is detected and the 52A input is not asserted. The CLOSE output stays closed until the 52A input asserts or until the reclosing relay reset interval expires, whichever occurs first. No event report is triggered. The CLOSE command has the same effect as the DC input.

Permissive Trip (PT):

The PT input is normally used in permissive transfer tripping schemes. When it asserts, an event is triggered and additional tripping conditions are allowed as selected in the logic setting procedure (see the LOGIC MPT command).

Block Trip (BT):

The BT input is normally used in blocking and fuse saving schemes. When it is not asserted, selected tripping conditions are allowed (see the LOGIC MTB command). This input also triggers an event report.

Circuit Breaker Monitor (52A):

The 52A input indicates the state of the breaker. The 52A is used by the tripping and closing functions and in the reclosing relay.

External Trigger for Event Report (ET):

An event report is triggered whenever the external trigger input is asserted. Asserting this input does not influence the protective functions in any way.

Relay Outputs

Seven output relays are provided. They are listed below with terminal numbers and contact types.

OUTPUT RELAY	TERMINAL NO.	CONTACT TYPE
TRIP	(13,14) (15,16)	a
CLOSE	(17,18)	a or b
A1	(19,20)	a or b
TRIPA	(21,22)	a or b
TRIPB	(23,24)	a or b
TRIPC	(25,26)	a or b
ALARM	(27,28)	a or b

All relay contacts are rated for circuit breaker tripping duty.

Three of the seven output relays perform fixed functions; the remaining four can be programmed with the LOGIC command.

TRIP Output:

This output closes for any number of user-selected conditions. The conditions are grouped as follows: unconditional, subject to PT input assertion, subject to the absence of BT input, and subject to the breaker being open. The TRIP output never closes for less than 60 ms. After this interval, it opens when the fault condition ceases and the breaker appears open as judged by the 52A input, or when the TARGET RESET button is pressed. The latter facilitates relay testing without using a breaker simulator.

CLOSE Output:

This output closes for reclose operations, assertion of the DC input, and in response to the CLOSE command. It opens when the 52A input is asserted or after the reclosing relay reset interval, whichever occurs first.

ALARM Output:

The ALARM output closes for the following conditions:

Three unsuccessful Level 1 access attempts: 1 second pulse
Any Level 2 access attempt: 1 second pulse
Self test failures: permanent contact closure or 1 second pulse, as directed by self test.

The ALARM output also closes momentarily when operators change settings or enter a date with a different year than the one currently stored in EEPROM (see the DATE command).

Programmable Outputs (A1, A2, A3, A4):

These four outputs may be assigned to any combination of the bits in the Relay Word.

Potential Inputs

The potential inputs should be driven from a set of three line potential transformers with their primaries connected in a grounded-wye configuration and their secondaries connected in four-wire wye. The relay contains a set of three input transformers connected in four-wire wye. Since the SEL-167 relay includes zero-sequence voltage polarization, it is necessary to connect the neutral input terminal to the star point of the PT secondaries.

Note that the SEL-167 relay determines the zero-sequence voltage from the three voltage inputs VA, VB, and VC, so a separate V0 input is not needed. The nominal voltage rating is 115 volts line-to-line or 67 volts line-to--neutral.

Terminal-number assignments for the potentials are:

Phase A	(29)
Phase B	(30)
Phase C	(31)
Neutral point	(32)

The PT secondary star point should be grounded only once, preferably at the PT location. A second ground of the neutral wiring causes ground potential differences to appear in the PT secondary measurements as a neutral shift.

Current Inputs

The rating of the input current transformers in the relay is 5 amperes nominal, 15 amperes continuous, and 500 amperes for one second.

Terminal-number assignments for the current circuits are:

IA-dot, IA	(1,7)	A-phase current
IB-dot, IB	(2,8)	B-phase current
IC-dot, IC	(3,9)	C-phase current
IP-dot, IP	(4,10)	residual polarizing current (if needed)

IRIG-B Input Description

The port labelled J201 / AUX INPUT is intended for the demodulated IRIG-B time code input. The pin definitions are shown below.

PIN	NAME	DESCRIPTION
2	IRIGIN HI	Positive IRIGB input
3	IRIGIN LOW	Negative IRIGB input
6	+5 *	
7	+12 *	
8	-12 *	
1,5,9	GND	Ground for ground wires and shields

* Consult the factory before using these power supply outputs.

The actual IRIG-B input circuit is a 56 ohm resistor in series with an optocoupler input diode. The input diode has a forward drop of about 1.5 volts. Driver circuits should be designed to put approximately 10 mA through the diode when "on".

The IRIG-B serial format consists of a one second long, 100 pulse code divided into fields. The SEL-167 relay decodes the second, minute, hour and day fields.

When IRIG-B data acquisition is activated either manually (with the IRIG command) or automatically, two consecutive frames are taken. The older frame is updated by one second and the two frames are compared. If they do not agree, the data are considered erroneous and discarded.

Automatic execution is invoked about once every five minutes, except near midnight on New Year's Eve. At this time IRIG-B data acquisition is halted so the system clock may implement the year change without interference from the IRIG-B clock.

This port accepts the demodulated version of the IRIG-B time code. An IRIG-B demodulator (SEL-IDM) is available from SEL to convert a modulated IRIG-B into eleven sources of demodulated IRIG-B.

DEFINITION OF LOGIC VARIABLES

The output relay states of the SEL-167 relay depend on the following:

relay elements
contact-monitoring inputs
setting parameters
logic programming
commands received over communications link
status of self tests

Since so many binary variables are involved, we define the functioning with Boolean logic equations. The logic variables involved are defined in the following section. Elements available in the Relay Word appear in boldface.

LOGIC DESCRIPTION

Relay Elements

Single-phase overcurrent relays	50A1 50B1 50C1	Nondirectional
	50A2 50B2 50C2	Nondirectional
	50A3 50B3 50C3	Nondirectional
Polyphase time-overcurrent relay	(driven by maximum phase current)	
pickup	51PP	Torque Control or nondirectional
trip	**51PT**	Torque Control or nondirectional
Residual time-overcurrent relay		
pickup	51NP	Torque Control or nondirectional
trip	**51NT**	Torque Control or nondirectional
Residual instantaneous-overcurrent	**50N1**	Nondirectional
Residual instantaneous-overcurrent	**50N2**	Nondirectional
Residual instantaneous-overcurrent	**50N3**	Nondirectional
Phase directional	32PQ	32PQF=forward; 32PQR=reverse
Negative-sequence directional	32Q	32QF=forward; 32QR=reverse
Zero-sequence dual pol. directional	32D	32DF=forward; 32DR=reverse

NOTE: The 32D is equivalent to 32V with 32VE enabled and 32IE disabled. The 32D is equivalent to 32I with 32IE enabled and 32VE disabled. The 32D is dual polarized when both 32VE and 32IE are enabled.

Timers

Z1GTMR	Zone 1 ground timer timeout operated by **67N1**	(Z1DG setting)
Z2GTMR	Zone 2 ground timer timeout operated by **67N2**	(Z2DG setting)
Z3GTMR	Zone 3 ground timer timeout operated by **67N3**	(Z3DG setting)
Z1PTMR	Zone 1 phase timer timeout operated by **67P1**	(Z1DP setting)
Z2PTMR	Zone 2 phase timer timeout operated by **67P2**	(Z2DP setting)
Z3PTMR	Zone 3 phase timer timeout operated by **67P3**	(Z3DP setting)
52BT	Time delayed inverse of 52A	(**52BT** setting)
79OI1	Reclosing relay first open interval expired	(79OI1 setting)
79OI2	Reclosing relay second open interval expired	(79OI2 setting)
79OI3	Reclosing relay third open interval expired	(79OI3 setting)
79RS	Reclosing relay reset interval timer expired	(79RS setting)

Enables from setting procedure

ZONE3 = F	Zone 3 is forward
ZONE3 = R	Zone 3 is reverse
32QE	Enables 32Q
32VE	Enables voltage polarization of 32D
32IE	Enables current polarization of 32D
67NE	Enables directional torque control for **67N1**, **67N2** and **67N3**
67PE	Enables directional torque control for **67P1**, **67P2** and **67P3**
51NTC	Selects torque control for 51N
51PTC	Selects torque control for 51P

Contact Inputs

DT	Direct trip
PT	Permissive transfer trip
BT	Block trip
DC	Direct close
52	Circuit breaker monitor
EXT	External trigger for event report

Contact Outputs

TRIP	Circuit breaker trip
CLOSE	Circuit breaker close
A1	Programmable output 1
A2	Programmable output 2
A3	Programmable output 3
A4	Programmable output 4
ALARM	System alarm

INTERMEDIATE LOGIC

The logic equations below represent combinations of the relay elements and other conditions. In the following equations the "*" indicates logical "and", while the "+" indicates logical "or". Elements available in the Relay Word appear in boldface.

50P3 = 50A3 + 50B3 + 50C3	Zone 3 phase fault
50P2 = 50A2 + 50B2 + 50C2	Zone 2 phase fault
50P1 = 50A1 + 50B1 + 50C1	Zone 1 phase fault
GF = 51NP + **50N1** + **50N2** + **50N3**	Ground fault
PF = 51PP + **50P1** + **50P2** + **50P3**	Phase fault
DFP = 32PQF * PF	Phase forward direction
DRP = 32PQR * PF	Phase reverse direction
D3P = **DFP** if ZONE3 is forward	
D3P = **DRP** if ZONE3 is reverse	
67P3 = [D3P + NOT(67PE)] * **50P3**	Zone 3 directional phase overcurrent element, reversible
67P2 = [DFP + NOT(67PE)] * **50P2**	Zone 2 directional phase overcurrent element
67P1 = [DFP + NOT(67PE)] * **50P1**	Zone 1 directional phase overcurrent element
DFG = 32QF * 32QE * (PF + GF) + 32DF * (32IE + 32VE) * GF + NOT(32QE + 32IE + 32VE)	Ground forward direction
DRG = 32QR * 32QE * (PF + GF) + 32DR * (32IE + 32VE) * GF	Ground reverse direction
D3G = **DFG** if ZONE3 is forward	
D3G = **DRG** if ZONE3 is reverse	

67N3 = [D3G + NOT(67NE)] * **50N3**	Zone 3 directional ground-overcurrent element, reversible
67N2 = [DFG + NOT(67NE)] * **50N2**	Zone 2 directional ground-overcurrent element
67N1 = [DFG + NOT(67NE)] * **50N1**	Zone 1 directional ground-overcurrent element
Z3PT = **67P3** * Z3PTMR	Zone 3 timeout-phase
Z2PT = **67P2** * Z2PTMR	Zone 2 timeout-phase
Z1PT = **67P1** * Z1PTMR	Zone 1 timeout-phase
Z3GT = **67N3** * Z3GTMR	Zone 3 timeout-ground
Z2GT = **67N2** * Z2GTMR	Zone 2 timeout-ground
Z1GT = **67N1** * Z1GTMR	Zone 1 timeout-ground

RELAY WORD

Relay elements and intermediate logic results are represented in a 32-bit Relay Word (grouped into four 8-bit words). The user selects bits in this word to perform the desired functions for controlling outputs and initiating or cancelling reclose. The selected bits are stored in masks for each function. You can program the bits in these masks with the LOGIC command.

RELAY WORD

DRP	50N1	50N2	50N3	DFP	50P1	50P2	50P3
DRG	67N1	67N2	67N3	DFG	67P1	67P2	67P3
51NT	Z1GT	Z2GT	Z3GT	51PT	Z1PT	Z2PT	Z3PT
ALRM	TRIP	TC	DT	52BT	SH1	TOCP	DCTH

The following Relay Word Bit Summary Table explains the meaning of each bit in the Relay Word.

RELAY WORD BIT SUMMARY TABLE

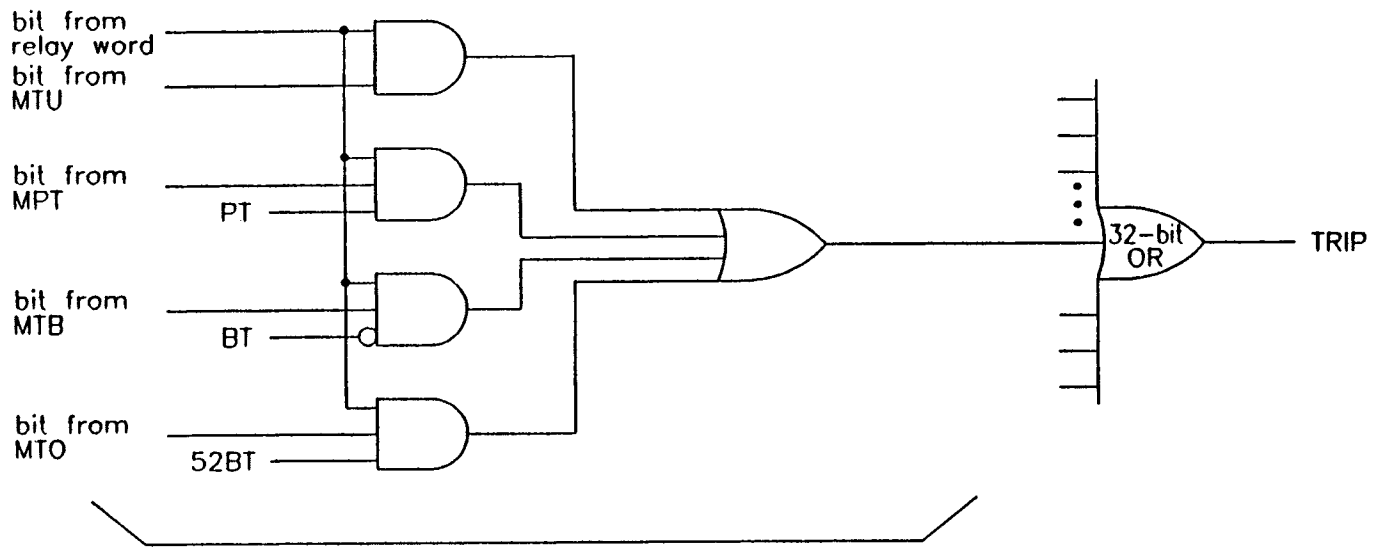
DRP - Direction reverse--phase fault
50N1 - Residual instantaneous-overcurrent element (nondirectional)
50N2 - Residual instantaneous-overcurrent element (nondirectional)
50N3 - Residual instantaneous-overcurrent element (nondirectional)
DFP - Direction forward--phase fault
50P1 - Zone 1 phase instantaneous-overcurrent element (nondirectional)
50P2 - Zone 2 phase instantaneous-overcurrent element (nondirectional)
50P3 - Zone 3 phase instantaneous-overcurrent element (nondirectional)

DRG - Direction reverse--ground fault
67N1 - Zone 1 ground directional overcurrent element (directional as enabled)
67N2 - Zone 2 ground directional overcurrent element (directional as enabled)
67N3 - Zone 3 ground directional overcurrent element (directional as enabled)
DFG - Direction forward--ground fault
67P1 - Zone 1 phase directional overcurrent element (directional as enabled)
67P2 - Zone 2 phase directional overcurrent element (directional as enabled)
67P3 - Zone 3 phase directional overcurrent element (directional as enabled)

51NT - Ground time-overcurrent trip (directional as enabled)
Z1GT - Zone 1 timeout-ground
Z2GT - Zone 2 timeout-ground
Z3GT - Zone 3 timeout-ground
51PT - Phase time-overcurrent trip (directional as enabled)
Z1PT - Zone 1 timeout-phase
Z2PT - Zone 2 timeout-phase
Z3PT - Zone 3 timeout-phase

ALRM - System alarm
TRIP - Circuit breaker trip
TC - Trip (OPEN) command
DT - Direct trip from **DT** input
52BT - Time delayed inverse of 52A
SH1 - Shot 1 reclosing detector
TOCP - Time-overcurrent pickup indicator (51PP + 51NP)
DCTH - Demand current threshold exceeded

The use of the Relay Word and programmable masks provides application flexibility without rewiring panels or changing jumpers on circuit boards.



SEL-167 PROGRAMMABLE TRIP LOGIC DIAGRAM

DWG. NO. A7-0188
DATE: 08-06-87

OUTPUT EQUATIONS

The logic for controlling the TRIP, A1, A2, A3, and A4 output relays is programmable for flexibility and testing. The logic is programmed by setting masks for various conditions applied to the general Relay Word.

The general form for each output equation follows:

Let R = Relay Word

MTU = mask for trip (unconditional)
MPT = mask for trip (permissive trip)
MTB = mask for trip (with no blocking)
MTO = mask for trip (with breaker open)

then: **TRIP** = R * MTU
+ R * MPT * PT
+ R * MTB * NOT (BT)
+ R * MTO * **52BT**

close **TRIP** contact = **TRIP**
open **TRIP** contact = NOT (**TRIP**) * NOT(52A + TARGET RESET button pushed) * (60 ms minimum **TRIP**)
close CLOSE contact = (DC + 79OI1 + 79OI2 + 79OI3 + CLOSE command) * NOT (52A)
open CLOSE contact = NOT (CLOSE) + 79RS

A1 = R * MA1
A2 = R * MA2
A3 = R * MA3
A4 = R * MA4

The "*" symbol indicates logical "and", while the "+" indicates logical "or".

RECLOSING RELAY

The reclosing relay provides up to three shots of automatic reclosing for selectable fault types and relay elements contained in the 32-bit Relay Word. The programmable logic provides access to the internally derived reclose initiate and cancel signals. The relay also accepts either external initiation or cancellation of reclosing. The three open intervals and the reset timer are individually settable through the SET command.

To provide flexibility in applying the SEL-167 relay to various reclosing schemes, the conditions for reclose initiation and cancellation are selected similarly to the output relay programming:

RI = R * MRI MRI selects reclose initiate conditions from the Relay Word
RC = R * MRC MRC selects reclose cancel conditions from the Relay Word

where MRI is the mask for reclose initiation, and MRC is the mask for reclose cancellation.

The open intervals do not begin until the TRIP output deasserts. Since the TRIP output never asserts for less than 60 ms, the open interval may start several milliseconds after the fault has actually cleared and the breaker opened.

Reclose is automatically cancelled when the circuit breaker is observed to trip with no fault condition present or for faults during the open interval of any shot.

TARGETS

The front panel targets illuminate for the conditions shown in the table.

TARGET LED	CONDITIONS FOR ILLUMINATION
PH1	Zone 1 phase involvement
G1	Zone 1 ground involvement
PH2	Zone 2 phase involvement
G2	Zone 2 ground involvement
PH3	Zone 3 phase involvement
G3	Zone 3 ground involvement
51P	Phase time-overcurrent involvement
51N	Residual time-overcurrent involvement

The targets display the latest relay element condition at the time of tripping. For example, zone targets illuminate if the current setting for that zone of protection is exceeded when tripping occurs. If a new fault occurs, the targets show the new fault.

To clear the targets, press the TARGET RESET button. All eight indicators illuminate for approximately one second as a lamp test. If they do not, the relay is disabled due to a self test failure. After a new fault occurs, the targets are cleared before the new fault targets are presented, so targets show the most recent fault. Pressing the TARGET RESET button unlatches the TRIP output from the 52A input. This feature is useful during relay testing and minimizes the risk of installing the relay with the TRIP output asserted.

SELF TESTS

The SEL-167 relay runs a variety of self tests to ensure continuous reliable operation. This section describes each test and the steps taken if a test fails. Some tests have warning and failure states, while others, such as the A/D test, only have failure states. The relay generates a status report after any change in self test status.

The ALARM contacts close after any self test fails. Failures that disable the control functions also place the output relay driver port in an input mode so no "a" contact outputs may be asserted. All self tests are run on power up before the relay is enabled or prior to enabling the relay after the setting procedure is used. Afterward, all self tests are run every few minutes.

Offset

The offset voltage of each analog input electronics channel is measured and compared against fixed limits. The relay issues a warning when the offset is greater than 50 millivolts in any channel. A failure is declared when the offset exceeds 75 millivolts. Use the STATUS command to display the offset levels of all channels.

Power Supply

The power supply voltages are limit-checked. The following table summarizes voltage limits.

SUPPLY	WARNING THRESHOLDS		FAILURE THRESHOLDS	
+5	5.3	4.7	5.4	4.6
+15	15.8	14.2	16.2	13.8
-15	-15.8	-14.2	-16.2	-13.8

The STATUS command response is transmitted for any failure or warning. If the +5 volt supply fails, all output relays are de-energized and blocked from operation. A failure of the ±15 volt supplies disables protective relay functions but not control functions. The ALARM relay remains closed for a power supply failure.

Random-Access Memory

The random-access memory (RAM) is periodically checked to ensure that each byte can be written to and read from correctly. There is no warning state for this test. If a problem is detected, the relay transmits a STATUS command message. This message includes the socket designation of the affected RAM IC. Protective and control functions are disabled for a RAM failure and the ALARM output relay contacts close.

Read-Only Memory

The read-only memory (ROM) is periodically tested by computing a checksum. If the computed value does not agree with the stored value, a ROM failure is declared. The STATUS command response is transmitted, all protective and control functions are disabled, and the ALARM relay contacts close.

Analog-to-Digital Converter

The analog-to-digital converter (ADC) changes voltage signals derived from the power system voltages and currents into numbers for processing by the microcomputer. The ADC test verifies converter function by checking its conversion time. If the conversion time is excessive or a conversion is started and never finishes, the test fails. There is no warning state for this test. Failure of the ADC disables the protective functions, but control functions are retained. The STATUS command response is transmitted and the ALARM relay contacts close if this test fails.

Master Offset

The master offset (MOF) test is a check of the offset in the multiplexer/analog to digital converter circuit. A grounded input is selected and sampled for dc offset. Warning threshold is 50 millivolts, failure threshold is 75 millivolts. A failure will pulse the ALARM contact closed for one second.

Settings

Two images of the system settings are stored in nonvolatile memory. These are compared when the SEL-167 relay is initially set and periodically thereafter. Should the images disagree, the setting test fails and all protective and control functions are disabled. The relay transmits a STATUS message to indicate the failed test. The ALARM relay remains closed for a setting failure.

SETTING PROCEDURE

You may enter the settings for the SEL-167 relay with the SET and LOGIC commands via serial interface PORT 1 or PORT 2. The settings are stored in nonvolatile memory, so they are retained when the power is off.

The SET and LOGIC command descriptions explain how to enter settings.

EVENT REPORT

The SEL-167 relay records an eleven cycle event report following any of these elements picking up:

67N1	67P1	51N
67N2	67P2	51P
67N3	67P3	

Event reports are also recorded due to assertion of the following inputs and execution of the following commands:

External Trigger input	Permissive Trip input
Direct Trip input	Block Trip input
OPEN command	TRIGGER command

A second report is triggered for the same fault if the trip occurs after the first report expires, so the beginning and end of each fault for which the relay trips is recorded. A second event report is not provided, however, if the TRIP output first asserts at or less than eleven cycles after the first report is triggered. (Note that reports are triggered at the 16th quarter cycle of data.)

Timing of the triggering instant is recorded to the nearest quarter-cycle, so that the duration of long faults can be computed from the time the first report is triggered by the fault, and the time the second report is triggered by the trip. The reported event time corresponds to the 16th quarter cycle of the event report in all cases. The event report contains voltages, currents, system settings, and other information. It is described in detail in the EVENT REPORTING section.

Execution of the CLOSE command does not trigger an event. Direct close, by asserting the DIRECT CLOSE input, does not trigger an event.

The twelve most recent event reports are stored in memory and may be retrieved using the EVENT command. A short history of the twelve most recent events is available using the HISTORY command.

FAULT LOCATOR

The SEL-167 relay fault locator is automatically triggered by any of several events. These events include pickup of certain relay elements, assertion of certain contact inputs or outputs, and user-entered commands. However, the fault locator can be either enabled or disabled with the LOCAT setting in the setting procedure.

Specifically, the triggering events are:

(1) RELAY ELEMENTS (high-level trigger)
Ground overcurrent Zones 1, 2, or 3 (67N1, 67N2, 67N3)
Phase overcurrent Zones 1, 2, or 3 (67P1, 67P2, 67P3)
Ground time-overcurrent 51N pickup
Phase time-overcurrent 51P pickup

(2) CONTACT INPUTS (rising edge trigger)
External Trigger
Direct Trip
Permissive Trip
Block Trip

(3) CONTACT OUTPUTS (rising edge trigger)
Trip

(4) USER ENTERED COMMANDS (rising edge trigger)
TRIGGER
OPEN

Note that the fault locator is triggered by the relay elements in a level sensitive manner. That is, additional event reports are not generated when additional relay elements pick up. Only the first relay element of any contiguous sequence triggers an event report.

Furthermore, all triggering relay elements must drop out for at least four cycles before they may initiate another event report. (This helps eliminate triggering multiple records for boundary faults.)

All other triggering events are rising-edge sensitive, meaning that for these events, additional reports are generated even while any or all relay elements remain picked up. This strategy permits, for example, the recording of fault clearing even when it occurs long after the initial event report is completed.

The fault location is always determined for event records in which any triggering relay elements are picked up, providing they are not picked up in the first seven rows of prefault data, or only in the last five rows of the event report. Furthermore, whenever the locator is able to determine the fault location, the corresponding record is labeled according to fault type, regardless of what actually triggered the event report. On the other hand, event records taken when no triggering relay elements are picked up are labeled as follows:

"EXT" for reports triggered externally via input contacts or by the "TRIGGER" command

or

"TRIP" for reports triggered by the assertion of the "TRIP" output contact.

The actual fault location algorithm is composed of two steps. First the fault type must be determined, and then the location calculated.

For the event reports, the fault type is determined largely independently of the relay element operations. Only the indicated zone is determined by relay elements, whereas the involved phases are determined by fault current comparison. (This is different from the TARGET data, which is completely derived from relay element operations.)

The compared currents are taken from the two rows at the middle of the stored fault data. If the uncompensated current magnitudes are in large ratios between phases (4:1 or more), then the fault type becomes immediately apparent as single- or two-phase. If not, the same current is load compensated by the two corresponding prefault current rows in the first cycle of the event report. If these fault current component magnitudes are in moderate ratios (1.5:1 or more), then the fault type is taken as single- or two-phase, or if the ratios are all less than 1.5, then the fault type is taken as three-phase. The explicit fault classification logic is as follows, where "I" values are uncompensated midfault currents, and "If" values are midfault currents compensated for load, yielding true fault current components:

```
      IF ( Imax  >   4 x Imed  ) THEN Single-phase
ELSE IF ( Imed  >   4 x Imin  ) THEN Two-phase
ELSE IF ( Ifmax > 1.5 x Ifmed ) THEN Single-phase
ELSE IF ( Ifmed > 1.5 x Ifmin ) THEN Two-phase
ELSE IF (  none of the above  ) THEN Three-phase.
```

This algorithm is largely immune to load and system grounding variations.

Once the fault type is determined, the fault locator employs the Takagi algorithm to locate the fault. Using both prefault and fault data, it compensates for the errors introduced by fault resistance in the presence of load flow. On the other hand, if no prefault data are provided by the event record, the SEL-167 relay gives a location based on a simple reactance measurement.

