SEL-2PG10
SEL-PG10

SINGLE-ZONE
PHASE DISTANCE RELAY
GROUND DIRECTIONAL
OVERCURRENT RELAY
FAULT LOCATOR

INSTRUCTION MANUAL

SEPTEMBER 20, 1993

SCHWEITZER ENGINEERING LABORATORIES
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Warning

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

ATTENTION!

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 accidential 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-2PG10 INSTRUCTION MANUAL ADDENDUM

Kilometer/60 Hz Options

The SEL-2PG10 instruction manual is written for fault locations in terms of miles. If your SEL-2PG10 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 60 Hz. One wavelength at 60 Hz is 5000 kilometers. For example, the line length of a 100-kilometer line in radians is:

$$(100/5000) \times 2 \times 3.14159 = 0.1257 \text{ radians}$$

The indication neglecting capacitance is about cos(0.1257) = 0.992 times the actual fault location, or about 0.79 kilometers short for a fault at the remote end of a 100-kilometer line.

References made to a sampling time of 1/240 seconds should be replaced with a time of 1/200 seconds.

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-200 SERIES RELAY ADDENDUM

The SEL-200 series relays with 125 Vdc optical isolator inputs now have level-sensitive inputs. These inputs compare to the original SEL-200 series relays as follows:

ORIGINAL SEL-200 SERIES OPTICAL ISOLATOR LOGIC INPUT RATING

125 Vdc: 80 - 150 Vdc; 4 milliamps at nominal voltage

NEW SEL-200 SERIES OPTICAL ISOLATOR LOGIC INPUT RATING

125 Vdc: 100 - 150 Vdc; 6 milliamps at nominal voltage

The optical isolator input does not assert for applied voltages less than 75 Vdc. The firmware remains unchanged.

JUMPER INSTALLATION INSTRUCTIONS FOR ALL 200-SERIES RELAYS EXCEPT SEL-279 AND SEL-279H

The power available from these ports is limited and should be used only for SEL-RDs, SEL-DTAs, dc-powered modems, or other low-wattage devices approved by SEL.

The power is available on either Port 1 or Port 2R. Port 2F, located on the front of the relay, does NOT have power available.

To install jumpers for supplying power through the rear EIA RS-232-C ports on all SEL-200 series relays (except SEL-279 and SEL-279H Relays), perform the following steps:

1. Remove the relay top cover or withdraw the main circuit board.

2. Locate jumpers JMP12 (+5 Vdc), JMP13 (+12 Vdc) and JMP14 (-12 Vdc) near the AUX INPUT connector.

3. Remove and install the needed jumpers in the "on" position.

4. Replace the top cover or re-insert the main circuit board. (Ensure that the board is correctly seated and the cables to the power supply and input transformers are reconnected.)

SEL-200 SERIES (SHALLOW) RELAY HARDWARE ADDENDUM

The shallow SEL-200 series hardware brings a reduction in unit depth and weight. It compares to the original SEL-200 series relay hardware as follows:

ORIGINAL SEL-200 SERIES RELAY HARDWARE SPECIFICATIONS

3.47" x 19.00" x 11.66" (8.81 cm x 48.26 cm x 29.62 cm) (H x W x D)

16 pounds (7.3 kg)