The fault locator depends on accurate transmission line parameters and instrument transformer ratios. Pay special attention to these potential sources of difficulty:

Instrument transformer ratio errors due to overburden by other devices
Capacitive potential transformer capacitor value
Transmission line parameter errors

Although the fault-location computation takes several seconds, faults in quick succession, such as occur in a reclosing sequence, are handled. This is because the fault data are stored, and subsequently processed in turn. As an example, suppose three faults occur within a few seconds. The data from them are stored as they occur. The fault-location computations begin with the first (oldest) fault and proceed until all three faults are processed. Each of the summary event reports is transmitted as soon as the corresponding fault location is available.

Shunt capacitance of the transmission line is not taken into account. The capacitance causes the fault location to appear more remote by, approximately, a factor of 1/cos(bL), where bL is the line length in radians at 60 Hz. One wavelength at 60 Hz is 3100 miles. For example, the line length of a 100-mile line in radians is calculated:

$$(100/3100) * 2 * 3.14159 = 0.2027 \text{ radians.}$$

The indication neglecting capacitance is about cos (0.2027) = 0.98 times the actual location, or about 2 miles short for a fault at the far end of a 100-mile line.

When compensation using shunt reactors is employed, and when the measured current equals the reactor current plus the line current, the shunt reactors reduce the errors due to neglecting the shunt capacitance of the transmission line.

DIRECTIONAL ELEMENTS

The SEL-167 relay contains three directional elements, applied as shown below:

FAULT TYPE	CRITERION	DIRECTIONAL ELEMENT
ABC AB, BC, CA, ABG, BCG, CAG	50A3+50B3+50C3	phase directional (32PQ)
AG, BG, CG	Depends on 32VE, 32IE, and 32QE	zero-sequence or negative-sequence settings only

The directional elements are phasor-product derived. For the negative-sequence element, the product is negative-sequence voltage times negative-sequence current, adjusted by the maximum torque angle (MTA) setting.

For the zero-sequence element, the product is the residual current adjusted by the MTA setting times the sum of the residual voltage plus polarizing current shifted in phase by the MTA setting.

The phase directional element is the positive-sequence voltage (eight cycles of memory polarization) times the positive-sequence current minus four times the negative-sequence voltage times the negative-sequence current, adjusted by the MTA setting.

TIME-OVERCURRENT ELEMENTS AND CURVES

The 51N and 51P time-overcurrent elements provide directional-forward or nondirectional protection. The trip (51NT and 51PT) states for both elements are available in the Relay Word for programming into any masks. The TOCP (time-overcurrent pickup) bit in the Relay Word is formed by either the 51N pickup or 51P pickup or both (51NP + 51PP).

You can select the time dial and the curve shape with the setting procedure. Four curve shapes are available. The curves and equations are provided at the end of this section.

The 51N and 51P characteristic is formed by a recursive sum of the magnitude or magnitude-squared of the residual current for the 51N or maximum phase current for the 51P, adjusted by the pickup setting for the appropriate element.

The time dial setting determines the limit the recursive sum must reach for a trip.

TIME-OVERCURRENT CURVE EQUATIONS

Let t = operating time in seconds,
TD = time dial setting,
M = multiples of pickup.

Curve 1 -- Moderately Inverse

$$t_M = TD \left[0.157 + \frac{0.668}{M-1} \right]$$

Curve 2 -- Inverse

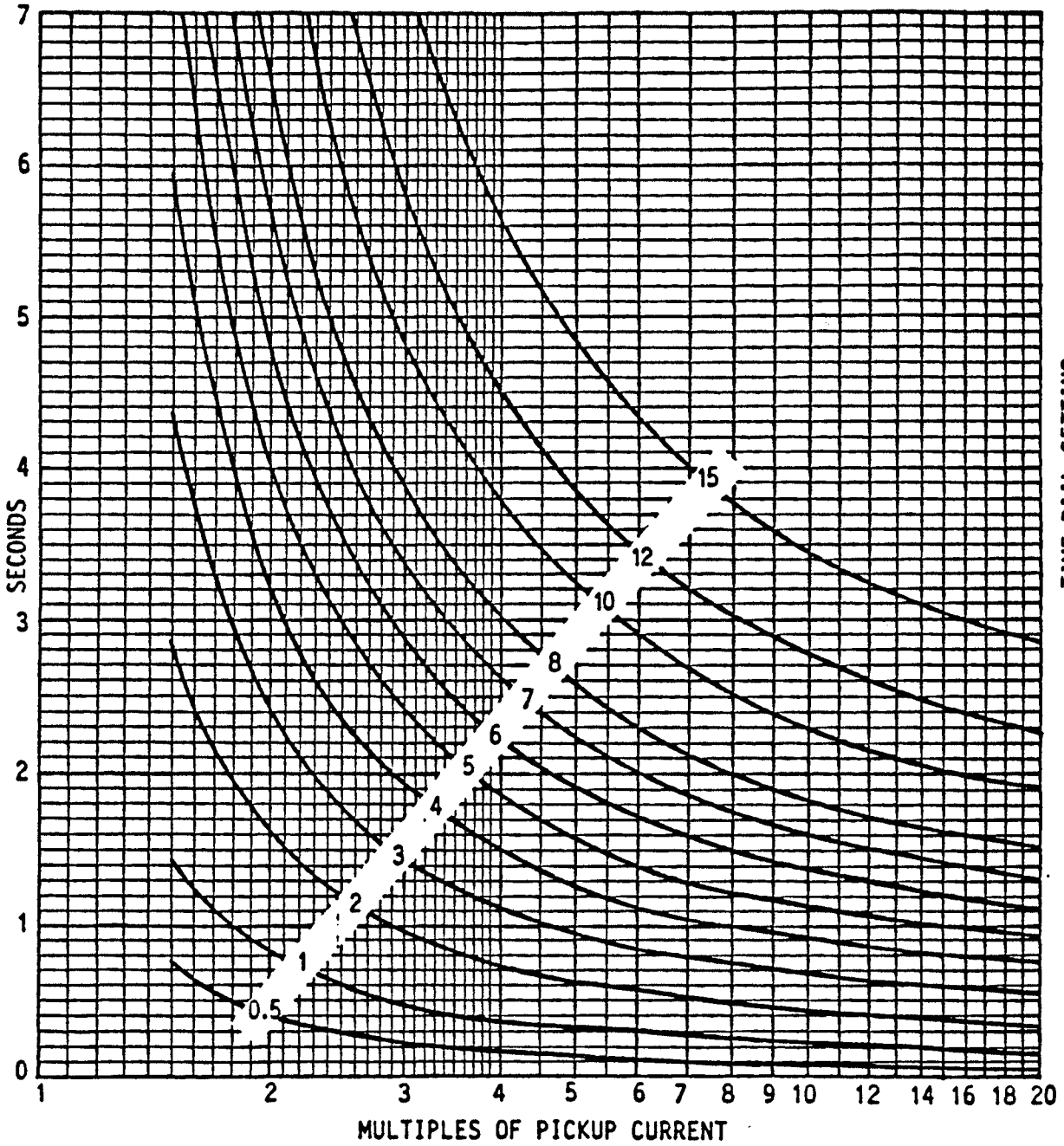
$$t_M = TD \left[0.180 + \frac{5.95}{M^2-1} \right]$$

Curve 3 -- Very Inverse

$$t_M = TD \left[0.0963 + \frac{3.88}{M^2-1} \right]$$

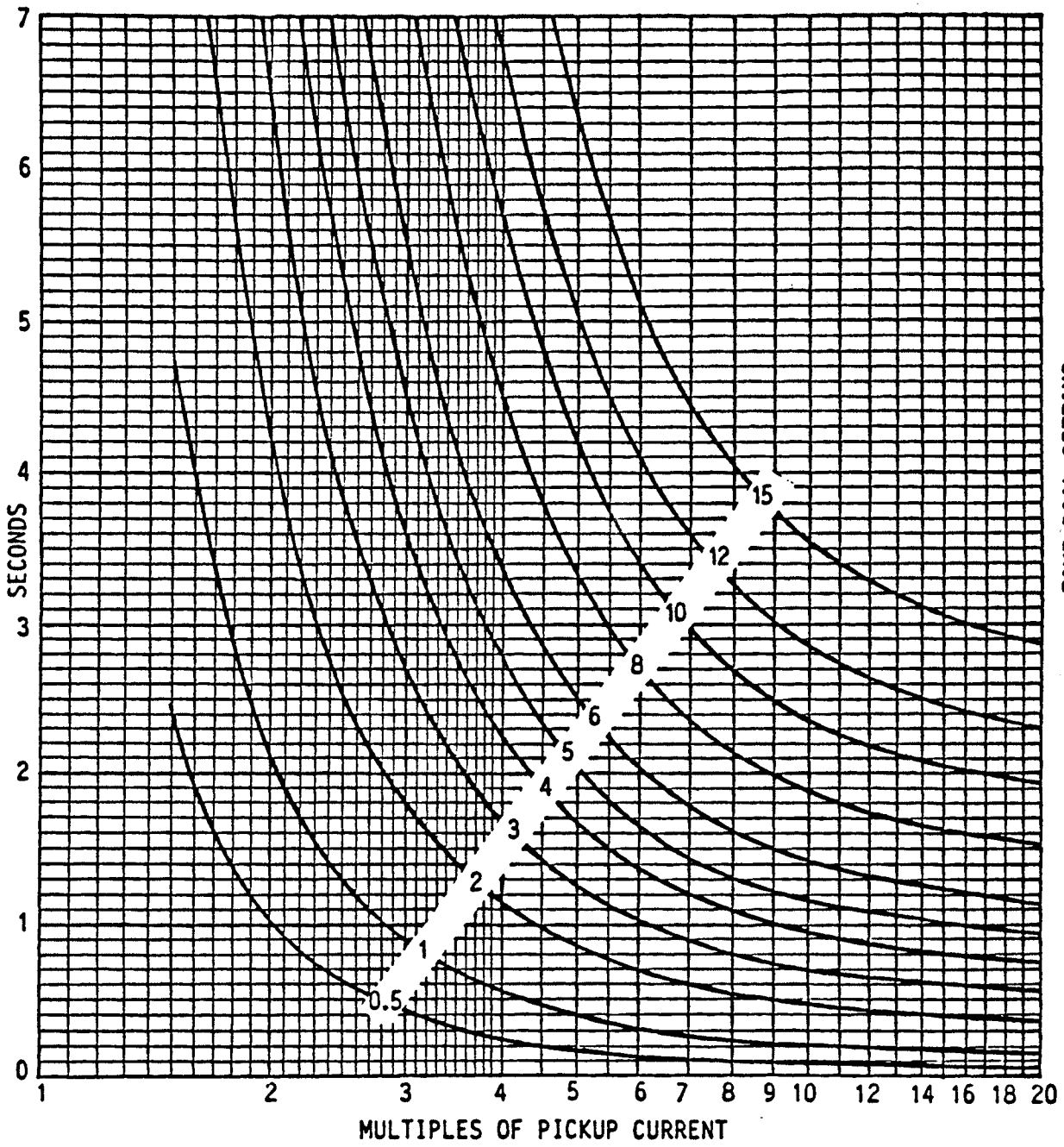
Curve 4 -- Extremely Inverse

$$t_M = TD \left[0.0352 + \frac{5.67}{M^2-1} \right]$$



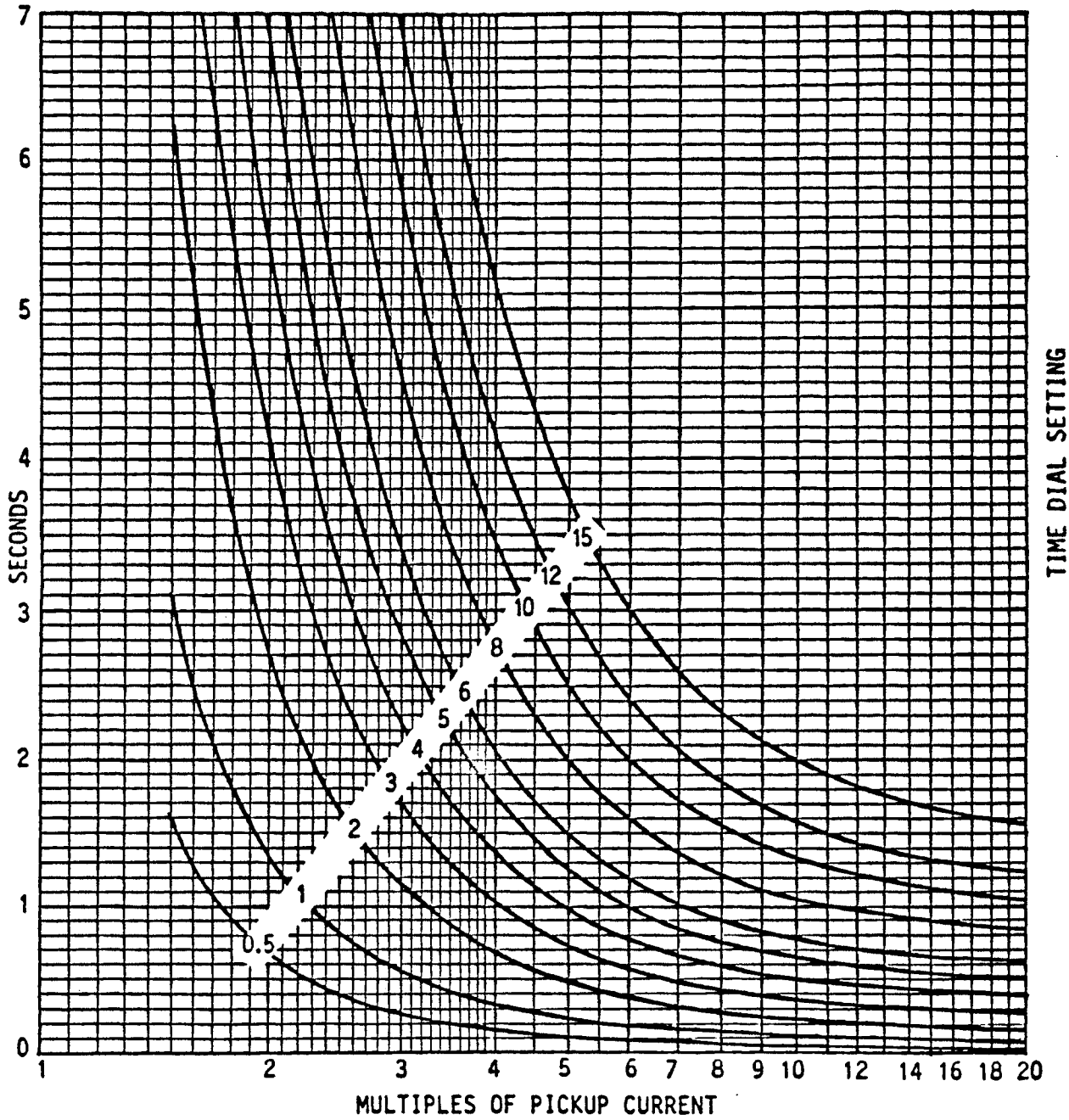
SEL-167 RESIDUAL OR PHASE TIME-OVERCURRENT ELEMENT (51N OR 51P)
MODERATELY INVERSE TIME CHARACTERISTIC (CURVE INDEX 1)

DWG. NO. A7-0242
DATE: 02-26-88



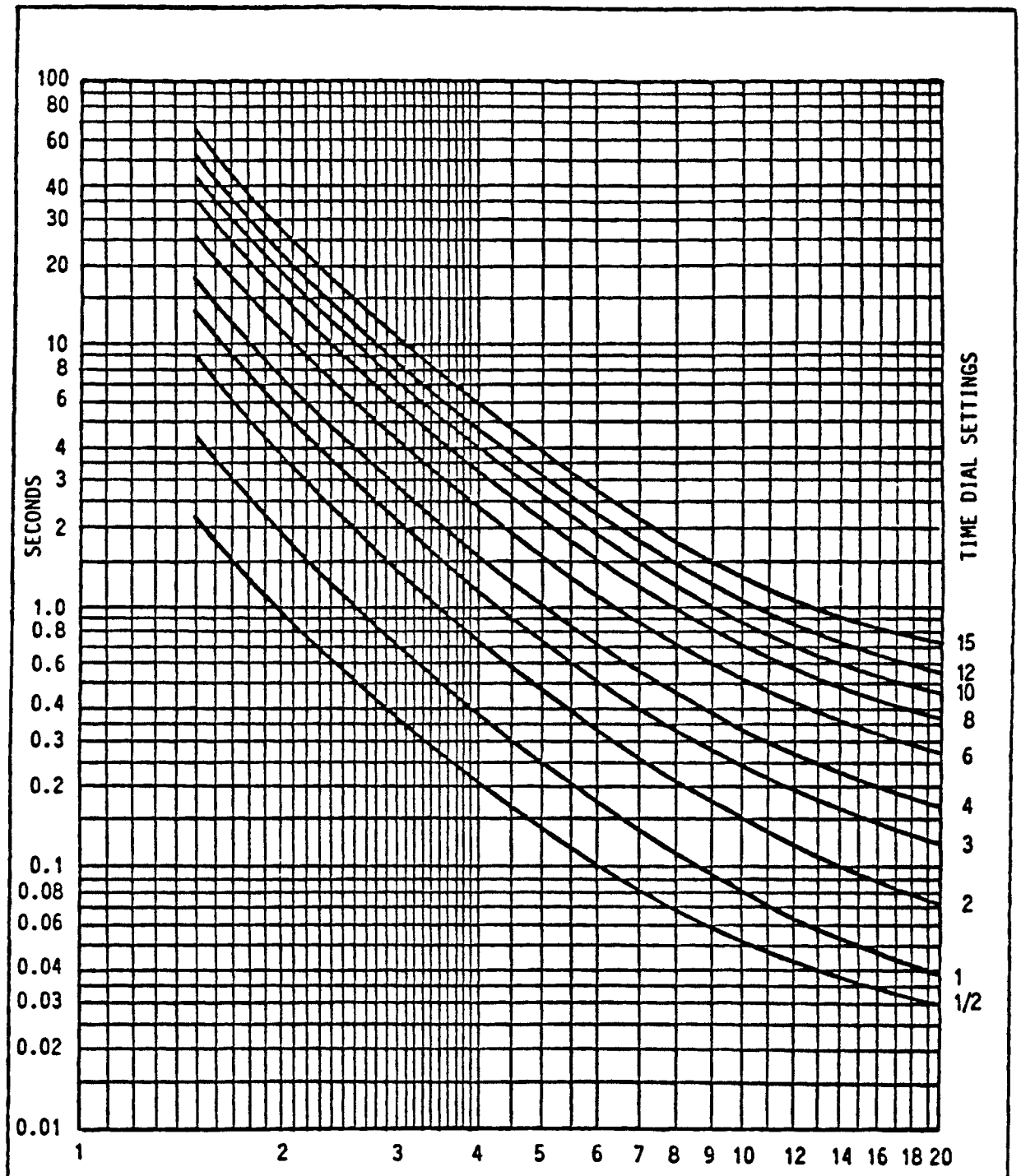
SEL-167 RESIDUAL OR PHASE TIME-OVERCURRENT ELEMENT (51N OR 51P) INVERSE TIME CHARACTERISTIC (CURVE INDEX 2)

DWG. NO. A7-0243
DATE: 02-26-88



SEL-167 RESIDUAL OR PHASE TIME-OVERCURRENT ELEMENT (51N or 51P) VERY INVERSE TIME CHARACTERISTIC (CURVE INDEX 3)

DWG. NO. A7-0244
DATE: 02-26-88



SEL-167 RESIDUAL OR PHASE TIME-OVERCURRENT ELEMENT (51N OR 51P) EXTREMELY INVERSE TIME CHARACTERISTIC (CURVE INDEX 4)

DWG. NO. A7-0196
DATE: 02-26-88

COMMANDS AND SERIAL COMMUNICATIONS

INTRODUCTION

The SEL-167 relay is set and operated via serial communications interfaces connected to a terminal and/or a modem or the SEL Protective Relay Terminal Unit. Communications serve these purposes:

1. SEL-167 relay receives and executes relay/fault locating settings.

2. SEL-167 relay transmits messages in response to changes in system status, e.g. self test warning.

3. SEL-167 relay generates an event record for any of the following conditions:

   a) a fault
   b) assertion of the EXTERNAL TRIGGER input
   c) assertion of the DIRECT TRIP input
   d) assertion of the PERMISSIVE TRIP input
   e) assertion of the BLOCK TRIP input
   f) in response to the TRIGGER command
   g) assertion of the TRIP output

   No event record is made for assertion of the DIRECT CLOSE input, assertion of the 52A input or execution of the CLOSE command.

4. SEL-167 relay responds to commands spanning all functions of the instrument, such as metering, setting the clock, and control operations.

Two access levels with separate passwords protect against unauthorized access through the communications ports.

It is impossible to disable any relaying or control functions via communications, unless a user enters erroneous or improper settings using the SET or LOGIC command.

SERIAL PORT CONNECTIONS AND CONFIGURATIONS

Two serial port connectors are located on the rear panel of the SEL-167 relay. The connectors are marked "PORT 1" and "PORT 2." Both ports adhere to RS-232-C data communications standards.

PORT 1 is intended for remote communications via a data modem. The MODEM COMMUNICATIONS section describes the available capabilities.

PORT 2 is intended for local communications via a CRT, printing terminal, or other device. Cable diagrams for several devices are provided in the INSTALLATION section of this manual.

The baud rates of the ports are set by jumpers located near the front of the main board. They are accessible by removing the top cover or the front panel. Available rates are 300, 600, 1200, 2400, 4800, and 9600 baud.

The serial data format is:

eight data bits
two stop bits
no parity bit

This format cannot be altered.

The port pin assignments and signal definitions are given below.

PIN	NAME	DESCRIPTION
2	TXD	Transmit data output
3	RTS	The SEL-167 relay asserts this line under normal conditions. When its received-data buffer is full, the line is deasserted, and does not assert again until the buffer has sufficient room to receive more data. Connected devices should monitor RTS (usually with their CTS input) and cease transmission when the line deasserts. If transmission continues, data may be lost.
4	RXD	Receive data input
5	CTS	The SEL-167 relay monitors CTS and transmits characters only if CTS is asserted.
6	+5 volts	
7	+12 volts	
8	-12 volts	
1,9	GND	Ground for ground wires and shields

COMMUNICATIONS PROTOCOL

Communications protocol consists of hardware and software features. Hardware protocol includes the control line functions described above. This section also describes a software protocol designed for manual and automatic communications.

1. All commands received by the SEL-167 relay must be of the form:

   <command><CR> or <command><CRLF>

   Thus, a command transmitted to the SEL-167 relay should consist of the command name, followed by either a carriage return or a carriage return and a line feed. When entering commands, you may truncate to the first three characters. Upper or lower cases are irrelevant for all command entries except passwords.

2. All messages transmitted by the SEL-167 relay are of the following format:

   <STX><MESSAGE LINE 1><CRLF>
   <MESSAGE LINE 2><CRLF>
   .
   .
   <LAST MESSAGE LINE><CRLF><PROMPT><ETX>

   That is, each message begins with the start-of-transmission character (ASCII 02), and ends with the end-of-transmission character (ASCII 03), and each line of the message includes a carriage return and line feed at its end.

   Note: The ENTER key on most key boards is configured to send the ASCII character 13 (^M) for a carriage return. This manual instructs you to press the ENTER key after commands, which should send the proper ASCII code to the relay.

3. The SEL-167 relay indicates the volume of data in its received-data buffer by an XON/XOFF protocol.

   XON (ASCII hex 11) is transmitted by the SEL-167 relay when the buffer drops below 1/4 full. The SEL-167 relay also asserts the RTS output.

   XOFF (ASCII hex 13) is transmitted when the buffer fills above 3/4 full. The SEL-167 relay deasserts the RTS output when the buffer is approximately 95% full. Automatic transmitting sources should monitor for the XOFF character and suspend transmission so that they won't overwrite the buffer. Transmission should resume when the XON character is received.

4. An XON/XOFF procedure may be used to control data transmission by the SEL-167 relay. When the SEL-167 relay receives XOFF while transmitting, it pauses until an XON character is received. If no message is being transmitted when XOFF is received, the SEL-167 relay blocks transmission of any message presented to its transmitting buffer. The message will be transmitted when XON is received.

   Reception of the CAN character (ASCII hex 18) aborts a pending transmission. This is useful in terminating unwanted transmissions.

5. Control characters can be sent from most keyboards using the following keystrokes:

XON: **<CONTROL>-Q** (hold down the Control key and press Q)
XOFF: **<CONTROL>-S** (hold down the Control key and press S)
CAN: **<CONTROL>-X** (hold down the Control key and press X)

COMMAND CHARACTERISTICS

The SEL-167 relay responds to commands sent to either serial communications interface. A two-level password system provides security against unauthorized access.

When the relay is first turned on, the instrument is in Access Level 0 and honors only the ACCESS command. It responds "Invalid command" or "Invalid access level" to any other entries.

Most commands may be used in Access Level 1, which is entered with the ACCESS command and the first password. This password is factory-set to OTTER, and may be changed with the PASSWORD command (Access Level 2).

Critical functions such as circuit breaker control and changing settings may be executed only from Access Level 2. You may enter Access Level 2 using the 2ACCESS command and the second password. The Level 2 password is factory-set to TAIL, and may be changed with the PASSWORD command.

Startup

After the relay is turned on, the instrument transmits the following message to the port designated as the "automatic" port:

```
Example 69 kV Line                    Date: 1/1/90          Time: 01:01:01

SEL-167
=
```

You should also hear the ALARM relay pull in, opening its "b" contact. The instrument is shipped with PORT 2 designated as the automatic port; you may use the SET command and the AUTO setting to select either PORT 1, 2, or both for the transmission of automatic responses from the SEL-167 relay (see SET command).

To enter Level 1, type the following on a terminal connected to PORT 2:

```
=ACCESS <ENTER>
```

The response is:

```
Password: ? @@@@@@
```

Enter the Level 1 password, e.g. **OTTER** and press **<ENTER>**. The response is:

```
Example 69 kV Line                    Date: 1/1/90          Time: 01:01:44

Level 1
=>
```

The equal sign and greater-than sign represent the Access Level 1 prompt. Any Level 1 command can be executed from this prompt.

Use a similar procedure to enter Access Level 2:

Type **2ACCESS <ENTER>** and listen for the ALARM relay to drop out and pull in. This command always pulses the ALARM relay contact for about one second, indicating an attempt at Level 2 Access. Enter the proper password, e.g. TAIL, when you receive the second password prompt. After you enter the second password, the relay opens access to Level 2, as indicated by the following message and the Level 2 prompt:

```
Example 69 kV Line                    Date: 1/1/90          Time: 01:01:50

Level 2
=>>
```

Any Level 1 or Level 2 command may be executed from this prompt.

Command Format

Commands consist of three or more characters; you may truncate commands to the first three characters to expedite entry. Upper or lower case characters may be used without distinction, except in passwords.

Items enclosed in square brackets [...] are optional.

Arguments must be separated from the command by spaces, commas, semicolons, colons, or slashes.

Commands may be entered any time after an appropriate prompt is displayed.

COMMAND DESCRIPTIONS

Access Level 0 Command

ACCESS

Use ACCESS to enter the system from the Level 0 prompt (=). After typing **ACCESS <ENTER>**, a prompt for the Level 1 password appears. Type the first password, and press **<ENTER>**. The factory set Level 1 password is OTTER, but should ultimately be changed by the end-user with the PASSWORD command from Access Level 2.

Successful access is indicated by the display example shown below:

```
=ACCESS <ENTER>
Password: ? OTTER

Example 69 kV Line                    Date: 1/1/90        Time: 01:02:05

Level 1
=>
```

The = > prompt indicates that you have reached Access Level 1.

After three successive failed access attempts, the ALARM contact is pulsed closed for one second. This feature can be used to alert operations personnel that possible unauthorized access is being attempted if the ALARM contact is connected to a monitoring system such as SCADA.

Access Level 1 Commands

2ACCESS

Use 2ACCESS to continue from Level 1 to Level 2. Type **2ACCESS <ENTER>** to display the prompt for the Level 2 password. Enter the second password in the same manner as the first and press **<ENTER>**. The factory set Level 2 password is TAIL, but should ultimately be changed by the end-user with the PASSWORD command.

Successful access is indicated by the display example shown below:

```
=>2ACCESS <ENTER>
Password: ? TAIL

Example 69 kV Line                    Date: 1/1/90        Time: 01:02:13
Level 2
=>>
```

The =>> prompt signifies that Access Level 1 and 2 commands may be entered. The ALARM contact is pulsed closed for one second (if no alarm condition exists, such as self test failure) for any Level 2 access attempt, successful or otherwise.

DATE [mm/dd/yy]

To display the current date stored in the internal calendar/clock, type **DATE <ENTER>**.
To set the date, type **DATE mm/dd/yy <ENTER>**.

To set the date to February 28, 1990, enter:

DATE 2/28/90 <ENTER>

The SEL-167 relay responds by setting the date, pulsing closed the ALARM relay as the year is stored in EEPROM (if the year entered differs from the year now stored), and displaying the set date.

EVENT [N]

You may view event records via an event report. To display the event report for the Nth event, type **EVENT N <ENTER>**. The parameter N is 1 for the most recent event through 12 for the oldest event stored in the SEL-167 relay memory. If N is not specified, the report defaults to one.

To inspect the newest report type **EVENT 1 <ENTER>**, or **EVE <ENTER>**. The report provides the relay identifier string, date, and time the event occurred. The next part of the report displays eleven cycles of data for the five current channels (IPOL, IR, IA, IB, and IC), three voltage channels (VA, VB, and VC), and the states of the internal relay elements, outputs, and inputs during the event. Next, the report shows the type of event, fault location in miles, primary ohms to the fault location, duration, and the maximum phase current measured at the midpoint of the fault. When a fault causes a trip, the fault targets are shown as well. The relay and logic settings are displayed at the end of the report.

Recall (from the COMMUNICATIONS PROTOCOL description) that you may use the CONTROL-X (cancel) sequence to terminate any transmission from the SEL-167 relay , CONTROL-S to pause, and CONTROL-Q to continue. These are useful in reviewing or terminating an event report.

When the event buffers are cleared by a control power interruption, all event data are lost. If the buffer is empty when an event is requested, the relay returns this message:

```
Invalid event
```

The EVENT REPORTING section provides a sample event report and explanation.

HISTORY

This command displays the date, time, and type of event for each of the twelve most recent events. If the event is a fault, the distance, duration, current, and fault targets (if the fault caused a trip) are also shown. An example of the display is provided below:

```
=>HISTORY <ENTER>

Example 69 kV Line                          Date: 3/1/90       Time: 11:12:12

#    DATE        TIME          TYPE  DIST    DUR     CURR     TARGETS
1    2/28/90   11:11:28.829    AGT   54.23   10.50   366.5    51N
2    2/28/90   11:11:28.429    AG    54.10   7.50    365.7
3    2/28/90   11:09:50.141    BC    9.05    4.00    1320.9   P1
4    2/28/90   11:08:58.787    BC    8.98    4.75    1155.9   G1
5
6
7
8
9
10
11
12
=>
```

Note that only four events have occurred since the relay was set or powered on.

Each event report is time tagged to the nearest quarter cycle (4.17 ms) and referenced to the 16th row of data in the report. All reports trigger at row 16. Thus, the duration of a long fault that triggers a report when the fault occurs and a second report when TRIP occurs is calculated using the difference between the two report times.

The TYPE column provides an abbreviated indication of event type found in the report. This is the same data presented as EVENT in the event summary automatically generated for each fault.

For faults, the indication includes phase-involvement information. The phase-involvement is determined independently from relay elements. Phase-involvement is determined solely from uncompensated and load compensated current magnitudes at the midpoint of the first contiguous relay pickup sequence in the event report. See the FAULT LOCATOR section for algorithmic details.

The phase-involvement is indicated as one of:

AG : For A-phase to Ground faults
BG : For B-phase to Ground faults
CG : For C-phase to Ground faults
AB : For A-B two-phase faults
BC : For B-C two-phase faults
CA : For C-A two-phase faults
ABG : For A-B two-phase to ground faults
BCG : For B-C two-phase to ground faults
CAG : For C-A two-phase to ground faults
ABC : For three-phase faults

For event reports triggered by the assertion of the TRIP output, the TYPE designation is appended with a "T". This aids in determining clearing times for faults which persist beyond the end of the first event report. For example, if the SEL-167 relay trips for a BG fault after completing the initial report, the second report shows "BGT" for TYPE.

For events other than faults, the TYPE indication is either "TRIP" or "EXT". The TYPE shows "TRIP" when the SEL-167 relay generates an event report in response to assertion of the TRIP output, which results from execution of the OPEN command during no-fault conditions. For all other events, TYPE shows "EXT", indicating a report generated in response to some external stimulus such as the assertion of the ET (External Trigger), PT (Permissive Trip), BT (Block Trip), or DT (Direct Trip) inputs or by execution of the TRIGGER command.

The DIST column presents the equivalent distance to a fault in miles. This is calculated using either the Takagi algorithm or a reactance measurement, depending on whether prefault data are available in the event report. For some boundary faults of long duration with sporadic relay operation, the fault-locator may not be able to locate the fault for every report generated. The DIST column can display "999999" in such cases (while this behavior can be contrived under test conditions, it is extremely rare in actual practice).

The column labeled DUR gives a measure of the fault duration. This is calculated using the first pickup of a Zone 1, 2, 3, 51N, or 51P relay element until the first dropout of all said relay elements. In other words, it is the duration of the first contiguous pickup of relay elements found in the long event report converted to units of cycles.

The CURR column shows the magnitude of the maximum phase-current measured at the middle of the fault in primary amperes.

The TARGETS column shows fault targets for faults which cause a trip to occur. If no trip occurred for the fault or the event is not a fault, this column is blank. These targets are the same as SEL-167 relay front panel targets.

IRIG

The IRIG command directs the relay to read the demodulated IRIG-B time code input if present at J201 on the rear panel.

If the time code is successfully read, the interval clock/calendar time and date are updated to the time code reading, and the relay transmits a message consisting of relay ID string, date, and time. An example of a successful read is shown below.

```
=>IRIG <ENTER>
Example 69 kV Line                    Date: 2/10/90     Time: 15:05:22

=>
```

If no time code signal is present at the AUX port or if the time code cannot be successfully decoded, the relay sends the error message "IRIGB DATA ERROR." An unsuccessful read causes the following output:

```
=>IRIG <ENTER>
IRIGB DATA ERROR

=>
```

NOTE: When the relay is connected to a time code signal via the AUX port it is normally unnecessary to synchronize using this command; the relay synchronizes automatically every few minutes. The command is provided as a test and setup feature, to avoid waiting for automatic synchronization during test and installation.

METER [N]

The currents, demand currents, peak demand currents, voltages, and real and reactive power are displayed in primary quantities of amperes, kilovolts, megawatts, and megavars. An example is shown below.

```
=>METER <ENTER>

Example 69 kV Line                          Date: 2/28/90     Time: 13:27:05


            A        B        C       AB       BC       CA
I (A)     105      102      104      180      177      182
D (A)     100      100      100
PD (A)    107      105      105
V (kV)   40.0     39.9     40.1     69.3     69.2     69.4

P (MW)   12.45
Q (MVAR) -0.08

=>
```

P and Q are positive when the power flow is out from the bus and into the line.

The optional command parameter N selects the number of times meter data are displayed. To view a series of eight meter readings type **METER 8 <ENTER>**.

Peak demand currents are reset when the optional command parameter N is selected as R. The command METER R resets the peak demand currents to the present demand current level.

QUIT

The QUIT command returns control to Access Level 0 from Access Level 1 or 2 and resets the targets to the Relay Targets (TAR 0). The terminal displays the relay I.D., date, and time. Use this command when you finish communicating with the SEL-167 relay to prevent unauthorized access. Note that control returns to Access Level 0 automatically after a settable interval of no activity. See the TIME1 and TIME2 settings of the SET command.

SHOWSET

Use SHOWSET to inspect the settings of the SEL-167 relay. The command displays the current relay and logic settings. Settings cannot be entered or modified with this command; they are entered using the SET and LOGIC commands in Access Level 2.

An example of the output from executing SHOWSET appears below.

```
=>SHOWSET <ENTER>

Settings for: Example 69 kV Line

R1    =49.83     X1    =56.32     R0    =56.07     X0    =143.07  LL   =60.00
CTR   =60.00     PTR   =600.00    MTA   =49.00     LOCAT =Y       DATC =15
DCTH  =120.00    79OI1 =40.00     79OI2 =60.00     79OI3 =80.00   79RS =240.00
51PP  =120.00    51PTD =1.00      51PC  =2         51PTC =N
50P1  =1158.00   50P2  =516.00    50P3  =210.00
Z1DP  =0.00      Z2DP  =160.00    Z3DP  =30.00
51NP  =30.00     51NTD =2.00      51NC  =2         51NTC =N
50N1  =1008.00   50N2  =450.00    50N3  =30.00
Z1DG  =0.00      Z2DG  =30.00     Z3DG  =10.00
52BT  =30        ZONE3 =R         67NE  =Y         67PE  =Y
32QE  =N         32VE  =Y         32IE  =Y
TIME1 =5         TIME2 =0         AUTO  =2         RINGS =3

Logic settings:

MTU  MPT  MTB  MTO  MA1  MA2  MA3  MA4  MRI  MRC
44   44   00   77   44   00   00   00   00   00
44   66   00   77   66   00   00   00   44   00
FF   FF   00   FF   FF   00   80   08   00   BB
30   00   00   30   00   01   00   00   00   30

=>
```

A brief line-by-line description of the settings follows:

Line 1: Positive- and zero-sequence impedances of the transmission line (primary ohms), and the line length (miles) for which the impedances are given.

Line 2: Current and voltage transformer ratios, maximum torque angle for the directional elements, fault locator enable, and demand ammeter time constant.

Line 3: Demand current threshold, three reclosing open interval delays and one reset delay.

Line 4: Phase time-overcurrent pickup, time dial, curve, and torque control by direction.

Line 5: Pickup settings for the three phase overcurrent elements.

Line 6: Zone 1, 2, and 3 time delays for the phase overcurrent elements.

Line 7: Residual time-overcurrent pickup, time dial, curve, and torque control enable.

Line 8: Zone 1, 2, and 3 residual instantaneous-overcurrent element pickup thresholds.

Line 9: Zone 1, 2, and 3 time delays for ground faults.

Line 10: 52B time delay, Zone 3 direction selection, and the enables for directionality of the ground and phase instantaneous elements.

Line 11: The enables for the negative-sequence directional, voltage-polarized zero-sequence directional, and current polarized zero- sequence directional elements.

Line 12: PORT 1 and 2 timeouts, the autoport for automatically transmitted messages, and the number of rings after which the modem will automatically answer.

The SET command provides a complete description of the settings.

The LOGIC command description has a detailed explanation of the logic settings. Each column in the logic settings display shows the masks for the four rows of the Relay Word as follows:

Row 1, of any column:	DRP	50N1	50N2	50N3	DFP	50P1	50P2	50P3
Row 2, of any column:	DRG	67N1	67N2	67N3	DFG	67P1	67P2	67P3
Row 3, of any column:	51NT	Z1GT	Z2GT	Z3GT	51PT	Z1PT	Z2PT	Z3PT
Row 4, of any column:	ALRM	TRIP	TC	DT	52BT	SH1	TOCP	DCTH

Logic settings appear in hexadecimal format. The following table shows the equivalencies between hexadecimal (hex) and binary numbers to facilitate examination of the logic settings display.

HEXADECIMAL	BINARY
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

For example, consider row 2 of mask MA1, which is set to 66 hex format. Using the table to convert 66 to binary:

66 -> 0110 0110.

Now build row 2 of the Relay Word for mask MA1 as follows:

DRG	67N1		67N2	67N3	DFG	67P1		67P2	67P3
0	1		1	0	0	1		1	0
		6					6		

STATUS

The STATUS command allows inspection of the self test status. The relay also automatically executes this command whenever a self test enters a warning or failure state, transmitting a STATUS report to the port selected for automatic transmissions (see AUTO setting of the SET procedure).

The STATUS report format is shown below.

```
=>STATUS <ENTER>

Example 69 kV Line                          Date: 3/1/90        Time: 01:04:56

SELF TESTS

W=Warn   F=Fail
        IP   IR   IA   IB   IC   VA   VB   VC
OS      0    0    2    2    4    -2   -2   -2
PS      4.99       15.14     -14.85
RAM     ROM        A/D    MOF     SET
OK      OK         OK     OK      OK

=>
```

The OS row indicates measured offset voltages for the eight analog channels. They are expressed in millivolts at the system point immediately ahead of the programmable-gain amplifier. Warning and failure thresholds are 50 and 75 millivolt deviations from zero, respectively.

An out-of-tolerance offset is indicated by a W (warning) or F (failure) following the displayed offset value.

The PS row indicates voltages for the three power supplies. Suffixes of W or F indicate warning or failure states of power supply voltage tests. Warning and failure levels are deviations by 0.3 and 0.4 volts for the 5 volt supply and 0.8 and 1.2 volts for the 15 volt supplies.

The last two rows report status for five tests. If a RAM or ROM test fails, the IC socket number of the defective part is indicated in place of OK.

The A/D self test checks the A/D conversion time. If it exceeds a threshold, the test fails and protective functions are disabled. The MOF test checks the offset in the MUX-PGA-A/D circuit when a grounded input is selected. It has the same warning and failure thresholds as the offset tests.

The SET self test compares two copies of the settings stored in nonvolatile memory. Failure of this test disables relay and control functions.

The following table shows relay actions in response to any anomalous self test condition, where F=Failure and W=Warning:

SELF TEST	STATUS MESSAGE	PROTECTION DISABLED	CONTROL DISABLED	ALARM OUTPUT
CHANNEL OFFSETS	W	no	no	no
	F	no	no	1 second contact pulse
+5V	W	no	no	no
	F	YES	YES	permanent contact assertion
±15V	W	no	no	no
	F	YES	no	permanent contact assertion
RAM	F	YES	YES	permanent contact assertion
ROM	F	YES	YES	permanent contact assertion
A/D	F	YES	no	permanent contact assertion
MASTER OFFSET	W	no	no	no
	F	no	no	1 second contact pulse
SETTINGS	F	YES	YES	permanent contact assertion

TARGETS [N] [K]

This command selects the information displayed on the front-panel target LEDs and communicates the state of selected LEDs.

When relay power is turned on, the LED display indicates the functions marked on the front panel. The LEDs default to displaying fault information shown in the RELAY TARGETS row of the following table.

Using the TARGET command, you may select any one of seven sets of data listed below to be printed and displayed on the front panel LEDs.

LED: 1		2	3	4	5	6	7	8	
N									
O	PH1	G1	PH2	G2	PH3	G3	51P	51N	RELAY TARGETS
1	DRP	50N1	50N2	50N3	DFP	50P1	50P2	50P3	RELAY WORD ROW #1
2	DRG	67N1	67N2	67N3	DFG	67P1	67P2	67P3	RELAY WORD ROW #2
3	51NT	Z1GT	Z2GT	Z3GT	51PT	Z1PT	Z2PT	Z3PT	RELAY WORD ROW #3
4	ALRM	TRIP	TC	DT	52BT	SH1	TOCP	DCTH	RELAY WORD ROW #4
5	52AT		ET	52A	DC	BT	PT	DT	CONTACT INPUTS
6		TRIP	CLOS	A1	A2	A3	A4	ALRM	CONTACT OUTPUTS

These selections are useful in testing, checking contact states, and remotely reading targets. "1" indicates an asserted element; "0" indicates an deasserted element.

The ALRM (ALARM) bit in target 4 (RELAY WORD ROW #4) and target 6 (CONTACT OUTPUTS) asserts for the ACCESS command, 2ACCESS command, and self test failures. It does not assert for the SET, LOGIC, PASSWORD, and DATE commands. This differs from the ALARM output relay, which asserts for all the above conditions.

The optional command parameter K selects the number of times the target data are repeatedly displayed for a given choice of parameter N. To see a series of ten readings of Relay Word Row #4, type **TARGET 4 10 <ENTER>**.

Be sure to return the target function to display the fault targets, so field personnel do not misinterpret the displayed data. The TAR 0 command displays fault targets.

Pressing the TARGET RESET button on the front panel clears the TAR 0 data and lights all target LEDs for approximately one second as a lamp test. Further, pressing the TARGET RESET button unlatches the TRIP output from the 52A input. This feature is useful during relay testing and minimizes the risk of re-installing the relay with the TRIP output asserted. The lamp test fails if the relay is disabled due to a self test failure.

The front panel targets can be reset to TAR 0 and cleared remotely or locally using the TARGET command. Type **TARGET R <ENTER>** to reset and clear the targets.

TIME [hh:mm:ss]

To check the internal clock, type **TIME <ENTER>**. To set the clock, type **TIME** followed by the desired setting and **<ENTER>**. Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas or slashes. For example, to set the clock to 23:30:00, enter: **TIME 23 30 00 <ENTER>** or **TIME 23:30:00 <ENTER>**, etc.

A quartz crystal oscillator provides the time base for the internal clock. The SEL-167 relay time code input may be used to synchronize its clock to an external clock with a demodulated IRIG-B time code output.

TRIGGER

Type **TRIGGER <ENTER>** to generate an event record. The relay transmits a response of "Triggered." The computer formats the just-triggered record (after a short delay), and a summary of the record is displayed.

The TRIGGER command is useful when inspecting phasor voltages and currents. When the SEL-167 relay is first installed, execute the TRIGGER command, draw the phasors (the EVENT REPORTING section explains how to do this), and check for the proper polarity and phase-sequence of the inputs.

Event records may also be generated without control action by asserting the EXTERNAL TRIGGER input.

Access Level 2 Commands

All commands are available from Access Level 2. However, the commands listed below are available only from Access Level 2. Recall that any attempt, successful or otherwise, to enter Access Level 2 causes the ALARM relay to assert for one second.

CLOSE

The CLOSE output relay may be closed by executing the CLOSE command or asserting the DIRECT CLOSE input as long as the 52A input is not asserted. The CLOSE output relay remains closed until the 52A input is asserted (indicating that the circuit breaker is closed) or until the reclose reset internal time (79RS) expires.

To close the circuit breaker using this command, type **CLOSE <ENTER>**. The prompting message "Close BREAKER (Y/N) ?" is displayed. Answering **Y <ENTER>** yields a second prompting string: "Are you sure (Y/N) ?". Typing **Y <ENTER>** closes the CLOSE output relay as long as 52A is not asserted. The message "Breaker CLOSED" is transmitted once the breaker closes or if it is already closed (as determined by the state of the 52A input). Answering **N <ENTER>** to either of the above prompts aborts the closing operation and transmits the message "Aborted".

The CLOSE command aborts unless the remote open/close jumper (JMP104) is in place on the main circuit board.

LOGIC [N]

The logic command programs a series of masks used for controlling the outputs and reclosing operations of the SEL-167 relay.

The parameter N specifies a mask to program. N can be any of the following:

MTU - Mask for unconditional trip
MPT - Mask for trip with permissive-trip input asserted
MTB - Mask for trip with block-trip input deasserted
MTO - Mask for trip with breaker open
MA1 - Mask for A1 relay control
MA2 - Mask for A2 relay control
MA3 - Mask for A3 relay control
MA4 - Mask for A4 relay control
MRI - Mask for reclose initiate
MRC - Mask for reclose cancel

The logic programming procedure requires entry of changes to the mask, or pressing **<ENTER>** to indicate no change. Each of the masks listed above is split into sections corresponding to the four rows of the Relay Word as follows:

Relay Word Row #1	DRP	50N1	50N2	50N3	DFP	50P1	50P2	50P3
Relay Word Row #2	DRG	67N1	67N2	67N3	DFG	67P1	67P2	67P3
Relay Word Row #3	51NT	Z1GT	Z2GT	Z3GT	51PT	Z1PT	Z2PT	Z3PT
Relay Word Row #4	ALRM	TRIP	TC	DT	52BT	SH1	TOCP	DCTH

When all data are provided for each row of the Relay Word, the new logic settings are displayed and a prompt issued requesting your approval to enable the SEL-167 relay with the new logic settings. Answering "Y" enters the new data, pulses the ALARM contact closed momentarily, and clears event buffers. "N" retains the old settings.

When executed, the logic command displays a header for each row of the Relay Word (as shown above) and the present logic masking for that particular mask. The relay displays a question mark prompt and waits for input. Enter only ones and zeros without spaces as input; one selects and zero de-selects a member of a Relay Word. Press **<ENTER>** if the entry is satisfactory. If you wish to change any member of a group, all eight members must be input, even if no change is needed for some members. If an error occurs during input of new data, the existing settings and question mark prompt are redisplayed to allow corrections.

Each mask is printed below, showing factory settings. **The masks must be properly configured for your application.**

The first four masks control the TRIP output.

```
=>> LOG MTU <ENTER>

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     1     0     0     0     1     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     1     0     0     0     1     0     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 1     1     1     1     1     1     1     1
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     1     1     0     0     0     0
```

The mask for unconditional trip (MTU) selects tripping by the Zone 1 ground and phase non-directional and directional elements, by timeout of the 51N and 51P element, by the Zone 1, 2, and 3 phase and ground timers, by execution of the trip command, and by direct trip input assertion.

```
=>> LOG MPT <ENTER>

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     1     0     0     0     1     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     1     1     0     0     1     1     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 1     1     1     1     1     1     1     1
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     0     0     0     0     0     0
```

The sample mask for permissive tripping (MPT) given above selects additional elements when the PT input asserts. The additional elements selected are the Zone 2 directional instantaneous outputs as would be desired in a permissive-overreaching transfer trip (POTT) scheme.

```
=>> LOG MTB <ENTER>

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     0     0     0     0     0     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     0     0     0     0     0     0     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 0     0     0     0     0     0     0     0
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     0     0     0     0     0     0
```

The sample mask for elements to be enabled when the blocking input is not asserted (MTB) contains all zeros.

```
=>> LOG MTO <ENTER>

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     1     1     1     0     1     1     1
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     1     1     1     0     1     1     1
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 1     1     1     1     1     1     1     1
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     1     1     0     0     0     0
```

The mask for elements to be enabled when the breaker is just opened or closed (MTO) selects a large number of elements for immediate tripping. The selected elements are enabled for a settable delay (52BT) after the breaker opens or closes (see 52BT setting in the SET command). Note that if the 52A input is not asserted, any element selected under MTO can trip the breaker.

The masks for reclose initiate and cancel follow.

```
=>> LOG MRI <ENTER>

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     0     0     0     0     0     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     1     0     0     0     1     0     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 0     0     0     0     0     0     0     0
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     0     0     0     0     0     0
```

```
=>> LOG MRC <ENTER>

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     0     0     0     0     0     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     0     0     0     0     0     0     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 1     0     1     1     1     0     1     1
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     1     1     0     0     0     0
```

Reclosing initiates for forward Zone 1 phase and ground faults. Reclosing cancels for other faults.

The last four masks control the programmable output relays A1-A4.

```
=>> LOG MA1 <ENTER>   (key TRANSFER TRIP)

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     1     0     0     0     1     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     1     1     0     0     1     1     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 1     1     1     1     1     1     1     1
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     0     0     0     0     0     0
```

MA1 selects faults for which permissive tripping is to be initiated. Relay A1 would then be connected to the tone transmitter to signal the remote end.

```
=>> LOG MA2 <ENTER>   (Demand Threshold)

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     0     0     0     0     0     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     0     0     0     0     0     0     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 0     0     0     0     0     0     0     0
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     0     0     0     0     0     1
```

MA2 selects the demand current threshold relay output alone.

```
=>> LOG MA3 <ENTER>        (51N Trip)

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     0     0     0     0     0     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     0     0     0     0     0     0     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 1     0     0     0     0     0     0     0
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     0     0     0     0     0     0
```

The ground time-overcurrent relay element is selected to program the MA3 so the A3 output asserts for any 51N trip.

```
=>> LOG MA4 <ENTER>   (51P Trip)

DRP   50N1  50N2  50N3  DFP   50P1  50P2  50P3
 0     0     0     0     0     0     0     0
DRG   67N1  67N2  67N3  DFG   67P1  67P2  67P3
 0     0     0     0     0     0     0     0
51NT  Z1GT  Z2GT  Z3GT  51PT  Z1PT  Z2PT  Z3PT
 0     0     0     0     1     0     0     0
ALRM  TRIP  TC    DT    52BT  SH1   TOCP  DCTH
 0     0     0     0     0     0     0     0
```

The sample mask for A4 (MA4) selects the 51P trip.

The programmable masks enable the outputs to be used for any desired function. Examples include separating outputs for phase and ground or by direction or zone.

OPEN

The TRIP output relay closes in response to the OPEN command as long as the TC (trip command) bit is selected in an appropriate TRIP MASK (one or more of MTU, MPT, MTB, or MTO). If the DC (Direct Close contact input) is asserted, the OPEN command is canceled and the relay sends an "Aborted" message. Otherwise the TRIP relay remains closed until the 52A input is deasserted. The TRIP output remains asserted a minimum of 60 ms in all cases.

To open the power circuit breaker by command, type **OPEN <ENTER>**. The prompt "Open BREAKER (Y/N) ?" is transmitted. Answering **Y <ENTER>** yields a second prompt: "Are you Sure (Y/N) ?". Answering **Y <ENTER>** again causes the TRIP output relay to close as described above. Answering **N <ENTER>** to either prompt aborts the OPEN command with the message "Aborted".

The OPEN command aborts unless the remote open/close jumper (JMP104) is in place on the main circuit board.

PASSWORD (1 or 2) [PASSWORD]

To inspect the passwords, type **PASSWORD <ENTER>**.

To change the password for Access Level 1 to BIKE enter:

PASSWORD 1 BIKE <ENTER>

The SEL-167 relay responds by setting the password, pulsing closed the ALARM relay, and transmitting the response "Set".

AFTER ENTERING NEW PASSWORDS, EXECUTE **PASS <ENTER>** TO INSPECT THEM. MAKE SURE THEY ARE WHAT YOU INTENDED. BE SURE TO WRITE DOWN THE PASSWORDS AFTER

CHANGING THEM. THERE IS NO COMMUNICATIONS PROCEDURE TO ACCESS THE SEL-167 RELAY WITHOUT THE PASSWORDS.