SEL-200 SERIES (SHALLOW) RELAY HARDWARE SPECIFICATIONS

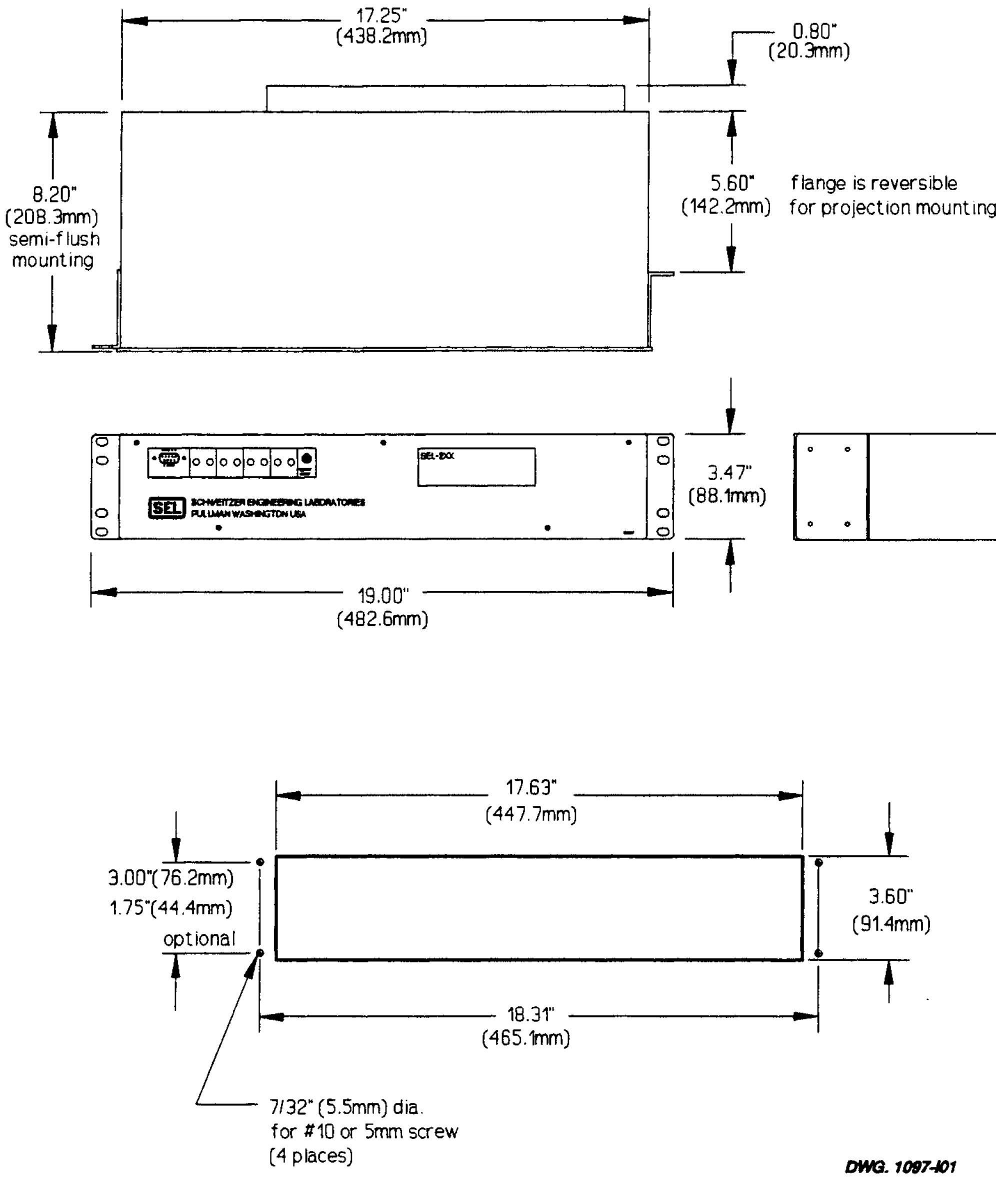
3.47" x 19.00" x 9.00" (8.81 cm x 48.26 cm x 22.86 cm) (H x W x D)

12 pounds (5.5 kg)

Depth (dimension D) is to the end of the rear panel terminal blocks.

This hardware is also equipped for low-level testing. The firmware remains unchanged.

The shallow SEL-200 series relay dimensions, panel cutout, and drill diagrams are on the following page. Note that the long cutout dimension has increased by 0.25" to 17.63" (44.77 cm).