Passwords can be any length up to six numbers, letters, or any other printable character except the delimiters (space, comma, semicolon, colon, slash). Upper and lower case letters are treated as different characters. Examples of valid, distinct passwords include:

OTTER otter Ot3456 +TAIL+ !@#$%^ SEL-167 123456 12345. 12345 ab1CDE

If passwords are lost or you need to operate the SEL-167 relay without password protection, install Jumper JMP103 on the main circuit board (no password protection). With no password protection, you may gain access without knowing the passwords and execute the PASSWORD command to discover or change the "forgotten" passwords.

SET [N]

The setting procedure involves answering prompting messages with new data or pressing **<ENTER>** to indicate no change. When all data are provided, the new settings are displayed and a prompt issued requesting your approval to enable the SEL-167 relay with the new settings. When you complete all desired setting changes, it is not necessary to scroll through the remaining settings. Type **END <ENTER>** after the last setting change to proceed to the new settings display and enable prompt. The END statement should not be used for the relay I.D. setting. Use CONTROL-X to abort the set procedure instead.

Error messages indicate when the entered data result in out-of-range settings. If no error messages are received, the relay is enabled with the new settings, the ALARM contact closes momentarily, and the event buffer is cleared.

The optional command parameter N can be one of the setting descriptors (except for the ID setting). The setting descriptor is the abbreviated description of the setting (e.g., 50P1 is the setting descriptor for the Zone 1 phase overcurrent element). See the following list for more descriptors. All settings prior to the one specified are skipped when the parameter N is input. For example, typing **SET Z3DP <ENTER>** will skip to the Z3DP setting and start the set procedure there.

The following data are required to set the relay:

R1, X1 (pos. seq. primary impedance of line 0-9999 ohms)
R0, X0 (zero seq. " " " " 0-9999 ohms)
LL Line length (0.1-999 miles)

CTR CT ratio (e.g. for 600/5, enter 120) (1-5000)
PTR PT ratio (e.g. 1200/1, enter 1200) (1-10,000)
MTA Maximum torque angle for directional elements (47-90 degrees)
LOCAT Do you want the fault locator enabled? (Y or N)
DATC Demand ammeter time constant (5-60 minutes)
DCTH Demand current threshold (25-50,000 primary amperes)

79OI1 Reclosing relay open interval 1 (¼ to 10,000 cycles; 0 disables reclosing for intervals 1, 2 and 3)
790I2 Reclosing relay open interval 2 (¼ to 10,000 cycles; 0 disables reclosing for intervals 2 and 3)
790I3 Reclosing relay open interval 3 (¼ to 10,000 cycles; 0 disables reclosing for interval 3)
79RS Reclosing relay reset time (60 to 8,000 cycles)

51PP Phase time-overcurrent pickup (0.25-50,000 primary amperes)
51PTD Phase time-overcurrent time dial (0.5-15)
51PC Phase time-overcurrent curve index. Choices are as follows:
Use 1 to select a moderately inverse curve
Use 2 to select an inverse curve
Use 3 to select a very inverse curve
Use 4 to select an extremely inverse curve
51PTC Do you want phase time-overcurrent directional torque control? (Y or N)

50P1 Zone 1 phase overcurrent element pickup (0.25-50,000 primary amperes)
50P2 Zone 2 phase overcurrent element pickup (0.25-50,000 primary amperes)
50P3 Zone 3 phase overcurrent element pickup (0.25-50,000 primary amperes)

Z1DP Zone 1 delay for phase and three-phase faults (0-60 cycles in ¼ cycle steps)
Z2DP Zone 2 delay for phase and three-phase faults (0-2000 cycles in ¼ cycle steps)
Z3DP Zone 3 delay for phase and three-phase faults (0-2000 cycles in ¼ cycle steps)

51NP Residual time-overcurrent pickup (0.25-50,000 primary amperes)
51NTD Residual time-overcurrent time dial (0.5-15)
51NC Residual time-overcurrent curve index. Choices are as follows:
Use 1 to select a moderately inverse curve
Use 2 to select an inverse curve
Use 3 to select a very inverse curve
Use 4 to select an extremely inverse curve
51NTC Do you want residual time-overcurrent directional torque control? (Y or N)

50N1 Zone 1 residual instantaneous-overcurrent (0.25-50,000 primary amperes)
50N2 Zone 2 residual instantaneous-overcurrent (0.25-50,000 primary amperes)
50N3 Zone 3 residual instantaneous-overcurrent (0.25-50,000 primary amperes)

Z1DG Zone 1 delay for ground faults (0-60 cycles in ¼ cycle steps) e.g., enter 10.25 for a delay of 10¼ cycles.
Z2DG Zone 2 delay for ground faults (0-2000 cycles in ¼ cycle steps)
Z3DG Zone 3 delay for ground faults (0-2000 cycles in ¼ cycle steps)
52BT 52B time delay (0.5 to 10,000 cycles in ¼ cycle steps)
ZONE3 Zone 3 direction (F = forward or R = reverse)
67NE Do you want directional torque control for the residual instantaneous-overcurrent elements? (Y or N)
67PE Do you want directional torque control for the phase instantaneous-overcurrent elements? (Y or N)

32QE Do you want negative-sequence directional supervision of the ground-overcurrent elements? (Y or N)
32VE Do you want zero-sequence voltage-polarization for the directional element enabled? (Y or N)
32IE Do you want zero-sequence current-polarization for the directional element enabled? (Y or N)

TIME1 Timeout for PORT 1 (0-30 minutes)
TIME2 Timeout for PORT 2 (0-30 minutes)
AUTO Autoport (PORT 1 or 2, or 3 for both PORTS 1 and 2)
RINGS The number of rings after which the modem answers (1-30 rings)

Refer to the functional description and be sure the settings you choose result in relay performance appropriate to your application. Schweitzer Engineering Laboratories® is not liable for misoperation due to incorrect setting, misinterpretation or misapplication.

As you enter settings, they are compared with setting limits above. Then the relay computes internal settings from your entries and checks to ensure that they fall within the specified range.

For example, let CTR=1000 and 50N1 = 1. Each of these settings is admissible alone, but together they result in a secondary pickup setting of 1 mA, which is out of range. Internal setting error messages indicate out-of-range settings after you enable the new settings (refer to the Specifications for the secondary ranges of the relay elements).

The AUTO setting selects PORT 1, 2, or both of the two serial ports for automatically transmitted messages. The table below shows the effect of each possible setting:

AUTO SETTING	AUTOMATIC MESSAGE DESTINATION PORT
1	1
2	2
3	1 and 2

EVENT REPORTING

INTRODUCTION

The SEL-167 relay transmits a summary event report in response to several events and saves a full event report in its memory. The summary report includes the identifier message entered at the beginning of the setting procedure as well as date, time, and type of event. If the event is a fault, the report displays fault location in miles, secondary ohms, fault duration, and a maximum fault current measurement. The report includes fault targets if the fault caused a trip (a setting permits disabling the fault locator).

The summary report is automatically transmitted from the designated automatic port (refer to AUTO setting) regardless of access level, as long as that port has not timed out. If the automatic transmissions are monitored by a dedicated channel or printed on a dedicated printer, enter zero for the timeout interval of the appropriate port (refer to TIME1, TIME2 settings).

The full report contains current and voltage information from which phasor diagrams of the prefault, fault, and postfault conditions may be constructed. It also contains status points spanning the states of all relay elements, inputs, and outputs. These are useful in reviewing fault duration, relay element responses, arrival time of transfer-trip signalling with respect to local relay response, etc.

The full report is not transmitted automatically due to its length (about one page). You may request a full report with the EVENT command, e.g., EVENT 1.

The twelve most recent events are stored in SEL-167 relay volatile memory. These data are retained as long as the control power remains on. This differs from the relay settings, which are retained in nonvolatile memory. Settings are retained until changed by the SET command, regardless of control power cycling. You may quickly review stored events with the HISTORY command.

Event reporting is triggered by any of the following:

Fault in any zone
Assertion of DIRECT TRIP input
Assertion of BLOCK TRIP input
Assertion of PERMISSIVE TRIP input
Assertion of EXTERNAL TRIGGER Input
Execution of OPEN command
Execution of TRIGGER command

Another event report is triggered for the same fault if the trip occurs after the end of the first report.

Event reporting is not triggered by any of the following:

Assertion of DIRECT CLOSE Input
Execution of the CLOSE command
Changes to the 52A input

See the FAULT LOCATOR subsection in the FUNCTIONAL DESCRIPTION section for more explicit information on event report triggering.

EXAMPLE EVENT REPORT

A full event report is provided at the end of this section. The report was generated in response to a simulated fault on the Example 69 kV Line described in the INITIAL CHECKOUT section of this manual. The report details an A-to-ground fault 9 miles away. Test set settings were computed using the BASIC program in the appendices and assume a source impedance of 0.2 of the total line impedance. For this test, the SEL-167 relay currents and voltages were provided by a Doble F-2000 Test System. A latching relay was used to simulate the circuit breaker action and to provide a contact whose state is sensed by the SEL-167 relay 52A input.

The settings for the test set appear below.

VA	VB	VC	IA	
28.71	76.59	68.45	19.18	volts or amps
0	-125	129	-59	degrees

In primary units of kilovolts and amperes, the voltages and currents are:

VA	VB	VC	IA	
17.2	46.0	41.1	1151	kilovolts or amperes

These were obtained using the potential and current transformer ratios assumed in the Example 69 kV Line. Note that these ratios are displayed at the end of the report:

PTR = 600 CTR = 60.

The following paragraphs describe the response of the SEL-167 relay to this simulated fault using information from the full event report.

INTERPRETATION OF VOLTAGE AND CURRENT DATA

The voltage and current data provided in the event report are determined using the secondary quantities presented to the rear panel of the SEL-167 relay through the processing steps outlined below.

1. The input analog signals are filtered by two-pole low-pass filters with cutoff frequencies of about 85 Hz.

2. The filtered analog signals are sampled four times per power system cycle and converted into numerical values.

3. The sampled data are processed by digital filters which remove dc and ramp components. The unit sample response of these filters is:

   1, -1, -1, 1

   This filter has the property of a double differentiator-smoother.

4. The digital filter output data are scaled into primary quantities using the current and potential transformer ratios entered in the setting procedure. Since the samples are taken four times per power system cycle and the four most recent samples are processed through the digital filter every quarter cycle, successive outputs of the filter arrive every 90 degrees. So, with respect to the present value of the filter output, the previous value was taken one-quarter cycle earlier and appears to be leading the present value by 90 degrees.

These filter output values can be used to represent the signals as phasors:

The PRESENT value of the output is the X-component of the phasor.
The PREVIOUS value of the output is the Y-component of the phasor.

It may seem confusing to refer to the older data as the leading component of the phasor. The following example may help. Consider a sinewave with zero phase shift with respect to t=0 and a peak amplitude of 1. Now consider two samples, one taken at t=0, and the other taken 90 degrees later. They have values 0 and 1, respectively. By the above rules, the phasor components are (X,Y) = (1,0). Now consider a cosine function. Its samples, taken at the same time instants, are 1 and 0, while its phasor representation is (0,1). The phasor (0,1) leads the phasor (1,0) by 90 degrees, and this agrees with the 90-degree lead of the cosine function with respect to the sine function.

To construct a phasor diagram of voltages and currents, select a pair of adjacent rows in a region of interest on the event report, e.g. prefault, fault, or postfault. On Cartesian coordinates, plot the lower row (more recent data) as the X-components and the upper row (older data) as the Y-components. Complete phasor diagrams may be rotated to the preferred angle of reference. The effective value of any phasor equals the square root of the sum of the squares of its components.

Note that moving forward one quarter-cycle causes all phasors to rotate 90 degrees, as can be seen by plotting the phasor diagram using rows 1 and 2, then rows 2 and 3.

For example, refer to the first and second rows of cycle 6 of data in the full report:

	Currents				Voltages			
IPOL	IR	IA	IB	IC	VA	VB	VC	
0	-1024	-1024	0	1	-1.1	-35.6	33.4	(Y-component)
0	526	526	0	0	17.2	-28.6	-23.7	(X-component)

These were taken near the "middle" of the fault, as can be judged from the action of residual-overcurrent elements.

Convert these to polar form (magnitude and angle):

	Currents				Voltages			
IPOL	IR	IA	IB	IC	VA	VB	VC	
0	1151	1151	0	0	17.2	45.7	41.0	(magnitude)
*	-63	-63	*	*	-4	-129	125	(angle)
*	-59	-59	*	*	0	-125	129	(angle + 4)

In the third row, four degrees are added to all angles of the second row to assign the phase-A voltage phasor as the zero degree reference. The magnitude and shifted angles can be compared to the test set settings given earlier. Angle measurement errors are one degree or less, while magnitude errors are less than one percent.

The event report indicates a fault current of 1154.4 amperes primary, which concurs with the 1151-ampere test set current as referred to primary.

The indicated fault location is 9.02 miles. The "actual" fault location is 9.00 miles. The error is 9.02 - 9.00, or 0.02 mile, less than 1.0 percent of the actual fault location for this example.

RELAY ELEMENTS STATUS INDICATORS

The columns headed "Relays" indicate the states of all relay elements. Active states of the various relay elements are indicated by designator symbols corresponding with the relay element names. Inactive states are indicated by periods placed in the columns. The entries for active relay elements are shown below.

50P : Phase overcurrent elements : 1=50P1 high set picked up
2=50P2 medium set
3=50P3 low set

67P : Directional phase overcurrent elements : 1=67P1 high set picked up
2=67P2 medium set
3=67P3 low set

51P : Phase time-overcurrent element : T=51PT trip threshold reached

50N : Residual-overcurrent elements : 1=50N1 high set picked up
2=50N2 medium set
3=50N3 low set

67N : Directional ground-overcurrent units : 1=67N1 high set picked up
2=67N2 medium set
3=67N3 low set

51N : Residual time-overcurrent element : T=51NTtrip threshold reached

The states of all output and input contacts are shown in the next two column groups, headed "Outputs" and "Inputs". Assertion of any output or input contact is indicated by an asterisk (*) in the corresponding column; nonassertion is indicated by a period. The contents of the columns are:

OUTPUTS

TP : TRIP output
CL : CLOSE output
A1 : PROGRAMMABLE output #1
A2 : PROGRAMMABLE output #2
A3 : PROGRAMMABLE output #3
A4 : PROGRAMMABLE output #4
AL : ALARM output

INPUTS

DT : DIRECT TRIP input
PT : PERMISSIVE TRIP input
BT : BLOCK TRIP input
DC : DIRECT CLOSE input
52A : BREAKER AUXILIARY 52A SWITCH input
ET : EXTERNAL TRIGGER (for event report) input

In the example event report, the first element to detect the fault picks up in the third quarter cycle of the fourth cycle of the event report.

This is the low set residual-overcurrent element (50N3), as indicated by the "3" in the 50N column. For almost every actual fault, the first element(s) to pick up will be found near the sixteenth row of data.

In the seventeenth row of the report, the Zone 3 phase overcurrent element picks up, as indicated by the "3" in the 50P column. The Zone 2 residual-overcurrent element picks up in the eighteenth row, as indicated by the "2" in the 50N column. In the next quarter cycle, the 67N2 element picks up and the A1 programmable output asserts. For the example settings, the A1 output is programmed to generate an over-reaching permissive signal for a POTT scheme, so it asserts as soon as any Zone 2 directional element picks up.

In the twenty-first quarter cycle, the Zone 1 residual-overcurrent element (50N1) picks up. The TRIP output asserts in response, because the 50N1 element was selected in the UNCONDITIONAL TRIP MASK (MTU) of the LOGIC settings.

The 52A contact input monitors the latching relay (circuit breaker simulator) state. This input deasserts in the 24th row of the report, indicating that the latching relay had changed to the "open" state about one cycle after tripping was initiated.

Fault duration can be estimated from the total time the relay elements are picked up. In the Sample Event Report, relay elements were picked up for a total of nineteen quarter cycles, or 4.75 cycles. This value is reported near the bottom of the report: Duration: 4.75.

See the HISTORY command description for further explanation of the data in this report.

FIRMWARE IDENTIFICATION

The event report provides a means of determining relay Firmware Identification Data (FID). The FID string is printed near the top of each long event report. String format is as follows:

FID = [PN] - R[RN] - V[VS] - D[RD]

Where:

[PN] = Product Name (eg: SEL-167)

[RN] = Revision Number (eg: 400)

[VS] = Version Specifications (eg: 656mp1)

[RD] = Release Date (eg: YYMMDD = 900323)

For the SEL-167 relay family of relays, the version specifications are interpreted as follows:

V[VS] = V[ABCDEF]

OPTION:	SPECIFIER:	SPECIFIER MEANING:	OPTION DESCRIPTION
A	5, 6	50 Hz, 60 Hz	Power System Frequency
B	1, 5	1 amp, 5 amps	Nominal Amps per Phase
C	1, 6	120 volts, 67 volts	Nominal Volts per Phase
D	m, k	miles, kilometers	Fault Locator Distance Units
E	p, n	positive, negative	Phase-Sequence of Power System
F	1, 2	standard, modified	Reclose Enable Option

Please contact Schweitzer Engineering Laboratories, Inc. for the available versions of the SEL-167 relay. The version specifications are not intended for ordering purposes but are intended as an identification of the software installed in a relay.

SAMPLE EVENT REPORT

Example 69 kV Line Date: 3/23/90 Time: 08:45:09.366

FID=SEL-167-R400-V656mp12-D900323

	Currents (amps)				Voltages (kV)			Relays 565565 071071 PPPNNN	Outputs TCAAAAA PL1234L	Inputs DPBD5E TTTC2T A
IPOL	IR	IA	IB	IC	VA	VB	VC			
0	0	0	0	1	-2.6	-33.1	36.0	.....	.....	....*.
0	0	1	0	0	40.0	-22.3	-17.8	.....	.....	....*.
0	0	0	0	-1	2.6	33.1	-36.0	.....	.....	....*.
0	0	-1	0	0	-40.0	22.3	17.8	.....	.....	....*.
0	0	-1	0	1	-2.6	-33.1	36.0	.....	.....	....*.
0	0	1	0	0	40.0	-22.3	-17.8	.....	.....	....*.
0	0	1	0	-1	2.6	33.1	-36.0	.....	.....	....*.
0	0	-1	0	0	-40.0	22.3	17.8	.....	.....	....*.
0	0	-1	0	1	-2.6	-33.1	36.0	.....	.....	....*.
0	0	1	0	0	40.0	-22.2	-17.8	.....	.....	....*.
0	0	1	0	-1	2.6	33.2	-36.0	.....	.....	....*.
0	0	-1	0	0	-40.0	22.2	17.8	.....	.....	....*.
0	0	-1	0	1	-2.6	-33.2	36.0	.....	.....	....*.
0	0	1	0	0	38.8	-22.8	-18.4	.....	.....	....*.
0	37	37	0	-1	0.4	33.2	-35.9	...3..	.....	....*.
0	-7	-8	0	0	-30.6	25.4	20.9	...3..	.....	....*.
0	-420	-418	0	1	0.3	-34.2	34.8	3..3..	.....	....*.
0	246	248	0	0	20.8	-27.9	-23.2	3..2..	..*...	....*.
0	886	886	0	-1	1.0	35.4	-33.6	2..22.	..*...	....*.
0	-506	-505	0	0	-17.6	28.5	23.7	22.22.	..*...	....*.
0	-1024	-1024	0	1	-1.1	-35.6	33.4	22.12.	*.*...	....*.
0	526	526	0	0	17.2	-28.6	-23.7	22.11.	*.*...	....*.
0	1025	1024	0	-1	1.1	35.6	-33.4	22.11.	*.*...	....*.
-1	-527	-526	0	-1	-17.1	28.6	23.8	22.11.	*.*...	....*.
1	-1025	-1025	0	1	-1.1	-35.6	33.4	12.11.	*.*...	.....
1	526	526	0	1	18.3	-28.0	-23.2	11.11.	*.*...	.....
-1	1012	1012	0	-1	3.2	35.6	-33.4	22.11.	*.*...	.....
0	-530	-530	0	0	-26.5	25.3	20.7	22.11.	*.*...	.....
0	-631	-629	0	1	-3.9	-34.6	34.6	22.22.	*.*...	.....
0	289	289	-1	0	36.4	-22.8	-18.5	22.22.	*.*...	.....
0	166	162	1	-1	2.5	33.4	-35.8	3..3..	*.....	.....
0	-32	-32	1	0	-39.5	22.2	18.0	...3..	*.....	.....
0	-24	-22	-1	1	-2.4	-33.2	35.9	...3..	*.....	.....
0	3	4	-1	0	40.0	-22.2	-17.9	.....	*.....	.....
0	4	3	1	-1	2.4	33.2	-35.9	.....	*.....	.....
0	-1	-1	1	0	-40.0	22.1	17.9	.....	*.....	.....
0	-1	-1	-1	1	-2.4	-33.2	35.9	.....	.....	.....
0	0	1	-1	0	40.0	-22.1	-17.9	.....	.....	.....
0	0	1	1	-1	2.4	33.2	-35.9	.....	.....	.....
0	0	-1	1	0	-40.0	22.1	18.0	.....	.....	.....
0	0	-1	-1	1	-2.4	-33.2	35.9	.....	.....	.....
0	0	1	0	0	40.0	-22.1	-18.0	.....	.....	.....
0	0	1	0	-1	2.4	33.3	-35.9	.....	.....	.....
0	0	-1	0	0	-40.0	22.1	18.0	.....	.....	.....

Event : AG Location : 9.02 mi 1.13 ohms sec
Duration: 4.75 Flt Current: 1154.4 Targets: G1

R1 =49.83	X1 =56.32	R0 =56.07	X0 =143.07	LL =60.00
CTR =60.00	PTR =600.00	MTA =49.00	LOCAT=Y	DATC =15
DCTH =120.00	79O11=40.00	79O12=60.00	79O13=80.00	79RS =240.00
51PP =120.00	51PTD=1.00	51PC =2	51PTC=N	
50P1 =1158.00	50P2 =516.00	50P3 =210.00		
Z1DP =0.00	Z2DP =160.00	Z3DP =30.00		
51NP =30.00	51NTD=2.00	51NC =2	51NTC=N	
50N1 =1008.00	50N2 =450.00	50N3 =30.00		
Z1DG =0.00	Z2DG =30.00	Z3DG =10.00		
52BT =30	ZONE3=R	67NE =Y	67PE =Y	
32QE =N	32VE =Y	32IE =Y		
TIME1=5	TIME2=0	AUTO =2	RINGS=3	

Logic settings:

MTU	MPT	MTB	MTO	MA1	MA2	MA3	MA4	MRI	MRC
44	44	00	77	44	00	00	00	00	00
44	66	00	77	66	00	00	00	44	00
FF	FF	00	FF	FF	00	80	08	00	BB
30	00	00	30	00	01	00	00	00	30

INSTALLATION

MOUNTING

The SEL-167 relay is designed for mounting by its front vertical flange in a 19-inch vertical relay rack. It may also be mounted semi-flush in a switchboard panel. Four #10 screws should be used for mounting. Front and rear panel drawings are included in the appendices.

FRAME GROUND CONNECTION

Terminal 35 or 36 on the rear panel must be connected to frame ground for safety and performance. These terminals connect directly to the chassis ground of the instrument.

POWER CONNECTIONS

Terminals 37 and 38 on the rear panel must be connected to a source of control voltage. Control power passes through these terminals to the fuse or fuses and toggle switch, if installed. It continues through a surge filter and connects to the switching power supply. The control power circuitry is isolated from the frame ground. The fuse is an MDL 1.

SECONDARY CIRCUITS

The SEL-167 relay presents a very low burden to the secondary current and potential circuits. Each current circuit is independent of the others; there is no interconnection of current circuits inside the instrument. When current polarization is not desired or required, terminals 4 and 10 may be left open-circuited.

The SEL-167 relay requires four-wire wye potentials because it includes the option of zero-sequence voltage-polarization of the ground relaying functions. It is not possible to directly apply the SEL-167 relay to circuits where line-to-line potential transformers are used. Please consider the SEL-167D or SEL-121D for such applications.

CONTROL CIRCUITS

The control inputs are dry. To assert the 52A input, control voltage must be applied to the 52A input terminals. Each input is individually isolated, and a terminal pair is brought out for each input. There are no internal connections between control inputs.

Control outputs are dry relay contacts rated for tripping duty. Each contact is protected by a metal-oxide varistor (GE V250LA40 or equal). These devices have an energy rating of 130 joules, maximum clamping voltage of 650 volts, and a minimum varistor voltage (for 1 mA dc current) of 354 volts.

Each control circuit input and output point is bypassed to chassis ground via a 0.0047 uF, 3000 Vdc ceramic disc capacitor.

COMMUNICATIONS CIRCUITS

Connections to the two RS-232-C serial communications ports are made via the two nine-pin connectors labeled PORT 1 and PORT 2 on the rear panel. Pins 1 and 9 connect directly to frame (chassis) ground. **These connections should not be relied upon for safety grounding, since their current-carrying capacity is less than control-power short-circuit current and protection levels.**

The communications circuits are protected by low-energy, low-voltage MOVs and passive RC filters. Communications circuit difficulties can be minimized by keeping the length of the RS-232-C cables as short as possible. Lengths of 12 feet or less are recommended; in no case should the cable length exceed 100 feet. SEL recommends shielded communications cable for lengths in excess of 10 feet. Modems are required for communications over long distances.

Route the communications cables well away from the secondary and control circuits. Do not bundle the communications wiring with secondary or control circuit wiring. Coupling invites the induction of noise from the control or secondary wiring into the communications wiring. This noise could exceed the communications logic thresholds, introducing communications errors. The IRIG-B clock cable should also be routed away from control wiring and secondary circuits.

JUMPER SELECTION

All jumpers are located on the front edge of the main board. They are easily accessed by removing the top cover or pulling the drawout assembly out from the front.

RS-232-C Jumpers

Jumper P105 provides for RS-232-C baud rate selection. The available baud rates are 300, 600, 1200, 2400, 4800, and 9600. To select a baud rate for a particular port, place the jumper so it connects the pin labeled with the desired port to a pin labeled with the desired baud rate.

Caution: Do not select two baud rates for the same port. This can damage the baud rate generator.

Password Protection Jumpers

When Jumper JMP103 is in place the password protection is disabled. This feature is useful if passwords are not required or when passwords are forgotten.

Remote Trip/Close Enable Jumper

You may execute remote trip/close commands when Jumper JMP104 is in place. If Jumper JMP104 is removed, attempts to use the OPEN or CLOSE commands result in an "Aborted" message.

SETTING PROCEDURE

The SET and LOGIC commands allow entry of settings for the SEL-167 relay via either serial interface port. Settings are stored in nonvolatile memory, so the relay retains them when the power is off.

The SET and LOGIC command descriptions explain how to enter settings.

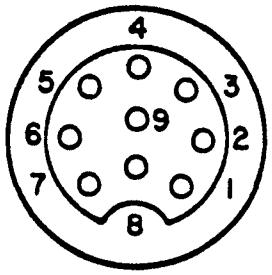
RS-232-C AND IRIG-B INSTALLATION

This section contains specific information concerning pinouts of the communications ports.