SEL-200 Series (Shallow) Relay Dimensions, Panel Cutout, and Drill Diagrams

TABLE OF CONTENTS

INTRODUCTION

Overview 1-1
General Information 1-1
Specifications 1-2
Basic Protective Capabilities 1-7
Hardware Description 1-9
Signal Processing 1-11

INITIAL CHECKOUT

Equipment Required 2-1
Checkout Procedure 2-1

FUNCTIONAL DESCRIPTION

Introduction 3-1
Inputs and Outputs 3-1
Definition of Logic Variables 3-4
Intermediate Logic 3-5
Relay Word 3-6
Output Equations 3-7
Targets 3-7
Self-Tests 3-8
Setting Procedure 3-10
Event Report and Fault Locator 3-10
Mho Units 3-13
Directional Elements 3-14
Time-Overcurrent Element 3-14
Time-Overcurrent Curve Equations 3-15

COMMANDS AND SERIAL COMMUNICATIONS

Introduction 4-1
Serial Port Connections and Configurations 4-2
Communications Protocol 4-4
Command Characteristics 4-6
Command Descriptions 4-8
SEL-2PG10 Distance Relay/Fault Locator Command Summary 4-23

EVENT REPORTING

Introduction 5-1
Example Event Report 5-2
Interpretation of Voltage and Current Data 5-2
Relay Elements Status Indicators 5-4
Firmware Identification 5-6
Sample Event Report 5-7

INSTALLATION

Mounting 6-1
Frame Ground Connection 6-1
Power Connections 6-1
Secondary Circuits 6-1
Control Circuits 6-2
Communications Circuits 6-2
Jumper Selection 6-2
EIA RS-232-C and IRIG-B Installation 6-4
Initial Checkout 6-5
SEL Direction and Polarity Check Form 6-12

MAINTENANCE AND TESTING

Test Procedure 7-1
Removal of Front Panel and Drawout Assembly 7-6
Calibration 7-6
Troubleshooting Guide 7-6
Program to Compute Test Set Settings for Testing Distance Relays 7-11

APPENDICES

Firmware Versions A-1
Parts Placement Diagram B-1
Settings Sheets C-1

TABLES

Table 1.1: Directional Element Sensitivities at Maximum Torque Angle (MTA) 1-5
Table 2.1: Fault Test Results 2-5
Table 3.1: Relay Word Bit Summary Table 3-6
Table 3.2: Power Supply Self-Test Limits 3-9
Table 4.1: SEL-2PG10 Relay Serial Port Connector Pin Assignments 4-3
Table 4.2: SEL-PG10 Relay Serial Port Connector Pin Assignments 4-4
Table 4.3: Hexadecimal/Binary Conversion 4-14
Table 4.4: Self-Test Summary 4-16
Table 4.5: Target LED Assignment 4-16

FIGURES

Figure 1.1: 32Q and 32V Polarization Criteria 1-5
Figure 1.2: 32I Polarization Criteria 1-5
Figure 1.3: Relay Function Block Diagram 1-8
Figure 1.4: Relay Hardware Block Diagram 1-10
Figure 3.1: Residual Time-Overcurrent Element Moderately Inverse Time Characteristic (Curve 1) 3-17
Figure 3.2: Residual Time-Overcurrent Element Inverse Time Characteristic (Curve 28 3-17
Figure 3.3: Residual Time-Overcurrent Element Very Inverse Time Characteristic (Curve 3) 3-19
Figure 3.4: Residual Time-Overcurrent Element Extremely Inverse Time Characteristic (Curve 4) 3-20
Figure 4.1: SEL-2PG10 Relay 9-Pin Connector Pin Number Convention 4-2
Figure 4.2: SEL-PG10 Relay 9-Pin Connector Pin Number Convention 4-3
Figure 6.1: 9-Pin Female Chassis Connector Pin Number Convention 6-4
Figure 6.2: Horizontal Front and Rear Panel Drawings 6-7
Figure 6.3: Relay Dimensions, Panel Cutout, and Drill Plan 6-8
Figure 6.4: Communications and Clock Connections - One Unit at One Location 6-9
Figure 6.5: Communications and Clock Connections - Multiple Units at One Location 6-9
Figure 6.6: SEL Relay Communications Diagram for Connection to the SEL-DTA 6-10
Figure 6.7: External AC Current and Voltage Connections 6-10
Figure 6.8: External DC Connection Diagram (Typical) 6-11
SEL Direction and Polarity Check Form 6-12

INTRODUCTION
TABLE OF CONTENTS

Overview 1-1
General Information 1-1
Specifications 1-2
Basic Protective Capabilities 1-7
Hardware Description 1-9
Signal Processing 1-11

FIGURES

Figure 1.1: 32Q and 32V Polarization Criteria 1-5
Figure 1.2: 32I Polarization Driteria 1-5
Figure 1.3: Relay Function Block Diagram 1-8
Figure 1.4: Relay Hardware Block Diagram 1-10

INTRODUCTION

OVERVIEW

The SEL-2PG10 Phase Distance and Ground Directional Overcurrent Relay with Fault Locator may be applied to protect transmission, subtransmission, and distribution lines.

This instruction manual applies to SEL-PG10 Relay. The SEL-2PG10 Relay has identical protection features, but use different hardware designs. Where there are differences between the two relay models, both relays are described.

The features of the SEL-2PG10 Relay include:

Distance Relaying for Phase and Three-Phase Faults

Directional Residual Overcurrent Protection for Ground Faults

Versatile User-Programmable Logic

Transmission Line Fault Locating

Event Recording

Automatic Self-Testing

Metering

Target Indicators for Faults and Testing

Time Code Input

Communications Port for Local and Remote Access

Compact and Economical

GENERAL INFORMATION

This introduction provides specifications for the SEL-2PG10 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 allow remote and local examination of a wide range of data, including voltages and currents presented to the instrument, system settings, and a history of the last twelve fault types and locations. You can enter and modify system settings remotely. A secure two-level password access scheme protects settings and circuit breaker control. An alarm contact allows you to monitor the relay for unauthorized access.

The relay includes a fault locator which uses fault type, prefault, and fault conditions to provide an accurate estimate of fault location. The system requires no 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 prefault, fault, and postfault voltages and currents. You can easily obtain parameters such as fault current sensed by the relay, relay response time, and total fault clearing time. The event report includes distance to the fault, fault type, and the state of all relay units during the event. Each event is time-tagged by the relay clock. You can generate the report upon command or by asserting either of the two external trigger inputs. This allows you to trigger the report from other equipment, such as oscillographic starting units or other relaying systems. The SEL-2PG10 Relay retains the last twelve event reports. You may recall any of these reports on command.

Use fault report data to construct phasor diagrams of the voltages and currents. These diagrams show prefault, fault, and postfault conditions. This information is useful in verifying short-circuit and load-flow calculations and transmission line constants as well as measuring voltage and current unbalance. You can also use it to check the input connections for proper phase-sequence rotation and polarity.

The instrument is designed to provide long-term accuracy and availability. The relay makes amplitude-dependent measurements with respect to a stable, precise internal voltage reference. 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

<u>Relay Functions</u>

Mho characteristics for phase-phase and three-phase faults
One phase-to-phase zone
One three-phase zone
Phase overcurrent elements supervise mho elements.

Residual overcurrent protection for ground faults
One instantaneous element
One definite time element
One time element with four selectable curve shapes

Negative- and zero-sequence directional elements for ground faults.
Zero-sequence element may be dual polarized.

Relay Elements

Phase Overcurrent Elements (Secondary Quantities)

50A, 50B, 50C (phase fault detectors)
Pickup: 0.5 to 40 A, ±0.1 A ±2% of setting
Transient overreach: 5% of set pickup

Distance Elements (Secondary Quantities)

Phase distance
21P: 0.125 to 64 ohms

Three-phase distance
21ABC: 0.125 to 64 ohms

Torque Angle Setting: 47° - 90° in 1° steps

Operating times
Mho elements operate in 10 - 45 ms (25 ms typical), including output relay delay. A 0 - 2000 cycle timer is provided for the mho elements.