The current drive for an IRIG-B "one" is 10 to 20 mA. The input circuit consists of a 56-ohm resistor in series with the photodiode input of an optical isolator. The photodiode has a forward voltage drop of about 1.8 volts. The input may be driven directly by the output of a TTL-level driver with sufficient current capability. Inputs may also be driven in a current loop from a higher-voltage driver.

A pin definition of the nine-pin port connectors and cabling information for the RS-232-C ports appears below. Several types of RS-232-C cables are given. These and other cables are available from SEL. Cable configuration sheets are also available at no charge for a large number of devices. Contact the factory to request configuration sheets.

Nine pin connector pin number convention

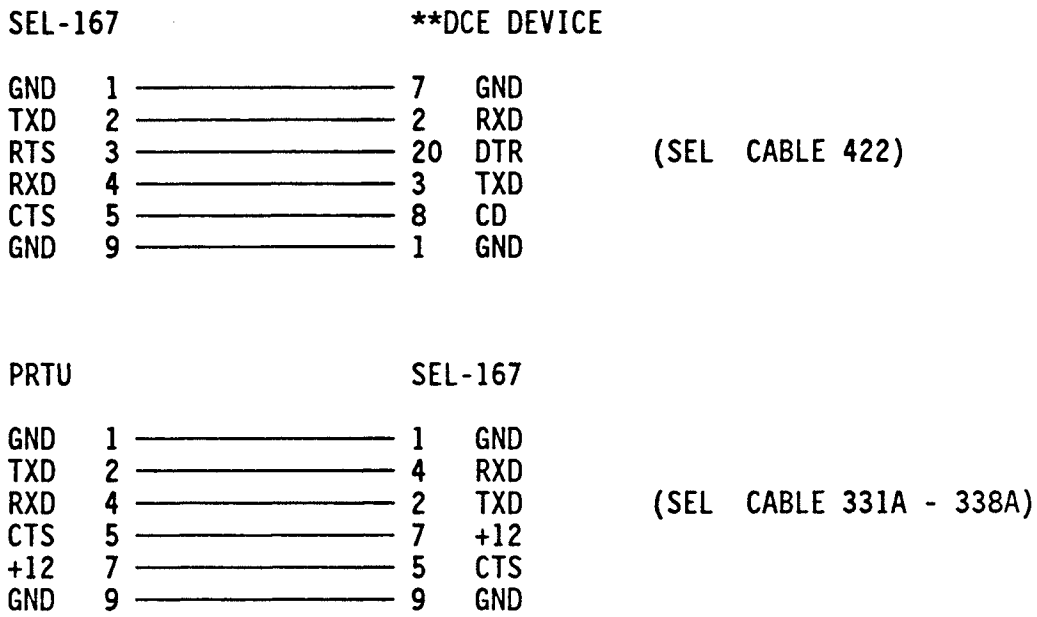


(Female chassis connector, as viewed from outside rear panel.)

RS-232-C cables

SEL-167			25-Pin *DTE DEVICE	
GND	1	7	GND	
TXD	2	3	RXD	
RTS	3	5	CTS	
RXD	4	2	TXD	(SEL CABLE 123)
CTS	5	4	RTS	
+5	6	6	DSR	
+12	7			
-12	8			
GND	9	1	GND	
		8	DCD	
		20	DTR	

SEL-167			9-Pin *DTE DEVICE	
GND	1	5	GND	
TXD	2	2	RXD	
RTS	3	8	CTS	
RXD	4	3	TXD	(SEL CABLE 134)
CTS	5	7	RTS	
		1	DCD	
		4	DIR	
		6	DSR	
		9	RI	



* DTE = Data Terminal Equipment (Computer, Terminal, Printer, etc.)
** DCE = Data Communication Equipment (Modem, etc.)

INSTALLATION CHECKOUT

The following suggestions may be used or combined with your normal practice. In no case should a recommendation be followed unless it is allowed by the rules of your normal practice.

A portable terminal or computer is a convenient tool for providing local communications with the SEL-167 relay during checkout in the field. Such a device should be connected to PORT 2 for checkout (with PORT 2 being designated as the automatic port using the AUTO setting in the SET command).

1. Apply control power and make sure the terminal displays the startup message. If not, set AUTO = 2, using the SET command on Access Level 2. Check the settings with the ACCESS and SHOWSET commands. Use the TIME and DATE commands to set the clock and date.

2. Apply three-phase voltages. Execute the METER command and verify that the readings are accurate. If not, be sure the correct PT ratio was entered and recall that displayed values are in primary line-to-neutral and line-to-line kV.

3. Use the TRIGGER command to save an event record. Type the EVENT 1 command and examine the triggered event record. Referring to the top row of data as the "Y" components and the next row as the "X" components, plot the three voltage phasors to ensure that they are 120 degrees apart, of reasonable magnitudes, and rotating in the positive-sequence direction. The zero-sequence voltage Y and X components

(times a factor of three) are the total of the three Y components and the total of the three X components. These sums should be near zero if balanced three-phase potentials are present.

4. Use the TARGET command to check the state of all contact inputs and outputs. For example, if the connections to the circuit breaker 52A contact are made when the circuit breaker is closed, the TARGET command with option 5 should show a one (1) under the 52A heading (type **TARGET 5 <ENTER>**).

5. Proceed to Access Level 2 with the 2ACCESS command and appropriate password. Be sure that the ALARM relay contacts close and open when the 2ACCESS command is executed (The ALARM pulse will not be detectable if the ALARM contacts are permanently asserted due to any other alarm condition).

6. The tripping function should be tested three ways. First, be sure the circuit breaker can be tripped by the SEL-167 relay when you execute the OPEN command. Be sure the TC bit is set in the MTU mask. Second, the circuit breaker should trip when you assert the DIRECT TRIP input, assuming that the DT bit is selected in the MTU mask. The TRIP output relay opens in both of these cases after the 52A input is deasserted, indicating that the circuit breaker has indeed opened. This function of monitoring the 52A contact ensures that the output relay does not inadvertently open while trip coil current is flowing in response to a control operation. Third, the circuit breaker should trip when you apply voltages and currents representing a fault condition for which the relay should respond. Here, the TRIP relay asserts regardless of the state of the 52A contact. It opens when the 52A input is deasserted AND fault conditions no longer exist. The TRIP output always remains closed for at least 60 ms.

7. There are two ways to close the circuit breaker: executing the CLOSE command or asserting the DIRECT CLOSE input. The CLOSE output relay asserts for either of these conditions if the 52A input is deasserted (indicating that the circuit breaker is open). The CLOSE relay deasserts when the 52A input is asserted or when the reclosing relay reset interval expires, whichever occurs first.

8. If the PERMISSIVE TRIP and BLOCK TRIP inputs are used, they should also be checked for proper operation (see the LOGIC MPT and LOGIC MTB settings). An event report should be generated for assertion of either the PT or BT inputs.

9. Asserting the EXTERNAL TRIGGER input should trigger the relay to record an event record. It does not affect the protective relaying functions in any way.

10. Use the STATUS command to inspect the self test status. You may wish to save the reading as part of an "as-left" record.

When local checkout is complete, communications with the instrument via a remote interface (if used) should be tested. Be sure, in particular, that the automatic port is properly assigned, and that desired timeout intervals are selected for each port. Also, be sure to record password settings.

SERVICE AND CALIBRATION

REMOVAL OF FRONT PANEL AND DRAWOUT ASSEMBLY

To prevent shock hazard, power to the relay must be interrupted before removing the front panel assembly.

1. Disconnect external power source.
2. Remove the four outermost front panel screws.
3. You may hinge the front panel forward and leave it connected, or remove it by disconnecting the display board ribbon cable and the power switch/fuse connector (if installed).
4. Remove the two hex head screws from the forward outside edges of the drawout assembly.
5. Disconnect the analog input connector from the main board (P 104). It is the right-most connector.
6. Remove drawout assembly by pulling on spacers located on the tray bottom with your index fingers.

CALIBRATION

Calibration of the system consists of trimming the gains and offsets of the analog channels.

Periodic calibration is unnecessary. However, calibration should be considered for the conditions listed below.

1. Replacement of any analog components in the system, including op amps, the A/D converter, or the sample/hold amplifiers.
2. Replacement of the input transformers or their secondary burden resistors.
3. Out-of-tolerance analog indication of voltages or currents.

EQUIPMENT REQUIRED

1. AC digital voltmeter.
2. Precision three-phase voltage and current source.
3. Computer terminal.

PROCEDURE

Offset Adjustments

1. Be sure all voltage and current inputs are zero at the relay rear panel and remove the top cover of the instrument.
2. Turn the system power on.
3. Execute the STATUS command to observe the offsets as required, while adjusting potentiometers R127-R133 and R138 for indications of 5 mV or less (clockwise rotation results in positive offset).

Gain Adjustments

The procedure below uses an ac source at the relay input, so the gain adjustments accommodate ratio error in the input transformers and error in the burden resistors at the input CT secondaries.

1. Connect a 50-volt 60 Hz source to the three voltage inputs and a 10-ampere source to the phase current inputs. Turn on the system power.
2. Type **METER 222 <ENTER>** to repeat the meter command and display 222 times (you may abort any command using the <CONTROL>-X key sequence).
3. Adjust R109-R114 for correct indication, considering your settings for the CT and PT ratios (counter-clockwise rotation increases gain).
4. Turn off the ac test source. Reconnect the current source to provide a test current of 10 amperes to the polarizing current input terminals.
5. Trigger an event with the TRIGGER command and type **EVE 1 <ENTER>** to list the event report. Using the current data shown in the IPOL columns, find the current magnitude by calculating the square root of the sum of squares using values in any adjacent rows. Adjust R108 (counterclockwise increases gain).

6. Repeat step 5 until correct indication is obtained.

7. Replace the instrument cover.

TROUBLESHOOTING GUIDE

Inspection Procedure

The following inspection procedure should be completed before the system is disturbed. After you finish the inspection procedure, proceed to the TROUBLESHOOTING TABLE.

1. Measure and record control power voltage present at terminals 37, 38.

2. Check to see that the power is on, but do not turn system off if it is on.

3. Measure and record the voltage present at all control inputs.

4. Measure and record the state of all output relays.

5. Inspect the cabling to the serial communications ports and be sure that a communications device is connected to at least one communications port.

TROUBLESHOOTING TABLE

All Front Panel LED'S Dark when TARGET RESET Button is Pushed

1. Power is off.

2. Blown fuse.

3. Input power not present.

4. Self test failure.

5. Target command improperly set.

Note: For 1, 2, 3, and 4, the ALARM relay contacts should be closed.

System Does Not Respond to Commands

1. Communications device not connected to system.
2. SEL-167 relay or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.
3. Internal ribbon cable connector loose or disconnected.
4. System is currently processing event record (wait several seconds).
5. System is attempting to transmit information, but cannot due to handshake line conflict (check communications cabling).
6. System is in the XOFF state, halting communications (type **<CONTROL> Q** to put system in XON state).

Tripping Output Relay Remains Closed Following Fault

1. 52A input remains asserted (i.e. circuit breaker auxiliary contact did not open with breaker).
2. Auxiliary contact inputs improperly wired.
3. Output relay contacts burned closed.
4. Failure of interface board.

No Prompting Message Issued to Terminal upon Power-Up

1. Terminal not connected to system.
2. Wrong baud rate.
3. Improper connection of terminal to system.
4. Other port designated as the AUTOMATIC port (see AUTO setting in the SET command).
5. Port timeout interval set to a value other than zero.
6. Failure of main board or interface board.

System Does Not Respond to Faults

1. Relay improperly set. Review your settings with the SET and LOGIC commands.

2. Improper test set settings.

3. CT or PT input cable wiring error. Check input voltages and currents with METER command and TRIGGER and EVENT sequence.

4. Analog input cable between transformer-termination and main board loose or defective.

5. Check built-in-test status with STATUS command.

Terminal Displays Meaningless Characters

1. Baud rate incorrectly set. Check terminal configuration: see COMMANDS AND SERIAL COMMUNICATIONS section.

Self-Test Failure: +5 Volts

1. Power supply +5 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self-Test Failure: +15 Volts

1. Power supply +15 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self-Test Failure: -15 Volts

1. Power supply -15 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self-Test Failure: Offset

1. Offset drift (adjust offsets).

2. A/D converter drift.

3. Loose ribbon cable from transformers to main board.

Self-Test Failure: ROM Checksum

1. EPROM failure (replace EPROMs).

Self-Test Failure: RAM

1. Failure of static RAM IC (replace RAM).

Self-Test Failure: A/D Converter

1. A/D converter failure.
2. RAM error not detected by RAM test.

Stall Relay Closed (Alarm)

1. Power is off.
2. Blown fuse.
3. Power supply failure.
4. Improper EPROMs or EPROM failure.
5. Main board or interface board failure.

MODEM COMMUNICATIONS

The SEL-167 relay interfaces directly with a commercial grade Hayes compatible telephone modem for automatic-answer dial-up communications applications. A field installation with an SEL-167 relay and a modem can be accessed by telephone with another modem and a computer or terminal.

The modem connects to PORT 1 with a cable available from SEL. The modem is normally powered from 120 Vac, but a dc powered modem is available which can be powered from the SEL-167 relay. Please contact SEL for further details.

The SEL-167 relay responds to control messages sent by the modem. These are RING, CONNECT, NO CARRIER, ERROR, and OK. The responses ensure that the modem is programmed to answer after the number of rings specified for RINGS in the SET command.

Keep the following points in mind when applying and using the SEL-167 relay and a modem in an automatic-answer scheme:

1. Modem setting considerations:

   a. Modem must be compatible with the Hayes "AT" command set.

   b. Modem must be set to auto answer.

   c. Modem must not echo commands sent to it.

   d. Modem must send responses to commands with verbose (English words) result codes.

   e. Modem must automatically or manually set communications parameters to 8 data bits, 2 stop bits, and no parity.

2. Always use a finite timeout interval, so that if communications are disturbed, the SEL-167 relay has a chance to reconfigure the modem and clear its communications buffers of data and control characters. An interval of five minutes is recommended (see the TIME1 setting). When the PORT 1 timeout occurs the SEL-167 relay sends a command to the modem to hang up. This feature helps prevent accumulation of a large telephone toll when no activity is sensed by the SEL-167 relay during the timeout interval.

3. Be careful about the number of rings programmed for the RINGS setting. It can be as many as 30, but large numbers result in long delays.

4. Some communications devices allow the use of an XON/XOFF communications protocol. In general, the SEL-167 relay functions quite well with these. However, these devices can occasionally leave the SEL-167 relay in the XOFF state upon hanging up. This is a problem because you must wait your timeout interval before the XOFF state is cancelled automatically by the SEL-167 relay. In the XOFF state, the SEL-167 relay cannot respond to the modem; it has been told to remain silent. If you call the SEL-167 relay and do not get a prompt, send an XON (<CONTROL>-Q).

5. For the same reason, do not hang up after you have stopped a transmission using XOFF (<CONTROL>-S). If you wish to terminate a lengthy transmission, use <CONTROL>-X.

6. When the modem answers the telephone, the SEL-167 relay forces it into its control state to ensure proper initialization. To do so, the SEL-167 relay sends the following string immediately after establishing the connection:

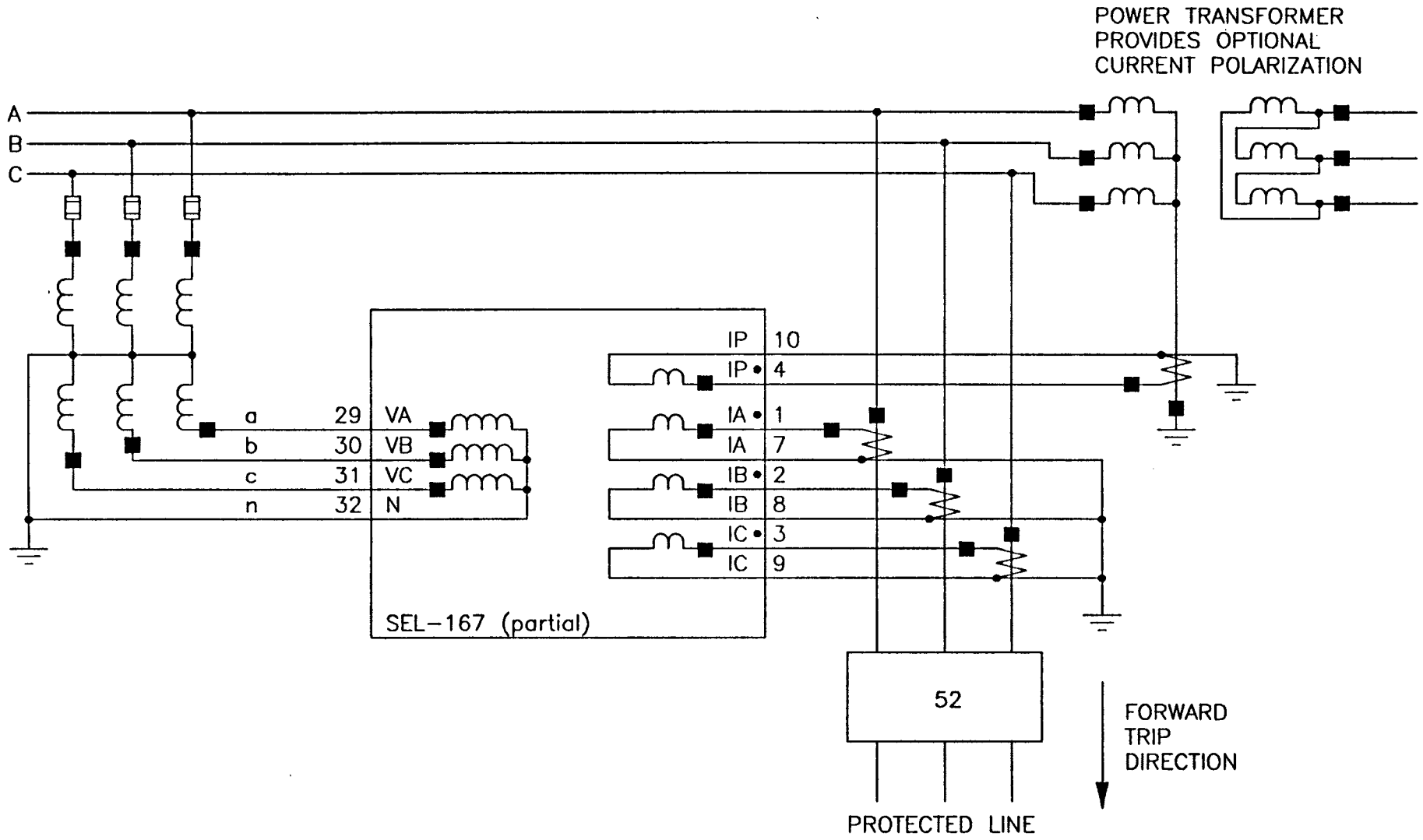
   AT+++

   Wait for the SEL-167 relay prompt before typing commands. If no prompt appears, send an XON or press **<ENTER>**.

7. If modem power is turned off and back on, many modems "forget" the number of rings to wait before answering. The SEL-167 relay programs the modem with this information. After power is restored, the modem will answer the first call on the first ring. For subsequent calls, it will answer after the number of rings programmed with the RINGS setting until power is interrupted again. The SEL-167 relay retains the number of rings in its nonvolatile memory, so control power interruptions do not disturb the setting.

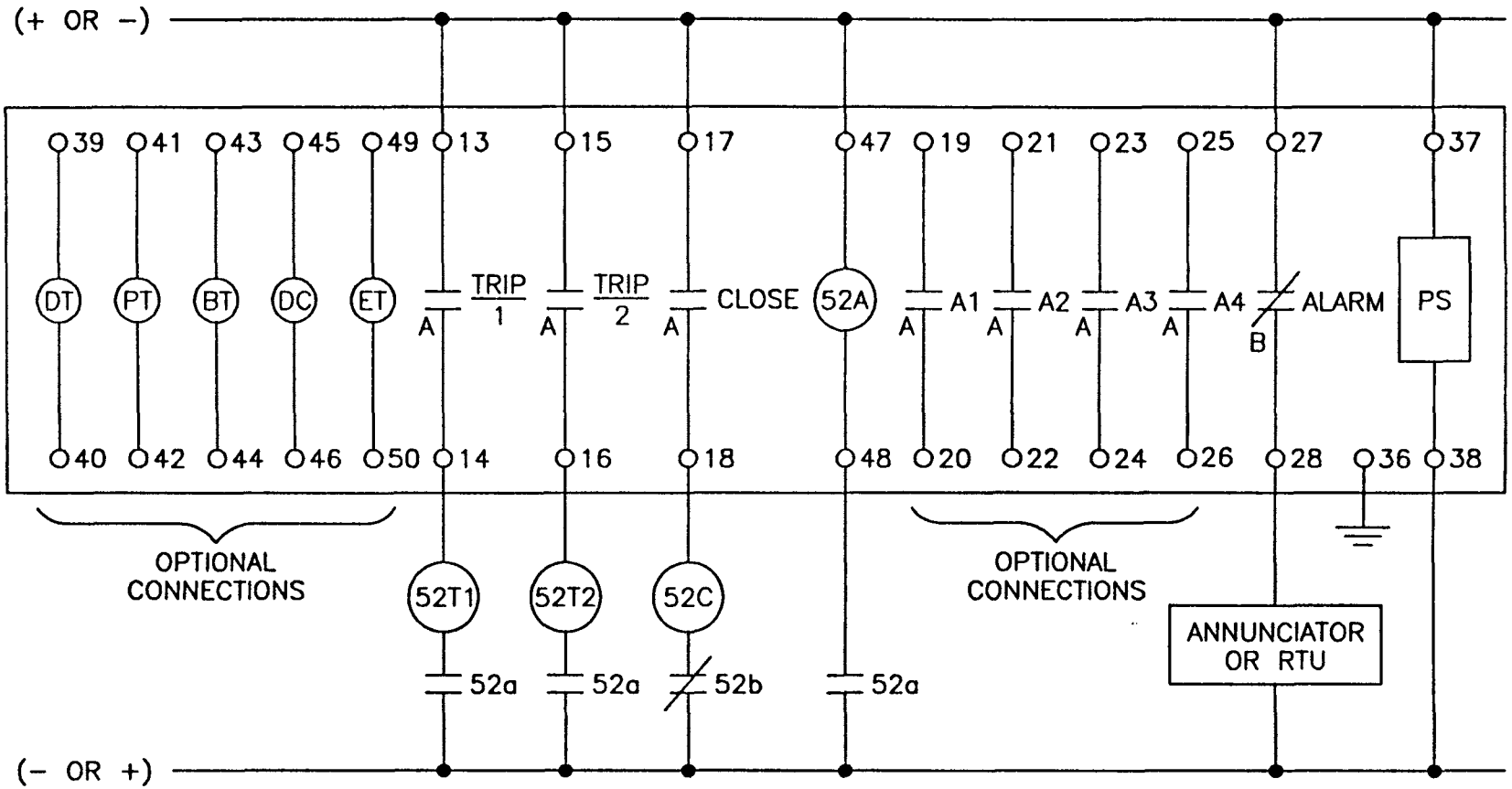
APPENDIX A

EXTERNAL CURRENT AND VOLTAGE CONNECTIONS
DC EXTERNAL CONNECTION DIAGRAM
COMMUNICATIONS AND CLOCK CONNECTIONS



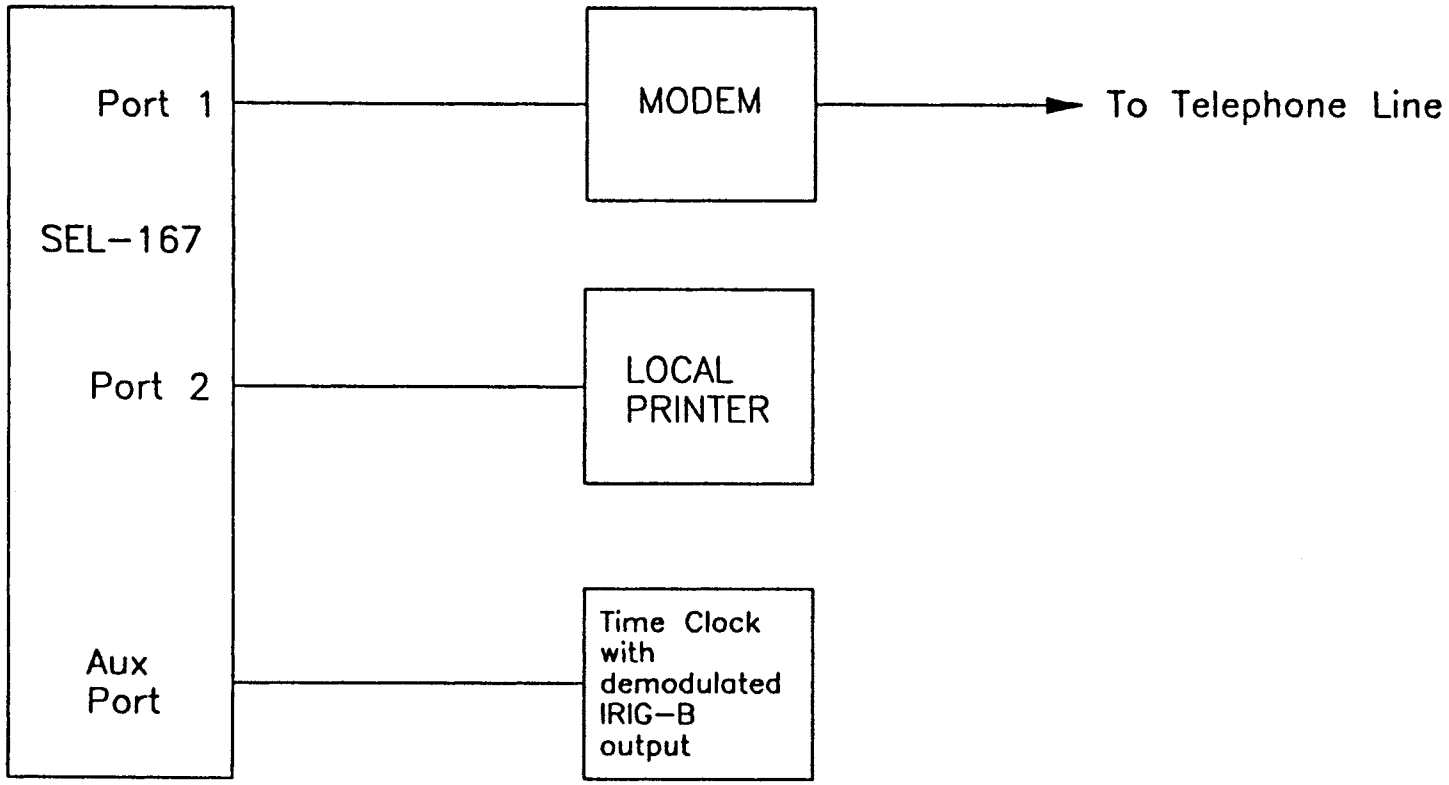
SEL-167 EXTERNAL CURRENT AND VOLTAGE CONNECTIONS

DWG. NO. A7-0219
DATE: 11-16-89
REV. 06-20-89



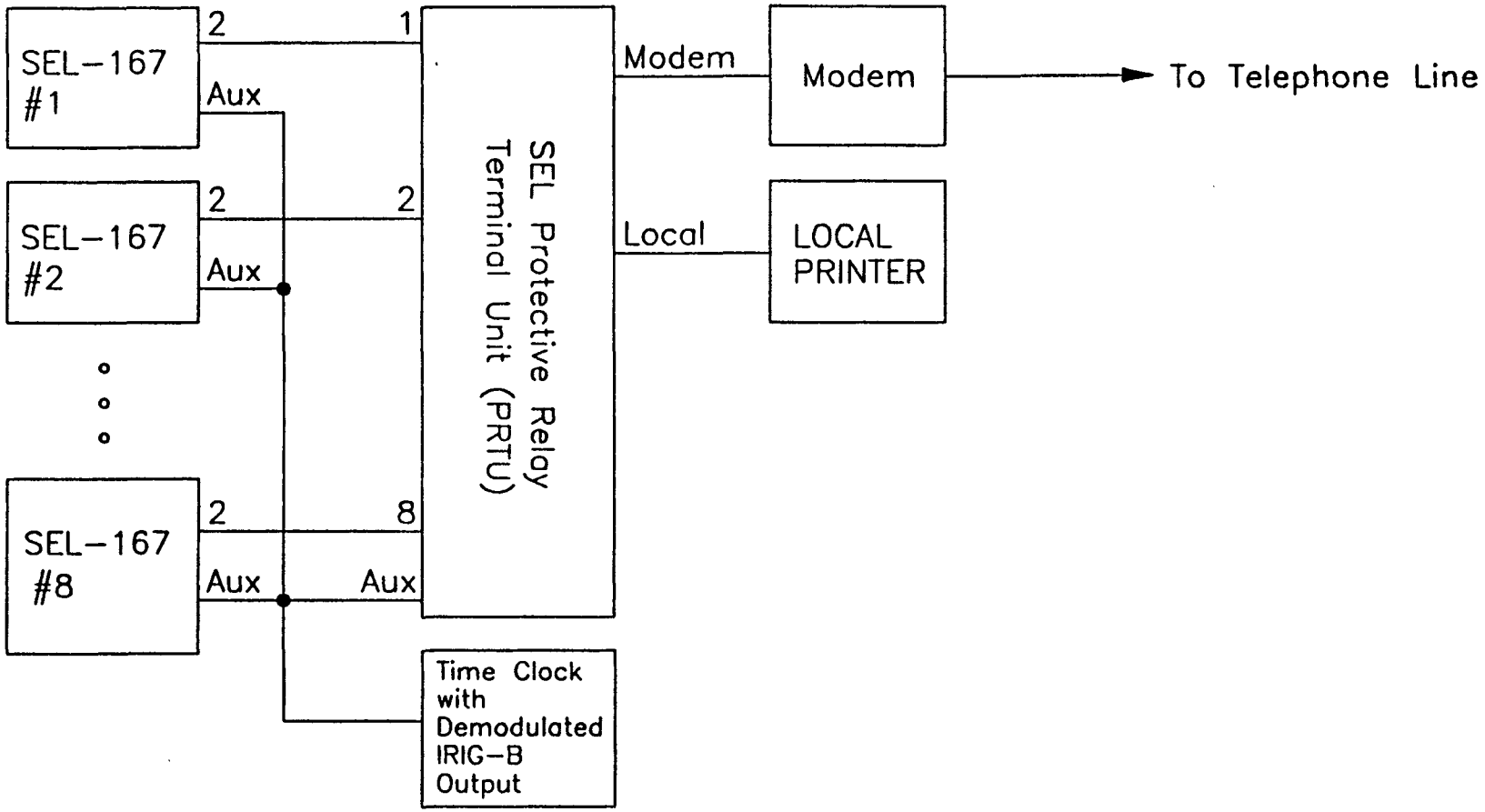
SEL−167 DC EXTERNAL CONNECTION DIAGRAM (TYPICAL)

DWG. NO. A7−0284
DATE: 04−27−88
REV. 02−22−89



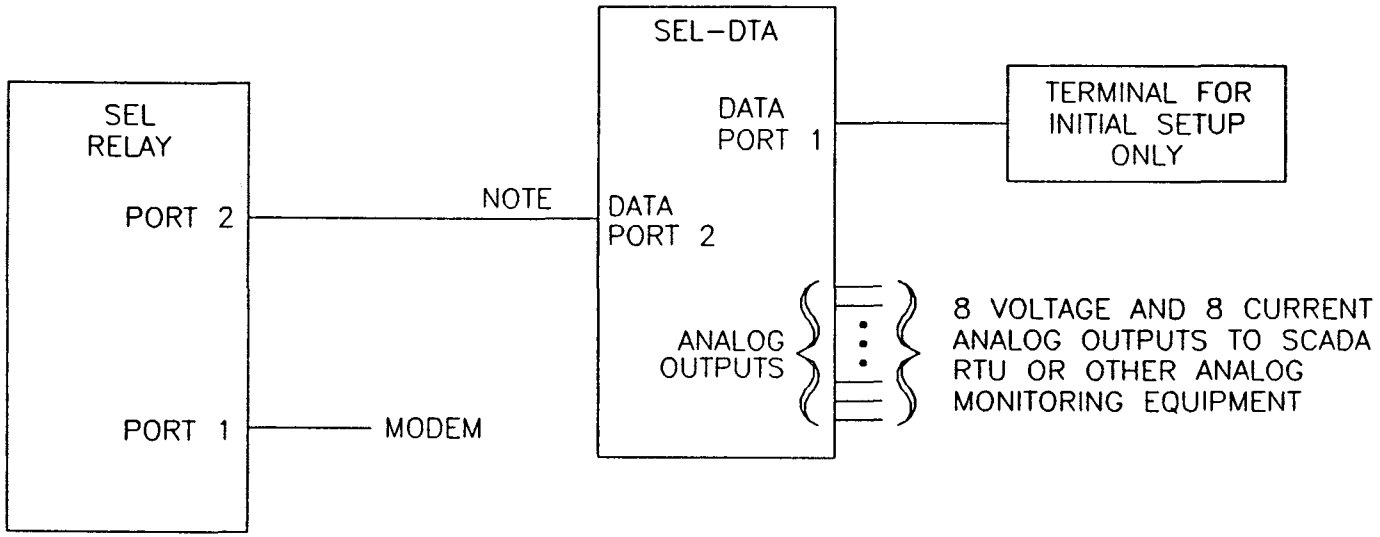
SEL–167 COMMUNICATIONS AND CLOCK CONNECTIONS
ONE UNIT AT ONE LOCATION

DWG. NO. A7–0223
DATE: 08–30–88
REV. 11–8–88



SEL-167 COMMUNICATIONS AND CLOCK CONNECTIONS
MULTIPLE UNITS AT ONE LOCATION

DWG. NO. A7-0224
DATE: 10-14-88
REV. 11-8-88



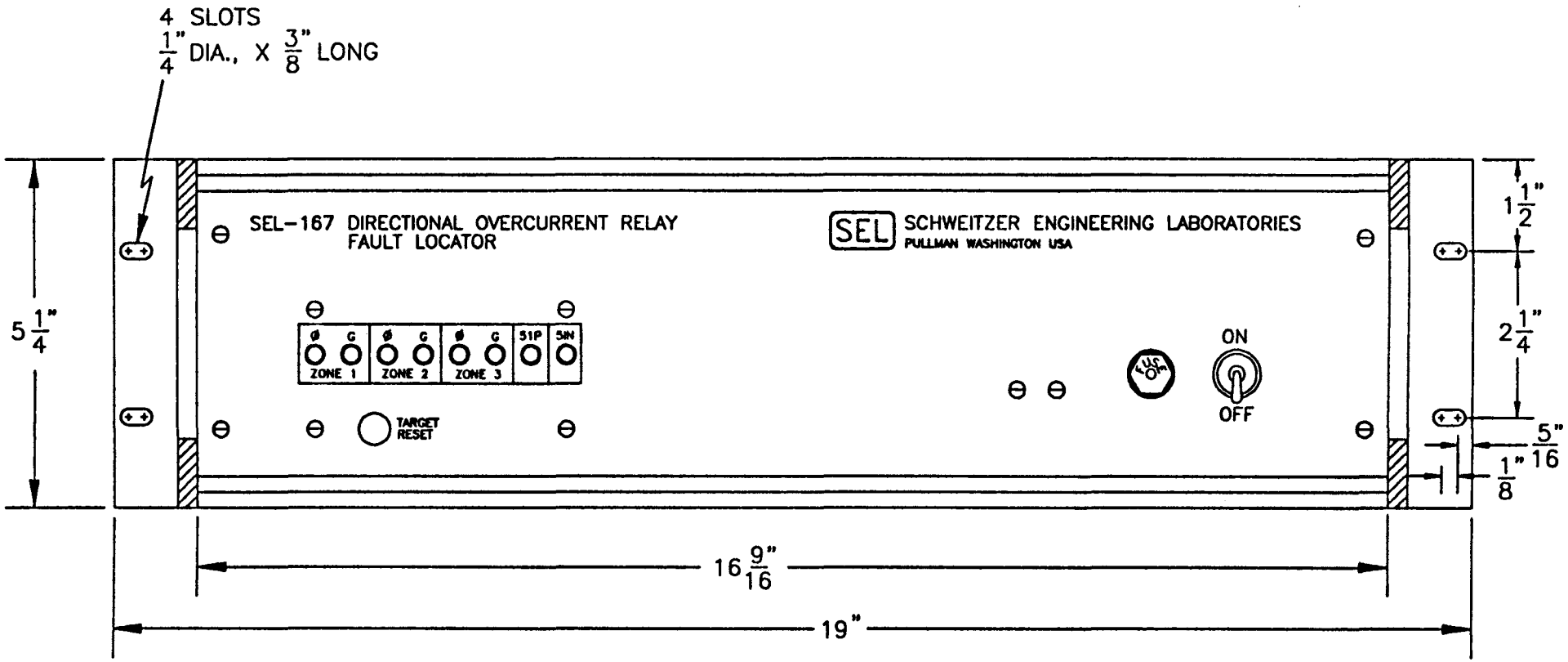
NOTE: SEL-DTA DISPLAY/TRANSDUCER ADAPTER (DTA)
DATA AND CONTROL POWER

SEL RELAY COMMUNICATIONS DIAGRAM FOR CONNECTION TO THE SEL-DTA

DWG. NO. A7-0413
DATE: 10-07-88

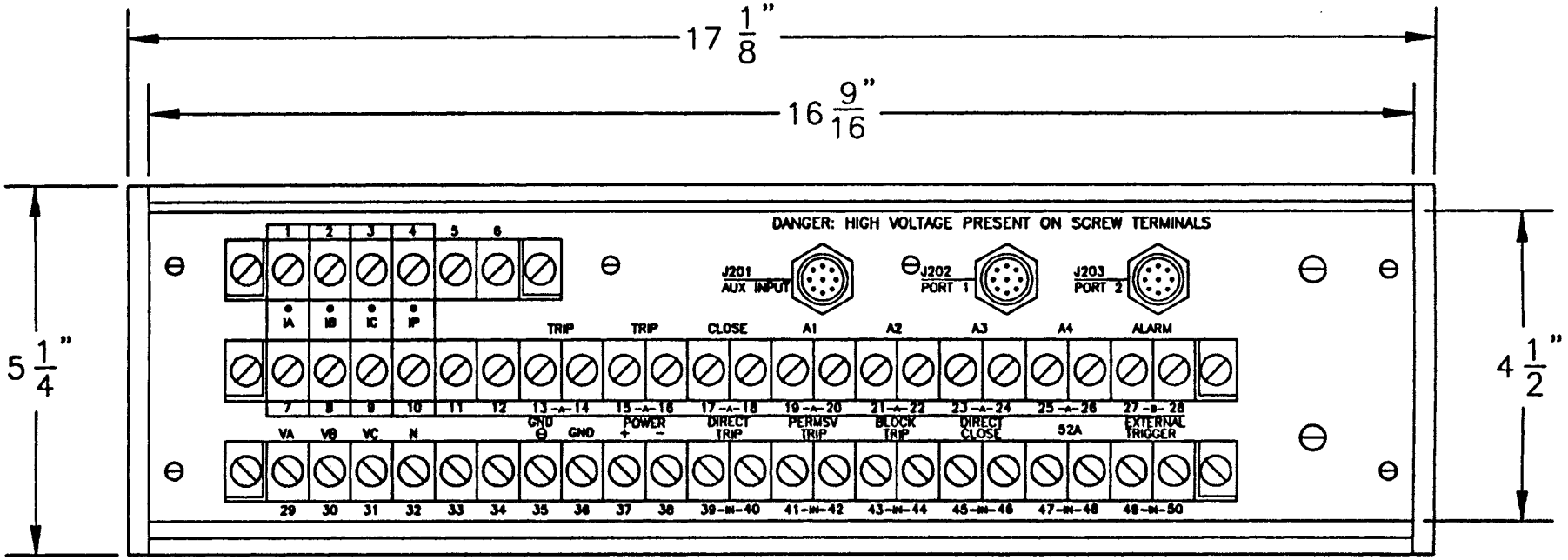
APPENDIX B

MECHANICAL DIMENSIONS
PANEL CUTOUT AND DRILL PLAN



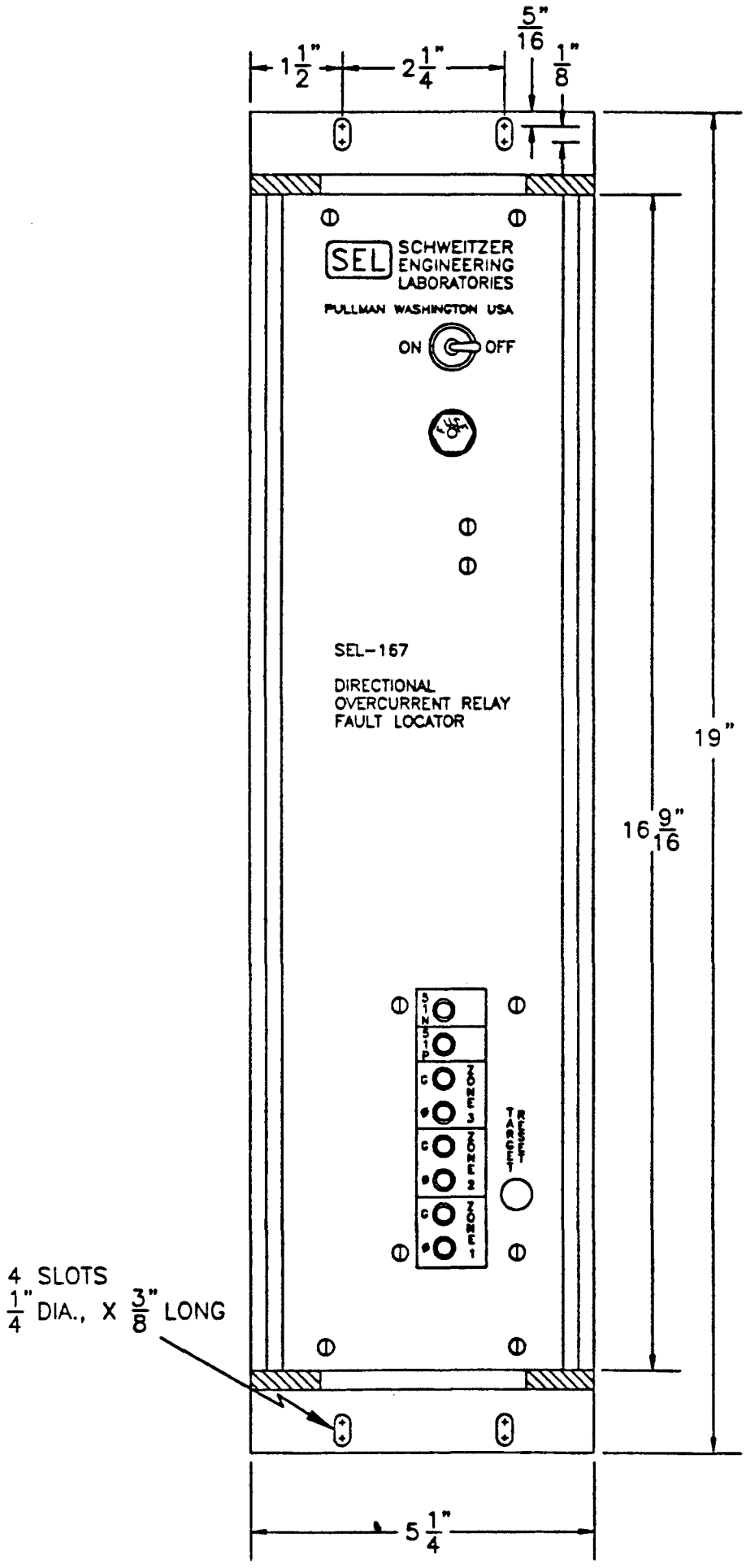
SEL-167 HORIZONTAL FRONT PANEL DRAWING

DWG. NO. A7-0232
DATE: 01-21-88
REV. 11-10-88



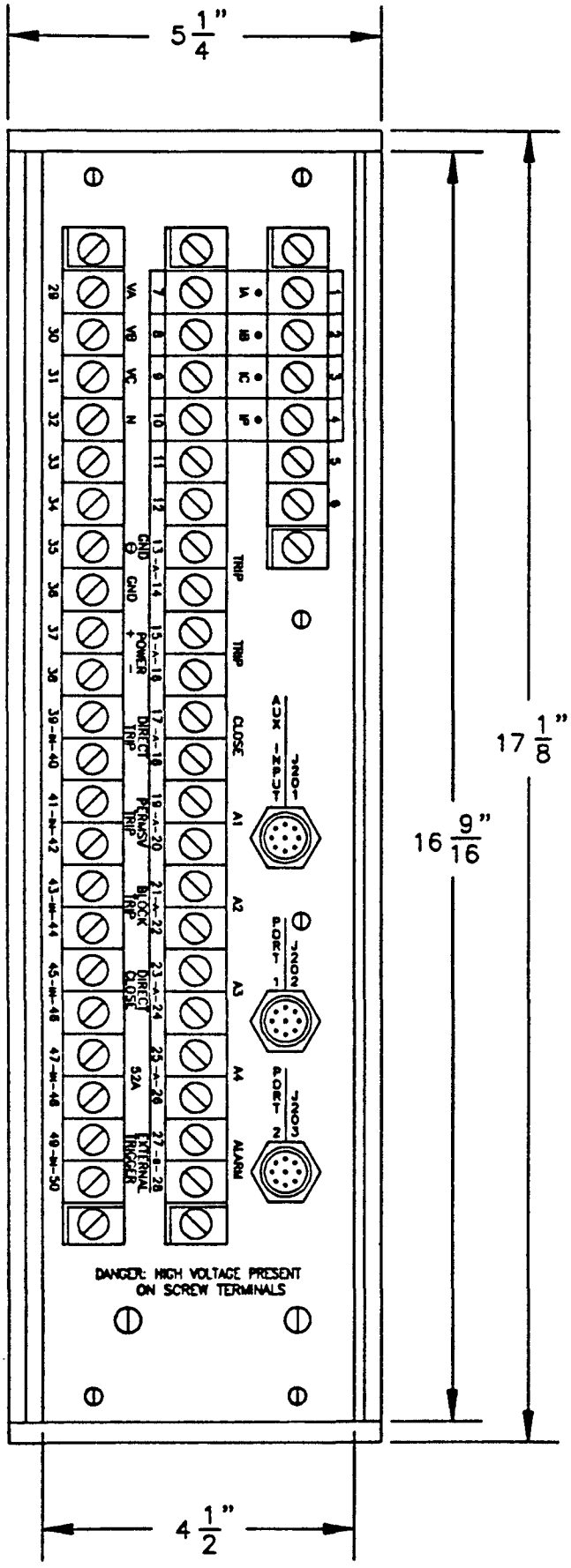
SEL-167 HORIZONTAL REAR PANEL DRAWING

DWG. NO. A7-0220
DATE: 01-16-88
REV. 11-10-88



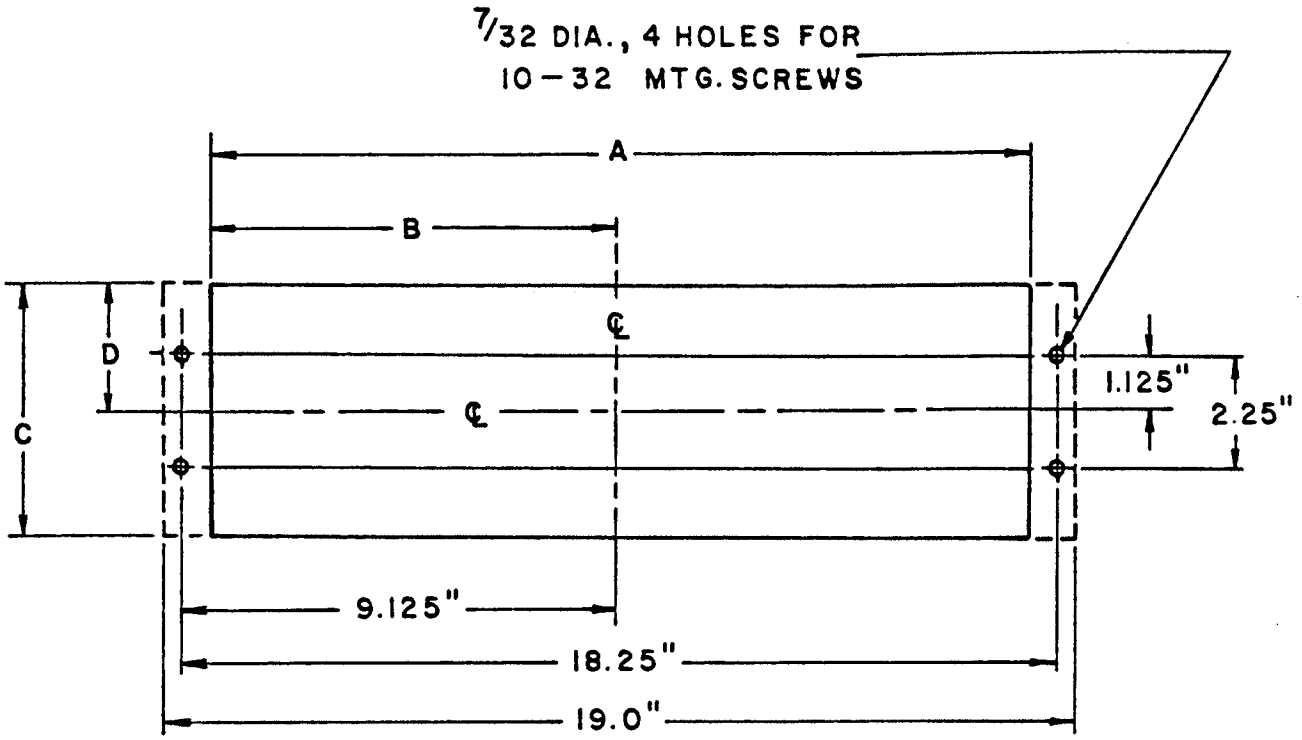
SEL-167 VERTICAL FRONT PANEL DRAWING

DWG. NO. A7-0233
DATE: 01-22-88
REV. 11-10-88



SEL-167 VERTICAL REAR PANEL DRAWING

DWG. NO. A7-0234
DATE: 01-28-88
REV. 11-10-88



DIMENSION A:
CASE: 17.00"
CUT OUT: 17.25" - 17.875"
17.375" PREFERRED

DIMENSION B:
CASE: 8.5"
CUT OUT: 8.625" - 8.9375"
8.688" PREFERRED

DIMENSION C:
CASE: 5.25"
CUT OUT: 5.35" - 5.45"

DIMENSION D:
CASE: 2.625"
CUT OUT: 2.675" - 2.725"

NOTE: ALL INSTRUMENTS MAY BE MOUNTED HORIZONTALLY (AS SHOWN) OR VERTICALLY.

PANEL CUTOUT AND DRILL PLAN FOR SEMI-FLUSH MOUNTING OF 5.25 INCH HIGH CASE

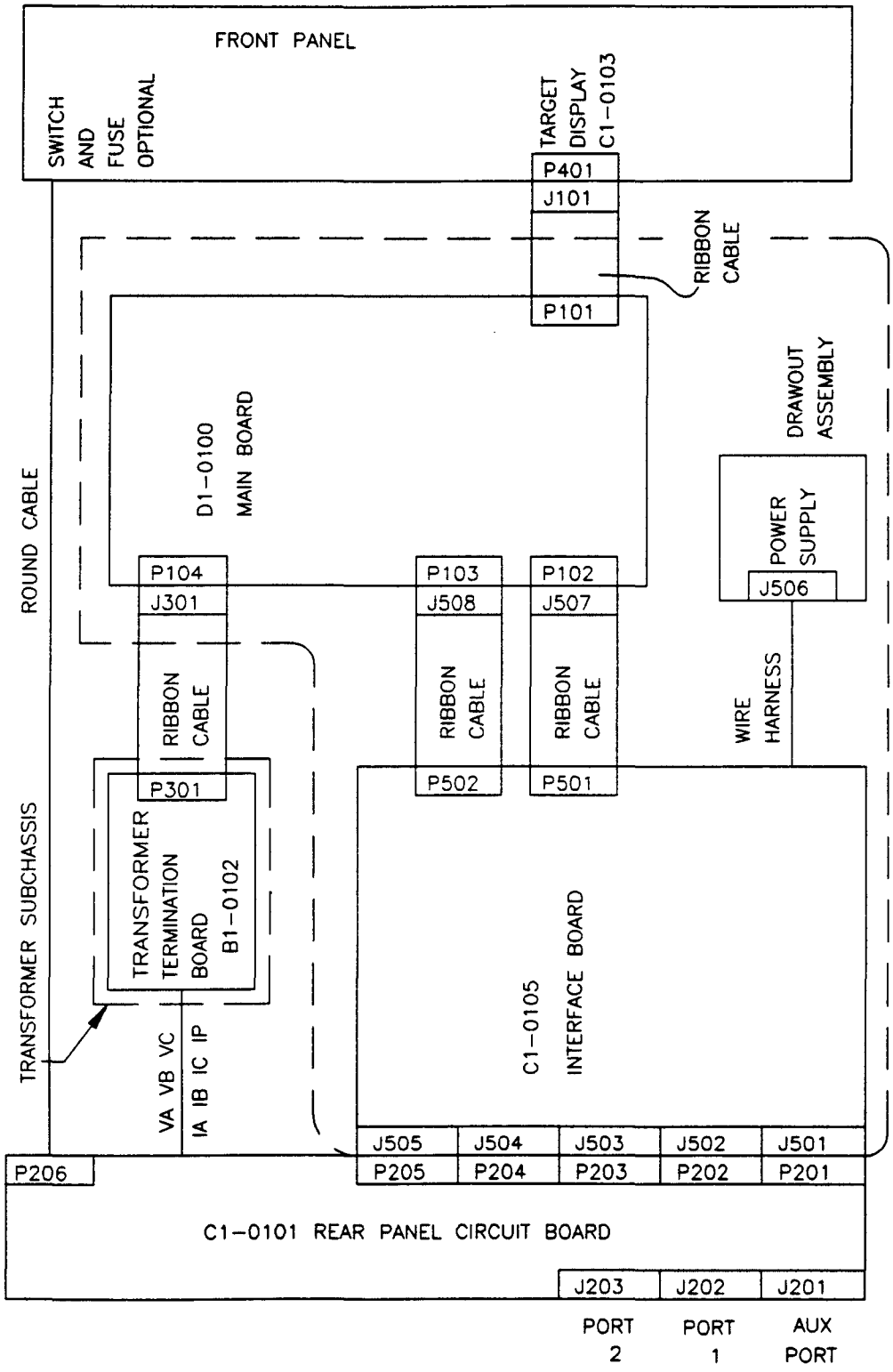
DWG. NO. A7-0174
DATE 5/11/87 JS
REV. 3/9/88

APPENDIX C

MODULE INTERCONNECTIONS

DWG. NO. A7-0905
DATE: 07-08-91

MODULE INTERCONNECTIONS



APPENDIX D

BASIC PROGRAM FOR COMPUTING TEST SET SETTING FOR DISTANCE RELAY/FAULT LOCATOR TESTING

SCHWEITZER ENGINEERING LABORATORIES, INC.
Making Electric Power Safer, More Reliable, and More Economical

ONEBUS: PROGRAM TO COMPUTE TEST SET SETTINGS FOR TESTING DISTANCE RELAYS

The BASIC program in this note determines voltages and currents which would appear on distance relay terminals for ground and phase faults on a radial system with source impedance at the same angle as line impedance. It is useful in determining test voltage and current settings for SEL distance relays and fault locating equipment.