Steady-state Error
5% of set reach ±0.01 ohm at maximum torque angle (MTA) for $V > 5$ V and $I > 2$ A.
10% of set reach ±0.01 ohm at maximum torque angle (MTA) for $5 > V > 1$ V and $0.5 < I < 2$ A.

Mho Transient Overreach
5% of set reach, plus steady-state error.

Mho Memory polarization
Three-phase element is memory polarized using voltage from a four-cycle memory.

Ground Overcurrent Elements (Secondary Quantities)

67NP residual time overcurrent element
Selectable curve shape (4 curves)
Timedial: 0.50 to 15.00 on 0.01 steps
Pickup: 0.25 to 6.3 A, ±0.05 A ±2% of setting
Timing: ±4% and ±1 cycle for residual current magnitude between 2 and 20 multiples of pickup.
May be directionally controlled (67NTC setting)

67NI residual overcurrent element
Pickup: 0.25 A to 48 times 67NP pickup for 67NP pickup < 3.15 A
0.5 A to 48 times 67NP pickup for 67NP pickup ≥ 3.15 A
Transient overreach: 5% of set pickup
A 0 - 2000 cycle timer is provided for the 67NI.

Ground Directional Elements

The relay provides four methods of polarizing the directional ground overcurrent elements:

1. Negative-sequence voltage and current
2. Zero-sequence voltage and measured residual current
3. External zero-sequence current and measured residual current
4. Methods 2 and 3 combined

With negative-sequence polarization selected, you may not select zero-sequence polarization. The primary setting procedure of the relay performs this check.

Negative-Sequence directional element

- The angle between the measured negative-sequence voltage and current adjusted by the MTA setting determines fault direction (see Figure 1.1)
- Angle: MTA setting
- Sensitivity: see Table 1.1

Zero-Sequence directional element

Voltage polarization

- The angle between the measured zero-sequence voltage and residual current adjusted by the MTA setting determines fault direction (see Figure 1.1)
- Angle: MTA setting
- Enabled with 32VE setting in the relay setting procedure
- Does not require an external voltage polarizing source
- Sensitivity: see Table 1.1

Current polarization

- The relay measures the angle between measured residual current and zero-sequence current from an external source to determine fault direction (see Figure 1.2)
- Angle: Zero degrees
- Enabled with the 32IE setting in the relay setting procedure
- Sensitivity: see Table 1.1

Note: If you want current polarization of the ground directional elements, you must wire an external zero-sequence current source to the Ipol inputs on the rear panel.

Table 1.1: Directional Element Sensitivities at Maximum Torque Angle (MTA)

Element	Negative-Sequence 32Q	Zero-Sequence 32D	
Sensitivity	0.10	(0.29)(67NP)	(0.44)(67NP)
Units	(V2)(I2)	(V0)(IR)	(IR)(IP)

Note: 32V and 32I sensitivities depend on the pickup setting of the residual time-overcurrent element 67NP.