The program was initially designed to run on a TRS-80 Model 100 briefcase computer but may be installed on virtually any personal computer or laptop.

The program first prompts you for the positive and zero-sequence impedances of the transmission line. Enter the data in secondary ohms for the entire length of the protected line.

Next, you may enter fault resistance, which is used in the ground-fault computations.

Enter source impedance as a per-unit value with a base of the previously-entered transmission line data. For example, if the radial system has a source impedance of about ten percent of the entered line impedance, enter 0.1 for the per-unit distance from the source to the bus.

Specify the distance from the bus to the fault as a fraction of the total line length. To obtain the voltages and currents for a fault one-half the way down the line from the bus, enter 0.5 for the distance from the bus to the fault.

After you enter this data, the program begins computations. The display then shows voltages and currents for both an AG and BC fault. These data can be entered into any active test source.

The bottom line of the display offers you a choice of entering new impedance data (I), changing the distance from the source to the bus (B), specifying a new fault location (F), or quitting (Q).

Home Office: 2350 NE Hopkins Court • Pullman, WA USA 99163-5603 Tel: (509) 332-1890 Fax: (509) 332-7990
Eastern Office: 71 E Rambler • Holland, PA USA 18966-2034 Tel & Fax: (215) 322-5226
Central Office: 140 Iowa Ave, Suite 201 • Belleville, IL USA 62220-3940 Tel: (618) 233-1010 Fax: (618) 233-1042

```
1     REM SCHWEITZER ENGINEERING LABORATORIES, INC.
2     REM 2350 NE Hopkins Court
3     REM Pullman, WA  99163-5603
4     REM
10    REM COMPUTE DOBLE SETTINGS FOR A ONE-BUS SYSTEM
20    REM HOMOGENEOUS SYSTEM
30    REM SOURCE VOLTS= 67 L-N
40    REM
50    REM ENTER IMPEDANCES FOR 100% OF LINE
60    INPUT "ENTER Z1: R,X";R1,S1
70    INPUT "ENTER Z0: R,X";R0,S0
75    INPUT "ENTER RF FOR GND FLTS";RF
80    REM
90    REM ENTER BUS LOC. FROM SOURCE
100   INPUT "DIST SOURCE TO BUS (PU OF LINE)";S
120   INPUT "DIST BUS TO FAULT (PU OF LINE)";F
130   REM
140   REM  PHASE A TO GROUND
150   REM COMPUTE POS SEQ CURRENT
160   X = R0+2*R1: Y = S0+2*S1
170   R3 = R1-R0:   S3 = S1-S0
180   AR=1/(S+F):  AI=0
190   BR=X       :  BI=Y
195   BR=BR+3*RF/(S+F)
200   GOSUB 2000
210   I = RR     :   J = RI
220   IA = 3*67*I:  JA=3*67*J
225   IB=0:JB=0:IC=0:JC=0
230   AR=X:AI=Y:BR=I:BI=J
232   GOSUB 1000
234   UA=67*(1-S*RR):VA=67*(-S*RI)
240   AR=R3       :AI=S3
250   BR=I        :BI=J
260   GOSUB 1000
270   TR=S*RR     :TS=S*RI
280   UB=67*(-0.5+TR)
290   VB=67*(-SQR(3)/2+TS)
300   UC=67*(-0.5+TR)
310   VC=67*(SQR(3)/2+TS)
315   FF$="A-G"
320   GOSUB 4041
500   REM  B-C FAULT
510   AR=1: AI=0
520   BR=2*R1*(S+F):BI=2*S1*(S+F)
530   GOSUB 2000
540   I=RR:J=RI
550   IA=0:JA=0
560   AR=I:AI=J:BR=0:BI=-67*SQR(3)
570   GOSUB 1000
580   IB=RR:JB=RI:IC=-IB:JC=-JB
590   UA=67:VA=0
600   AR=I:AI=J:BR=S*RI:BI=S*S1
610   GOSUB 1000
620   AR=RR:AI=RI:BR=0:BI=SQR(3)
630   GOSUB 1000
635   TR=RR:TS=RI
640   UB=67*(-0.5+TR)
650   VB=67*(-SQR(3)/2+TS)
660   UC=67*(-0.5-TR)
670   VC=67*(0.5*SQR(3)-TS)
675   FF$="B-C"
680   GOSUB 4041
900   INPUT "IMP BUS FAULT OR QUIT (I,B,F,Q)";A$
910   IF A$ = "I" THEN GOTO 50
920   IF A$ = "B" THEN GOTO  75
930   IF A$ = "F" THEN GOTO 120 ELSE GOTO 999
999   END
1000  REM MULT SUBROUTINE
1010  REM AR,AI * BR,BI = RR,RI
1020  RR=AR*BR-AI*BI
1030  RI=AI*BR+AR*BI
1040  RETURN
2000  REM DIVISION SUBROUTINE
2010  REM AR,AI / BR,BI = RR,RI
2020  D = BR*BR + BI*BI
2030  RR = AR*BR + AI*BI
2040  RR = RR/D
2050  RI = BR*AI - AR*BI
2060  RI = RI/D
2070  RETURN
3000  REM RECT TO POLAR CONV
3010  REM AR,AI, TO RH, TH
3020  PI = 3.14159265358
3030  IF (AR=0 AND AI=0) THEN    RH=0: TH=0: RETURN
3040  IF (AR=0 AND AI>0) THEN    RH=AI: TH=90:RETURN
3050  IF (AR=0 AND AI<0) THEN RH=-AI: TH=-90: RETURN
3060  IF (AR>0) THEN TH=(180/PI)*ATN(AI/AR)
3070  IF (AR<0) THEN TH=(180/PI)*ATN(AI/AR)+180
3080  IF TH>180 THEN TH = TH-360
3090  RH=SQR(AR*AR+AI*AI)
3100  RETURN
4041  AR=UA:AI=VA:GOSUB 3000
4042  UA=RH:VA=TH
4043  AR=UB:AI=VB:GOSUB 3000
4044  UB=RH:VB=TH-VA
4045  AR=UC:AI=VC:GOSUB 3000
4046  UC=RH:VC=TH-VA
4047  AR=IA:AI=JA:GOSUB 3000
4048  IA=RH:JA=TH-VA
4049  AR=IB:AI=JB:GOSUB 3000
4050  IB=RH:JB=TH-VA
4055  AR=IC:AI=JC:GOSUB 3000
4060  IC=RH:JC=TH-VA
4061  VA=0
4100  PRINT " VA   VB   VC   IA   IB   IC"
4130  PRINT USING"##.# ";UA;UB;UC;IA;IB;IC,
4132  PRINT FF$
4140  PRINT USING"#### ";VA;VB;VC;JA;JB;JC
4150  RETURN
```

APPENDIX E

TEST PROCEDURE

SEL-167 TEST PROCEDURE

Testing the relay requires that you complete the Initial Checkout in Section Two of this manual as well as the steps below.

Initial Checkout

Be sure to finish the Initial Checkout in Section Two before using the tests below. The checkout procedure makes it easy to set up the relay for testing and ensures proper functioning.

Setting Test

To make sure the SEL-167 relay accepts settings, perform the following steps:

1. Gain Level 2 Access (see ACCESS and 2ACCESS commands).
2. Type **SET** and press **<ENTER>**.
3. Change one setting. For example, change the maximum torque angle (MTA) from 49 to 60 degrees.
4. Type **END <ENTER>** to complete the setting procedure. When you receive the "OK (Y or N) ?" prompt, answer **YES <ENTER>**. The ALARM contact should close for several seconds while the relay computes internal settings, unless an alarm condition exists (i.e. self test failure).
5. Use SHOWSET to inspect the settings; make sure your change was accepted.
6. Use SET and SHOWSET again to restore and check the settings.
7. Type **LOG MTU <ENTER>**.
8. Change one bit.
9. Complete the logic setting procedure.
10. Type **LOG MTU <ENTER>** again, and make sure the bit change is present. Restore the setting, and use SHOWSET to check the original setting.

METER Test

This single-phase test checks the magnitude accuracy and phase balance.

1. Connect the voltage input terminals VA, VB, and VC. Apply 50 Vac from the terminals to the neutral point.

2. Connect the current inputs in series and apply a current of five amperes through the three inputs. One way to do so without a test set is to derive this current using a resistor and a stepdown transformer energized from the same source. When the instruments provide 50 Vac input to the voltage inputs, the phase angle between the current and the voltage is nearly zero.

3. Use the METER command to inspect the measured voltages, currents, and power. Voltages VA, VB, and VC should equal the applied voltage times the potential transformer ratio setting. With the Example 69 kV Line settings, you should obtain:

$$VA = VB = VC = 50 * 600 = 30 \text{ kV}. \quad (\pm 0.5\ \%)$$

Voltages VAB, VBC, and VCA should be less than 0.3 kV.

Similarly, currents IA, IB, and IC should equal the applied current times the current transformer ratio. With the Example 69 kV Line settings, you should obtain:

$$IA = IB = IC = 5 * 60 = 300 \text{ A}. \quad (\pm 1\ \%)$$

Difference currents IAB, IBC, and ICA should be less than 6 amperes.

The power reading should be:

$$VA*IA + VB*IB + VC*IC = 27 \text{ MW}.$$

The reactive power reading should be less than 0.24 MVAR.

Directional Element Checking

Type **TAR 1 <ENTER>** (TARGETS command) to observe Relay Word Row #1 (r1) with the DFP and DRP bits for testing the negative-sequence element. The DFP bit status is displayed on the fourth LED from the right. The DRP bit status is displayed on the eighth LED from the right.

The negative-sequence element may be checked as follows:

Apply VA = 30 volts, VB = 0, and VC = 0. This results in an applied V2 = 10 volts.

Apply IA = 3 amperes, corresponding to a negative-sequence current of one ampere.

Move the phase of the current with respect to the voltage, and observe the boundary of the directional element at MTA ±90 degrees.

The voltage-polarized part of the zero-sequence element is checked identically to the negative-sequence element, except the DFG and DRG bits are used for testing. They are located in Relay Word Row #2 (r2) in the same relative location as the DFP and DRP bits, respectively. Type **TARGET 2 <ENTER>** to display Relay Word Row #2.

Apply the same voltages and currents used for the negative-sequence element test. This yields an applied V0 = 10 volts and I0 of 1 ampere.

Move the phase of the current with respect to the voltage, and observe the boundary of the zero-sequence directional element at MTA ±90 degrees.

The current polarization is checked by turning off the voltage and applying a second current source to the polarizing current input (IP). Use an amplitude of 3 amperes and move the phase of IA with respect to IP. Maximum torque is at zero degrees, so you should observe the boundary of the characteristic at ±90 degrees.

Observe the DFP and DRP bits to check the positive-sequence element. Apply the following balanced three-phase voltages to the relay:

	VA	VB	VC	
MAGNITUDE	67	67	67	(volts)
ANGLE	0	-120	120	(degree)

Use an amplitude of 5 amperes for IA and move the phase of IA with respect to the balanced three-phase currents. Observe the boundary of the positive-sequence directional element at MTA ±90 degrees.

Overcurrent Element Checking

Type **TARGET 1 <ENTER>** to check pickup of the 50N1, 50N2, and 50N3 residual-overcurrent elements. The command displays Relay Word Row #1 with the overcurrent element bits on the target LEDs.

Apply current to one phase, and observe the pickup and dropout of each element.

Check the pickup and dropout of the phase overcurrent elements in a similar manner by typing **TARGET 1 <ENTER>** to display the 50P1, 50P2, and 50P3 bits on the LEDs. Apply current to one phase, and observe the pickup and dropout of each element.

Check the pickup of residual time-overcurrent element (51NP) and phase time-overcurrent element (51PP) with the TOCP (Time-overcurrent pickup indicator: 51NP + 51PP) bit in Relay Word Row #4. Type **TARGET 4 <ENTER>** to check these pickups. Set the pickup of the element not being tested greater than the element being tested. Apply current to one phase (close in magnitude to the set pickup) and observe the pickup and dropout of the element. Change the pickup levels and test the other element.

Testing the Input Circuits

1. Use the TARGETS command to set the LEDs to follow the contact inputs. Type **TAR 5 <ENTER>**.

2. Apply control voltage to each input and observe that the corresponding target LED turns on. Event reports should be triggered whenever you energize the DT, PT, BT, and ET inputs.

Testing the Serial Ports

The Initial Checkout procedure assumes that you connect a terminal to PORT 2. Set the baud rate of PORT 1 to the same value as that of PORT 2 and switch your terminal from PORT 2 to PORT 1. Make sure you can communicate through this port.

Testing the IRIG-B Time Code Input

1. Connect a source of demodulated IRIG-B time code to the Auxiliary Port of the SEL-167 relay with a series resistor to monitor the current. Adjust the source to obtain an "ON" current of about 10 mA.

2. Execute the IRIG command, and make sure the SEL-167 relay clock displays the correct date and time.

Note: For a convenient, inexpensive test of the IRIG-B port, use a recording of the IRIG-B signal passed through a simple demodulator. Please contact the factory for further details.

Testing the Power Supply Voltages

1. Execute the STATUS command and inspect the voltage readings for the +5 and ±15 volt supplies.

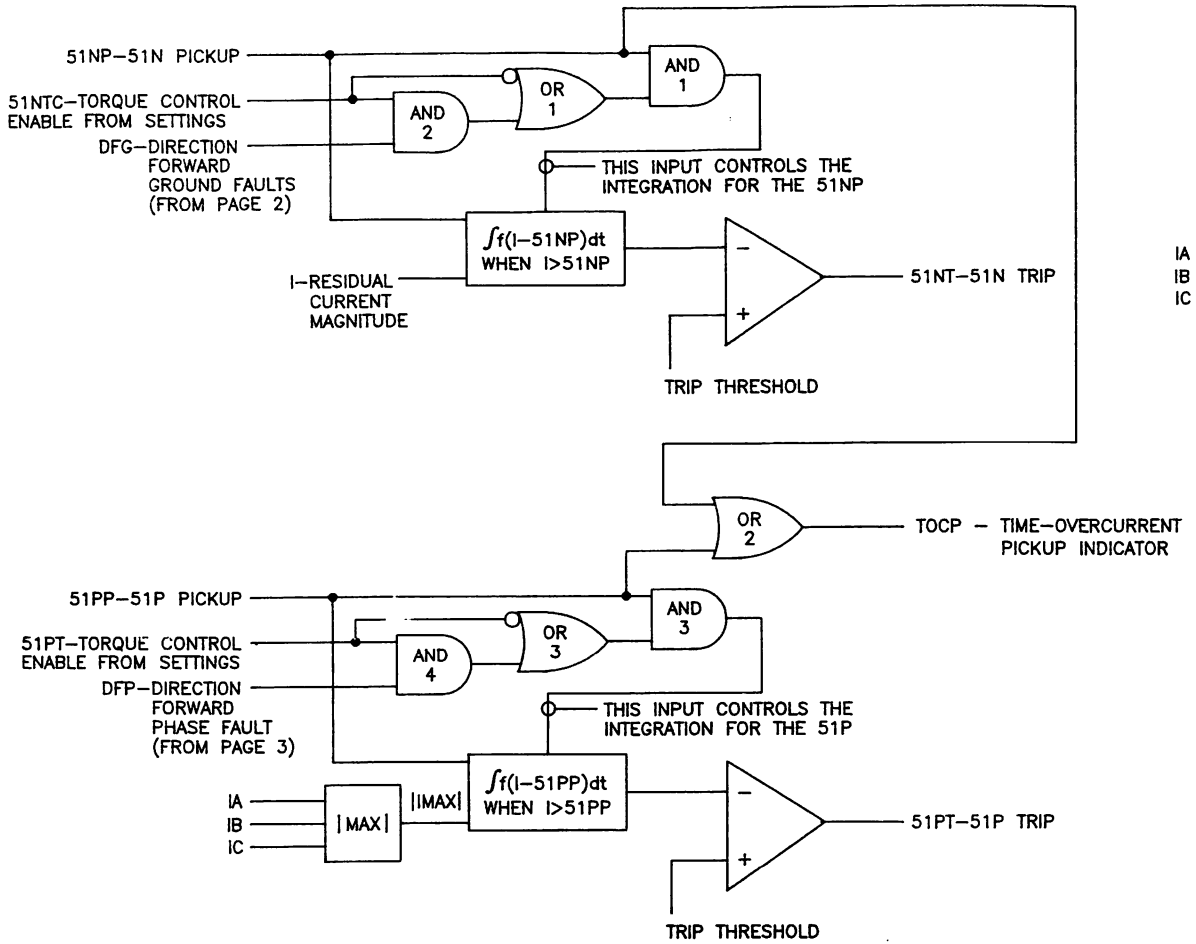
2. At the Auxiliary Port, use a voltmeter to read the +5 and ±12 volt outputs. The 12 volt outputs are derived from the 15 volt supplies using three-terminal regulators.

3. Compare the +5 volt readings from the status report and the voltmeter. The voltage difference should be less than 50 mV, and both readings should be within 0.15 volts of five volts.

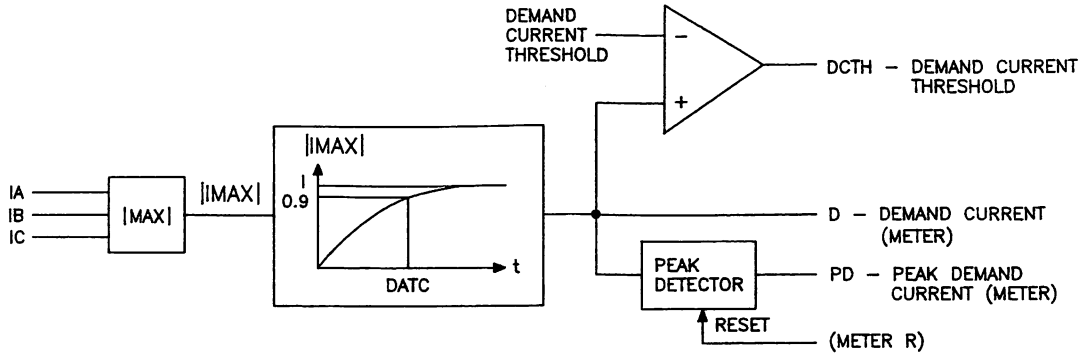
4. The 12 volt supplies should be within 0.5 volt of their nominal values.

APPENDIX F

LOGIC DIAGRAMS



SEL–167 PHASE TIME–OVERCURRENT (51P) AND GROUND TIME–OVERCURRENT (51N) LOGIC DIAGRAM



SEL–167 DEMAND AMMETER

UNLESS OTHERWISE NOTED ALL DIMENSIONS ARE IN INCHES
.XXX DIMENSIONS NOT TO SCALE

USED ON: SEL–167

RELEASED | APP. | CH. | DR.

TOL EXCEPT AS NOTED
HOLE DIA.
XX ± .01"
XXX ± .005"
ANG. ± 1°

ITEM	PART NO.	DESCRIPTION	QTY.

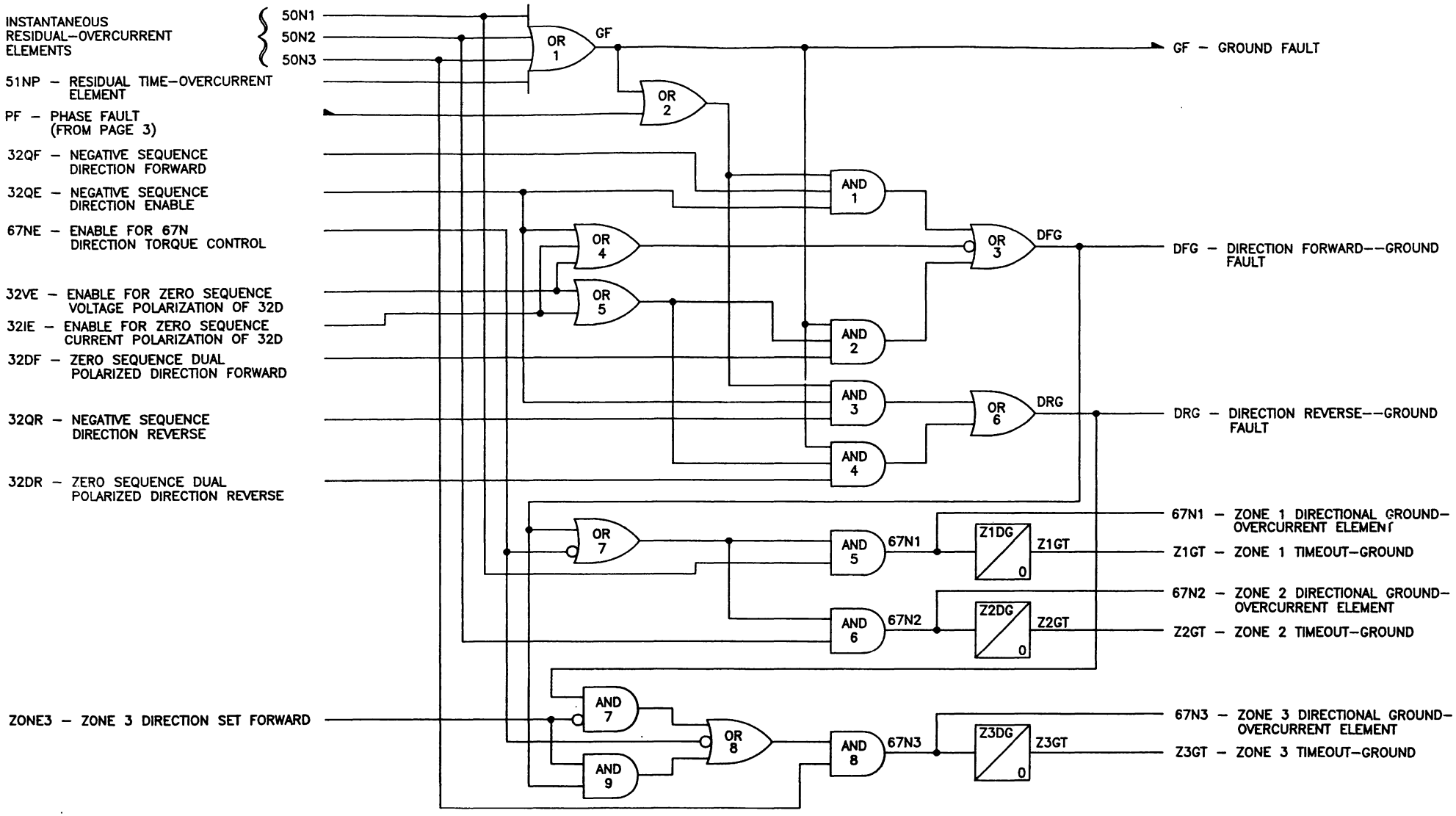
SCALE: NONE

TITLE: SEL–167 LOGIC DIAGRAMS

SEL SCHWEITZER ENGINEERING LABORATORIES PULLMAN WASHINGTON USA

DWG. NO. B7–0287 REV. I

SHEET 1 OF 4



SEL–167 INSTANTANEOUS AND DIRECTIONAL GROUND–OVERCURRENT LOGIC DIAGRAM

UNLESS OTHERWISE NOTED ALL DIMENSIONS ARE IN INCHES
.XXX DIMENSIONS NOT TO SCALE

USED ON: SEL–167

RELEASED | APP. | CH. | DR.

TOL. EXCEPT AS NOTED
HOLE DIA.
XX ± .01"
XXX ± .005"
ANG. ± 1°

ITEM	PART NO.	DESCRIPTION	QTY.

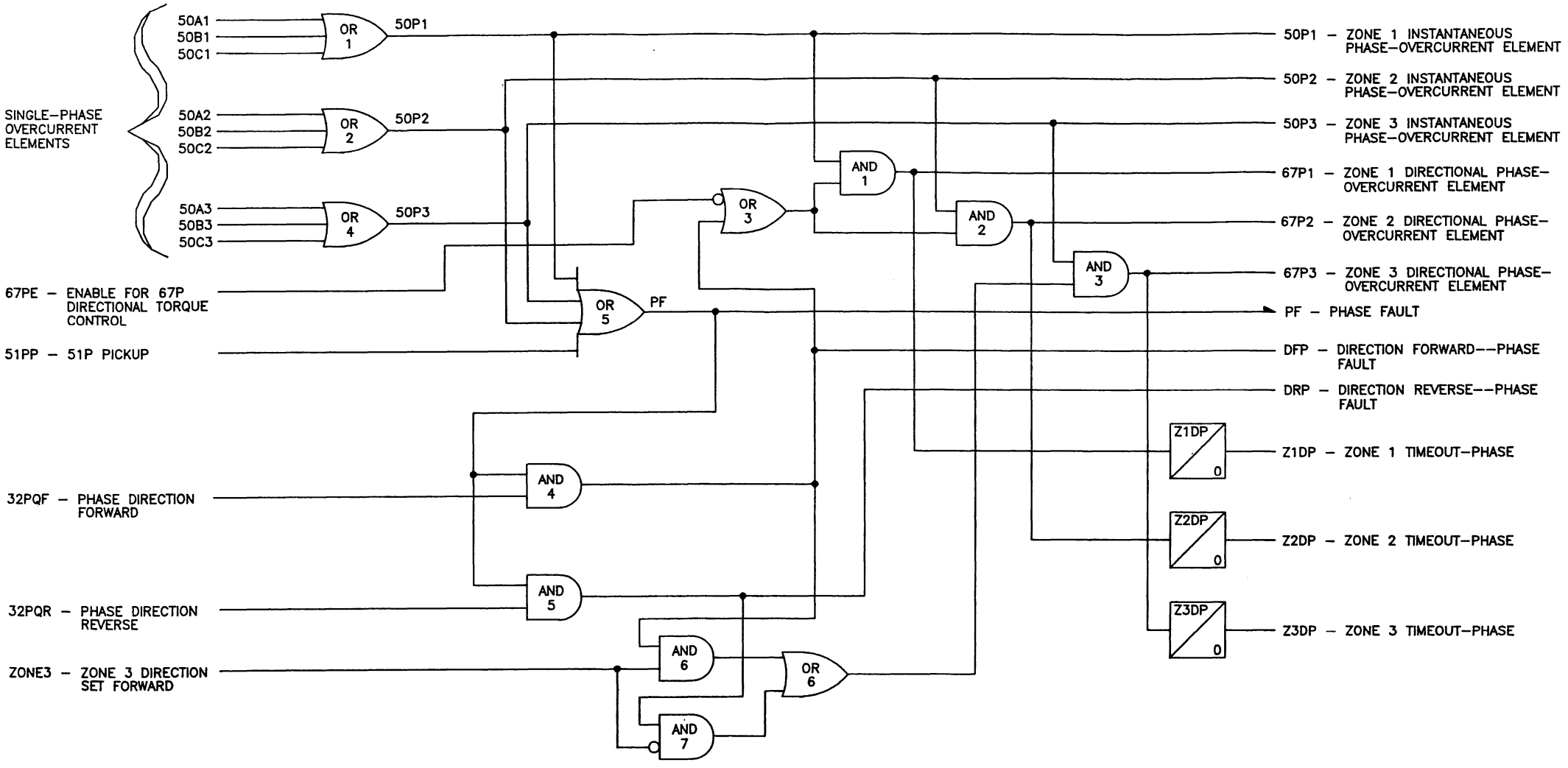
SCALE: NONE

TITLE: SEL–167 LOGIC DIAGRAMS

SEL SCHWEITZER ENGINEERING LABORATORIES PULLMAN WASHINGTON USA

DWG. NO. B7–0287 REV. I

SHEET 2 OF 4



SEL–167 INSTANTANEOUS AND DIRECTIONAL PHASE–OVERCURRENT LOGIC DIAGRAM

UNLESS OTHERWISE NOTED ALL DIMENSIONS ARE IN INCHES

.XXX DIMENSIONS NOT TO SCALE

USED ON: SEL–167

RELEASED | APP. | CH. | DR.

TOL. EXCEPT AS NOTED

HOLE DIA.

XX ± .01"
XXX ± .005"
ANG. ± 1°

ITEM	PART NO.	DESCRIPTION	QTY.

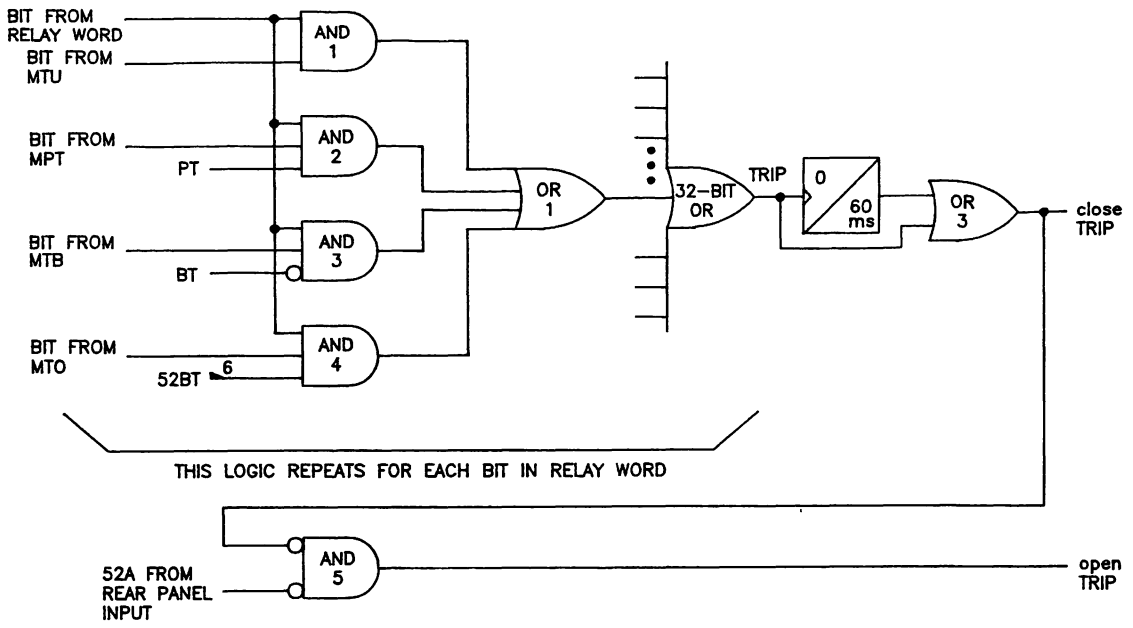
SCALE: NONE

TITLE: SEL–167 LOGIC DIAGRAMS

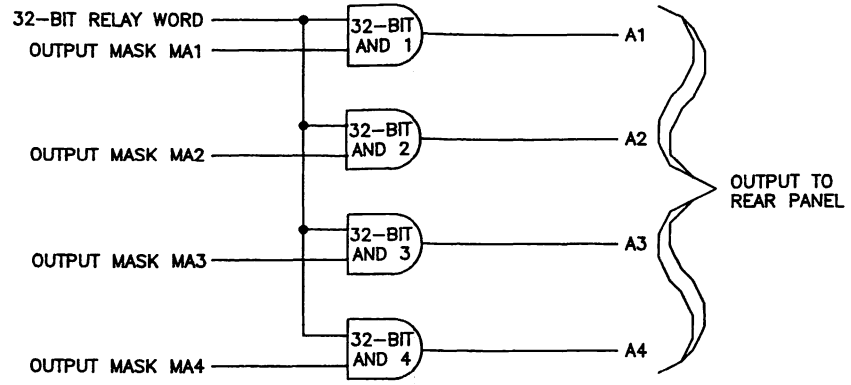
SEL SCHWEITZER ENGINEERING LABORATORIES PULLMAN WASHINGTON USA

DWG. NO. B7–0287 REV. I

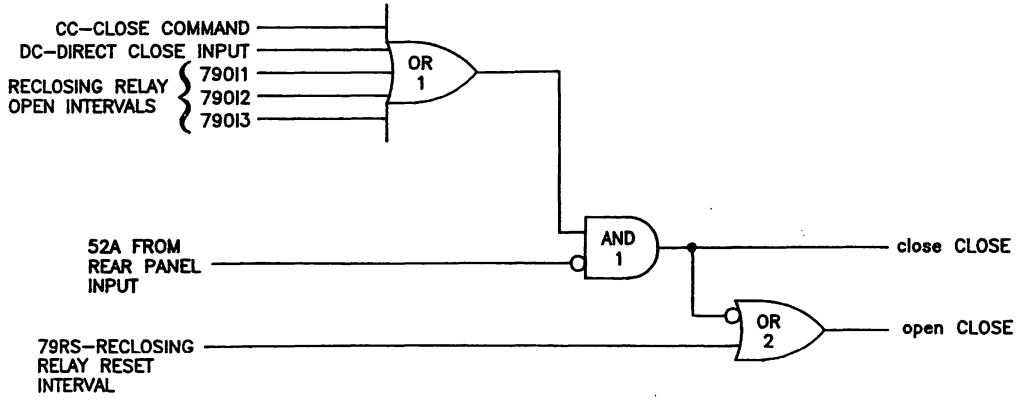
SHEET 3 OF 4



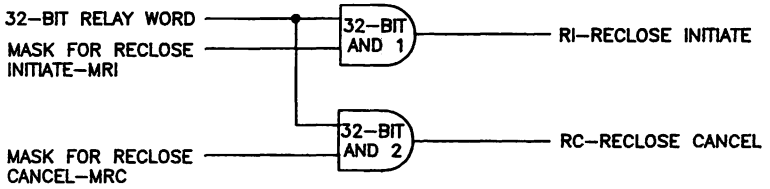
SEL–167 PROGRAMMABLE TRIP LOGIC DIAGRAM



SEL–167 PROGRAMMABLE OUTPUT LOGIC DIAGRAM



SEL–167 CLOSE LOGIC DIAGRAM



SEL–167 PROGRAMMABLE RECLOSE INITIATE AND CANCEL LOGIC DIAGRAM

MTU–MASK FOR UNCONDITIONAL TRIP
MPT–MASK FOR TRIP WITH PERMISSIVE–TRIP ASSERTED
MTB–MASK FOR TRIP WITH BLOCK–TRIP UNASSERTED
MTO–MASK FOR TRIP WITH BREAKER OPEN
PT–PERMISSIVE TRANSFER TRIP
BT–BLOCK TRIP
52BT–52A INPUT TIMER INVERTED OUTPUT

UNLESS OTHERWISE NOTED ALL DIMENSIONS ARE IN INCHES
.XXX DIMENSIONS NOT TO SCALE
USED ON SEL–167
RELEASED
APP.
CH.
DR.
TOL. EXCEPT AS NOTED
HOLE DIA.
XX ± .01"
XXX ± .005"
ANG. ± 1°

ITEM	PART NO.	DESCRIPTION	QTY.

SCALE NONE
TITLE SEL–167 LOGIC DIAGRAMS
SEL SCHWEITZER ENGINEERING LABORATORIES PULLMAN WASHINGTON USA
DWG. NO. B7–0287 REV. I
SHEET 4 OF 4

APPENDIX G

APPLICATION IDEAS

SEL-167 APPLICATION IDEAS

Radial Feeder Protection

The directional elements are easily disabled by setting 67NE and 67PE to "N". This allows set up of traditional 50/51, 50N/51N protection. Use one each of the extra 67N/67P elements through their timers (e.g. Z2P, Z2G) to control a programmable output for bus/breaker backup protection. The fault locator is useful for directing line crews to the sectionalizing switches closest to the fault. Use the remote setting feature to quickly optimize settings when line sections are back fed. The demand ammeter threshold (DCTH) bit can control an output to signal load encroachment or overload.

Backup Relay

Use long definite-time setting on phase elements to backup primary phase distance elements (e.g. SEL-121G or SEL-121F relays). Set the ground elements with some additional time delay. Reverse the 67P3 and 67N3 direction, and set their timers long for local bus backup and breaker failure.

Fault Locator for Several Radial Feeders

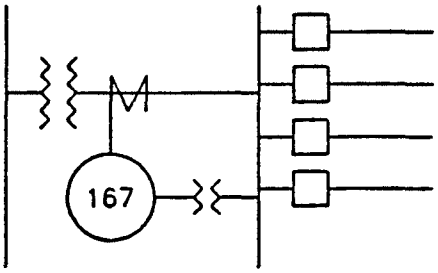
Connect the SEL-167 relay to the low-side bushing CTs and bus PTs, so the relay receives the total current into all feeders from that bus. When a fault occurs on any of the feeders, the SEL-167 relay will locate it. Errors due to the load current in the unfaulted feeders are normally negligible (the faulted feeder is easily identified from its own protection). Use long time delays for breaker/bus backup to trip the primary breaker.

Test Instrument

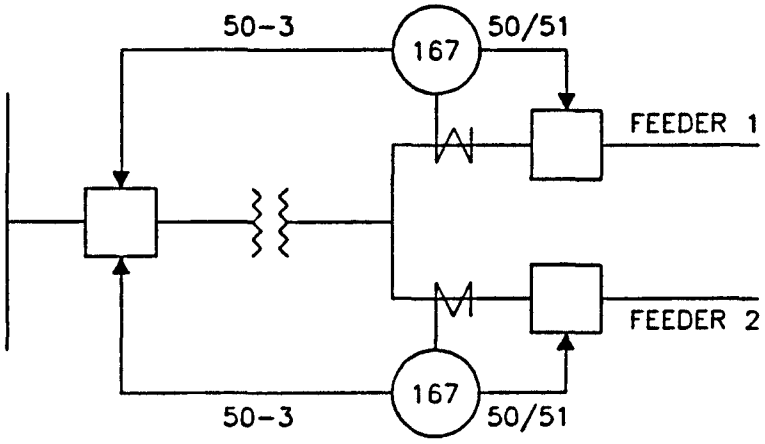
The SEL-167 relay is both low in cost and simple to connect; it is easily installed for data collection during station commissioning or other tests. Use it when energizing new lines, capacitor banks, transformers, reactors, cables, etc.

Portable Relay Terminal

Configure the SEL-167 relay for use as a portable temporary line or feeder terminal. Its compact size and 21 pound weight make application easy and fast. Use it when conventional relays must be taken out of service for testing, in emergency situations, and in temporary feeder installations.



LOCATE FAULTS ON MANY FEEDERS
USING ONE FAULT–LOCATING RELAY



50/51/50–2 FOR FEEDER PROTECTION

50–3 DEFINITE–TIME DELAY FOR BREAKER BACKUP

FEEDER RELAYS PROVIDE BREAKER BACKUP

DWG. NO. A7–0555
DATE: 06–19–88

SEL-167 DIRECTIONAL OVERCURRENT RELAY/FAULT LOCATOR COMMAND SUMMARY

Level 0

ACCESS Answer password prompt (if password protection enabled) to gain access to Level 1. Three unsuccessful attempts pulses ALARM relay.

Level 1

2ACCESS Answer password prompt (if password protection enabled) to gain access to Level 2. This command always pulses the ALARM relay.

DATE Show or set date. DAT 2/3/89 sets date to Feb. 3, 1989. Pulses the ALARM relay momentarily when a different year is entered than previously stored year. The month and date settings are overridden when IRIG-B synchronization occurs.

EVENT Show event record. EVE 1 shows long form of most recent event.

HISTORY Show DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION, CURRENT, and TARGETS for the 12 most recent faults.

IRIG Force immediate execution of time-code synchronization task.

METER Show primary current, demand current, peak demand, voltage, and real and reactive power. METER runs once. "METER N" runs N times. " METER R" resets the peak demand currents.

QUIT Return to Access Level 0 and reset targets to target 0.

SHOWSET Show the relay and logic settings. This command does not affect the settings. The logic settings are shown in hexadecimal format for each mask.

STATUS Show self test status.

TARGETS Show data and set target lights as follows:

TAR 0: Relay Targets	TAR 1: RELAY WORD #1
TAR 2: RELAY WORD #2	TAR 3: RELAY WORD #3
TAR 4: RELAY WORD #4	TAR 5: Contact Inputs
TAR 6: Contact Outputs	TAR R: Clears targets and returns to TAR 0

Be sure to return to TAR 0 when done, so LEDs display fault targets.

TIME Show or set time. TIM 13/32/00 sets clock to 1:32:00 PM. This setting is overridden when IRIG-B synchronization occurs.

TRIGGER Trigger and save an event record. (Type of event is EXT).

Level 2

CLOSE Close circuit breaker, if allowed by jumper setting.

LOGIC Show or set logic masks MTU, MPT, MTO, MTB, MRI, MRC, MA1-MA4. ALARM relay closes while new settings are being computed, and event data buffers are cleared.

OPEN Open circuit breaker, if allowed by jumper setting.

PASSWORD Show or set passwords. Pulses the ALARM relay momentarily when new passwords are set.
PAS 1 OTTER sets Level 1 password to OTTER.
PAS 2 TAIL sets Level 2 password to TAIL.

SET Initiate setting procedure. ALARM relay closes while new settings are being computed, and event data buffers are cleared.

Use the following to separate commands and their parameters: space, comma, semicolon, colon, slash.

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court
Pullman, WA 99163-5603
TEL: (509) 332-1890 FAX: (509) 332-7990

SEL/11-88, 5-90

EXPLANATION OF EVENT REPORT

Example 69 KV Line Date: 3/28/88 Time: 08:45:09.366

FID=SEL-167-R400-V656mp12-D900323

Currents (amps)					Voltages (kV)			Relays 565565 071071 PPPNNN	Outputs TCAAAAA PL1234L	Inputs DPBD5E TTTC2T A
IPOL	IR	IA	IB	IC	VA	VB	VC			
0	886	886	0	-1	1.0	35.4	-33.6	2..22.	..*....	....*.
0	-506	-505	0	0	-17.6	28.5	23.7	22.22.	..*....	....*.
0	-1024	-1024	0	1	-1.1	-35.6	33.4	22.12.	*.*....	....*.
0	526	526	0	0	17.2	-28.6	-23.7	22.11.	*.*....	....*.
0	1025	1024	0	-1	1.1	35.6	-33.4	22.11.	*.*....	....*.
-1	-527	-526	0	-1	-17.1	28.6	23.8	22.11.	*.*....	....*.

Event : AG Location : 9.02 mi 1.13 ohms sec
Duration: 4.75 Flt Current: 1154.4 Targets: G1

R1 =49.83	X1 =56.32	R0 =56.07	X0 =143.07	LL =60.00
CTR =60.00	PTR =600.00	MTA =49.00	LOCAT=Y	DATC =15
DCTH =120.00	79OI1=40.00	79OI2=60.00	79OI3=80.00	79RS =240.00
51PP =120.00	51PTD=1.00	51PC =2	51PTC=N	
50P1 =1158.00	50P2 =516.00	50P3 =210.00		
Z1DP =0.00	Z2DP =160.00	Z3DP =30.00		
51NP =30.00	51NTD=2.00	51NC =2	51NTC=N	
50N1 =1008.00	50N2 =450.00	50N3 =30.00		
Z1DG =0.00	Z2DG =30.00	Z3DG =10.00		
52BT =30	ZONE3=R	67NE =Y	67PE =Y	
32QE =N	32VE =Y	32IE =Y		
TIME1=5	TIME2=0	AUTO =2	RINGS=3	

Currents and voltages are in primary amps and kV. Rows are 1/4 cycle apart. Time runs down page. Obtain phasor RMS value and angle using any entry as Y-component, and the entry immediately underneath as the X-component. For example, from bottom rows, IAY = 1024, IAX = -526. Therefore, IA = 1151 amps RMS primary, at an angle of ATAN(1024/-526) = 117 degrees, with respect to the sampling clock.

<FID> Row 2 shows the Firmware Identification Data. This line varies according to version.

<Relays> Columns show states of internal relay elements ---> Designators

50P : phase overcurrent	: 50P1, 50P2, 50P3	---> 1,2,3
67P : directional phase overcurrent	: 67P1, 67P2, 67P3	---> 1,2,3
51P : phase time-overcurrent	: 51PT	---> T
50N : inst ground overcurrent	: 50N1, 50N2, 50N3	---> 1,2,3
67N : directional ground overcurrent	: 67N1, 67N2, 67N3	---> 1,2,3
51N : ground time-overcurrent	: 51NT	---> T

<Outputs> Columns show states of output contacts: ON = "*" , OFF = "."
TP=TRIP, CL=CLOSE, A1-A4=PROGRAMMABLE, AL=ALARM

<Inputs> Columns show states of input contacts:
DT=DIRECT TRIP, PT=PERMISSIVE TRIP, BT=BLOCK TRIP, DC=DIRECT CLOSE, 52A=PCB A-CONTACT, ET=EXTERNAL TRIGGER (event report)

<Event> Event type is one of AG,BG,CG = single-phase, AB,BC,CA = 2-phase ABG,BCG,CAG = 2-phase to ground, ABC = 3-phase followed by a "T" if a TRIP triggered the report
Other indications are TRIP = triggered by TRIP output and EXT = externally or otherwise triggered

<Location> Distance to fault in miles. Indeterminate distance is 999999.

<Ohms Sec> Distance to fault in secondary ohms. Indeterminate ohms is 9999.

<Duration> Fault duration determined from relay element(s) pickup time

<Flt Current> Max phase current (primary amps) taken near middle of fault

<Targets> The targets indicate the relay elements that caused the trip. These targets are the same as the targets displayed on the front panel of the SEL-167 via the TARGET 0 command. The targets field indicates any combination of the following:

P1: Zone 1 phase fault
G1: Zone 1 ground fault
P2: Zone 2 phase fault
G2: Zone 2 ground fault
P3: Zone 3 phase fault
G3: Zone 3 ground fault
51P: Phase time-overcurrent trip
51N: Residual time-overcurrent trip

R1,X1,R0,X0	Primary series impedance settings for transmission line
LL	Line length corresponding to specified line impedances
CTR, PTR	Current and potential transformer ratios (XTR:1)
MTA	Maximum torque angle for the directional elements
LOCAT	Enable or disable fault locator (Y/N)
DATC	Demand ammeter time constant
DCTH	Demand current threshold
79OI1,2,3,RS	Three-shot recloser Open and Reset intervals
51PP,TD,C,TC	Phase time-overcurrent pickup, Time-Dial, Curve, Torque Control
50P1,2,3	Phase inst-overcurrent pickup settings zones 1, 2 and 3
Z1DP,2,3	Zones 1, 2 and 3 timer settings for 3- and 2-phase faults
51NP,TD,C,TC	GND time-overcurrent Pickup, Time-Dial, Curve, Torque Control
50N1,2,3	Ground inst-overcurrent pickup settings zones 1, 2 and 3
Z1DG,2,3	Zone timers for ground faults
52BT	52B delay setting (for switch-onto-fault coordination)
ZONE3	Directional orientation of all zone 3 elements (Fwd/Rvs)
67NE,PE	Ground and phase fault torque control enables
32QE,VE,IE	Ground fault directionality from (V2,I2), or (V0/IP,I0)
TIME1,2	Communications port timeout intervals (automatic log-off)
AUTO	Port assignment for automatic message transmissions
RINGS	Number of rings to wait before modem answers telephone

<Logic Settings> See LOGIC command for a description of mask setting.

SEL-167 DIRECTIONAL OVERCURRENT RELAY/FAULT LOCATOR COMMAND SUMMARY

Level 0

ACCESS Answer password prompt (if password protection enabled) to gain access to Level 1. Three unsuccessful attempts pulses ALARM relay.

Level 1

2ACCESS Answer password prompt (if password protection enabled) to gain access to Level 2. This command always pulses the ALARM relay.

DATE Show or set date. DAT 2/3/89 sets date to Feb. 3, 1989. Pulses the ALARM relay momentarily when a different year is entered than previously stored year. The month and date settings are overridden when IRIG-B synchronization occurs.

EVENT Show event record. EVE 1 shows long form of most recent event.

HISTORY Show DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION, CURRENT, and TARGETS for the 12 most recent faults.

IRIG Force immediate execution of time-code synchronization task.

METER Show primary current, demand current, peak demand, voltage, and real and reactive power. METER runs once. "METER N" runs N times. " METER R" resets the peak demand currents.

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TIME Show or set time. TIM 13/32/00 sets clock to 1:32:00 PM. This setting is overridden when IRIG-B synchronization occurs.

TRIGGER Trigger and save an event record. (Type of event is EXT).

Level 2

CLOSE Close circuit breaker, if allowed by jumper setting.

LOGIC Show or set logic masks MTU, MPT, MTO, MTB, MRI, MRC, MA1-MA4. ALARM relay closes while new settings are being computed, and event data buffers are cleared.

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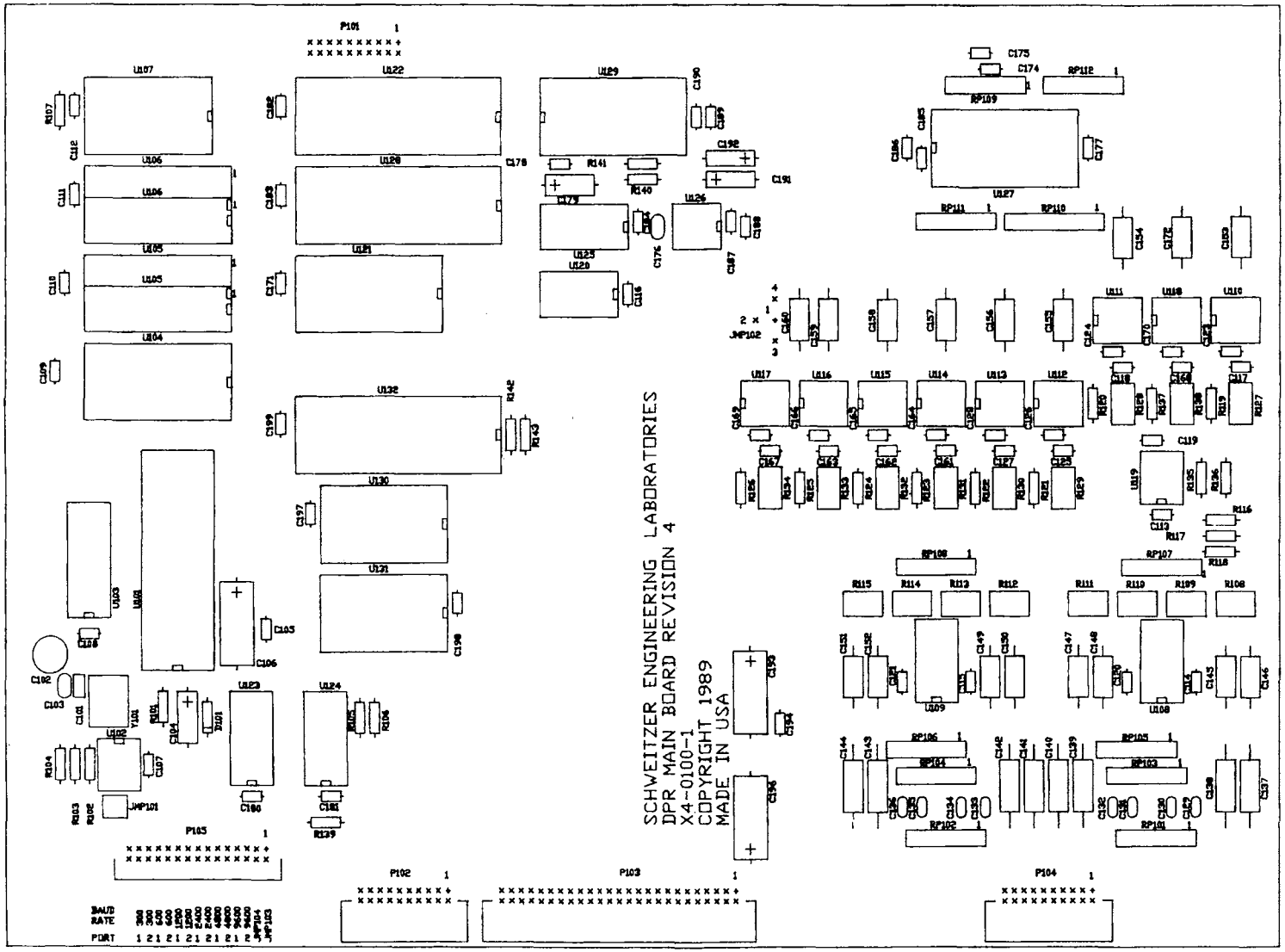
RINGS	Number of rings to wait before modem answers telephone

<Logic Settings> See LOGIC command for a description of mask setting.



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UNLESS OTHERWISE NOTED
ALL DIMENSIONS ARE IN INCHES

.XXX DIMENSIONS NOT TO SCALE

USED ON

RELEASED	
APP.	
CH.	
DR.	

TOL. EXCEPT AS NOTED

HOLE DIA.

XX ± .01"
XXX ± .005"
ANG. ± 1°

ITEM	PART NO.	DESCRIPTION	QTY.

SCALE: NONE

TITLE: DPR MAIN BOARD REVISION 4 PARTS PLACEMENT DIAGRAM

SEL SCHWEITZER ENGINEERING LABORATORIES PULLMAN WASHINGTON USA

DWG. NO. B1-0100 REV. 4

SHEET 1 OF 1