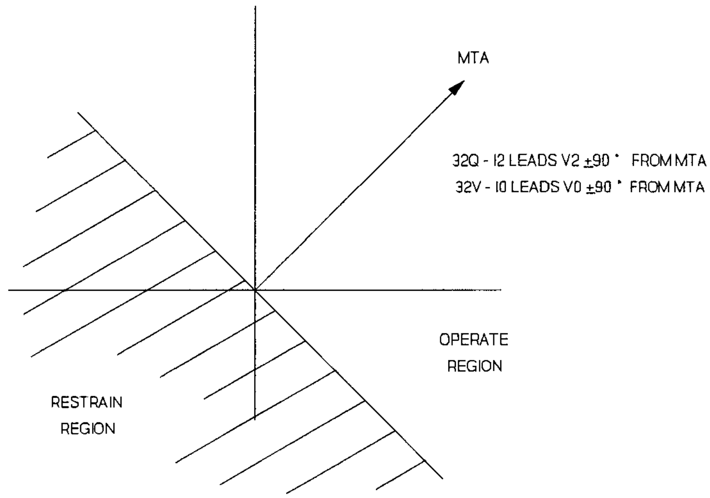


Figure 1.1: 32Q and 32V Polarization Criteria

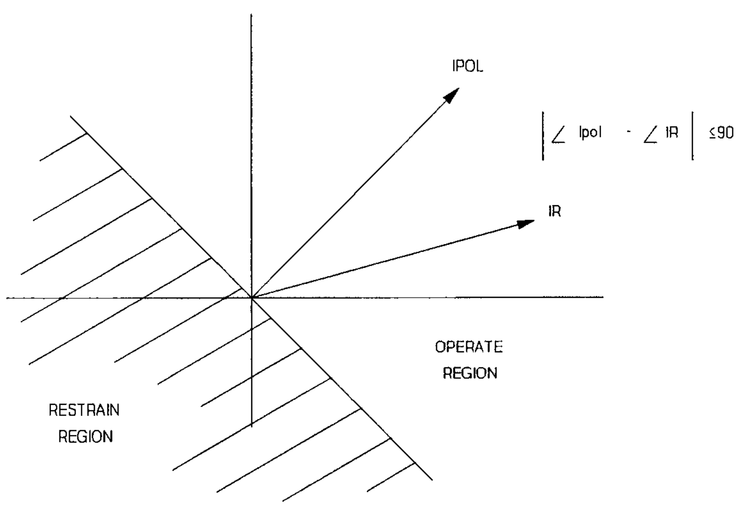


Figure 1.2: 32I Polarization Criteria

Fault Location	The relay computes fault location from the event reports stored after each fault. Algorithm compensates for prefault current, providing improved accuracy for high-resistance faults.
Fault Reporting	The relay retains data records for the last twelve faults. Reports include current, voltage, relay element, and input/output contact information. Reports can also be triggered by command or contact closure. If the relay trips after the end of the event report, the trip triggers a second report.
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 volt nominal phase-to-phase, three-phase four-wire connection
Rated Input Current	5 amps per phase nominal 15 amps per phase continuous 500 amps for one second thermal rating
Output Contact Current	30 amp make per IEEE C37-90 para 6.7.2 6 amp carry continuously MOV protection provided
Logic Input Ratings	24 Vdc: 10 - 30 Vdc 48 Vdc: 25 - 60 Vdc 125 Vdc: 60 - 200 Vdc 250 Vdc: 200 - 280 Vdc Current = 4 mA at nominal voltage
Power Supply	24/48 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 EIA RS-232-C)
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	3.5" x 19" x 10.5" (8.89 cm x 48.2 cm x 26.7 cm) (H x W x D), SEL-2PG10 5.25" x 19" x 13" (13.3 cm x 48.2 cm x 33.0 cm) (H x W x D), SEL-PG10 Mounts in EIA 19" rack, or panel cutout.
Unit Weight	16 pounds (7.3 kg), SEL-2PG10 21 pounds (9.5 kg), SEL-PG10
Shipping Weight	26 pounds (11.8 kg), including two instruction manuals, SEL-2PG10 32 pounds (14.5 kg), including two instruction manuals, SEL-PG10
Operating Temperature	-40° F to 158° F (-40° C to 70° C)
Burn-in Temperature	Each relay is burned in at 60° C for 100 hours

BASIC PROTECTIVE CAPABILITIES

The SEL-2PG10 Relay provides protection for transmission line faults of all types.

The SEL-2PG10 Relay Function Block Diagram (Figure 1.3) illustrates the basic configuration of the protective capabilities. Section 3: FUNCTIONAL DESCRIPTION provides complete descriptions of the logic.

The protective relaying elements receive analog inputs from current and voltage transformers and save the data for features such as metering and fault locating.

Relay elements process the analog data. The relay performs intermediate logic, including overcurrent supervision of mho elements, directional supervision of residual-overcurrent elements, and grouping certain elements into zones.

The Relay Word records the states of intermediate results and other information.

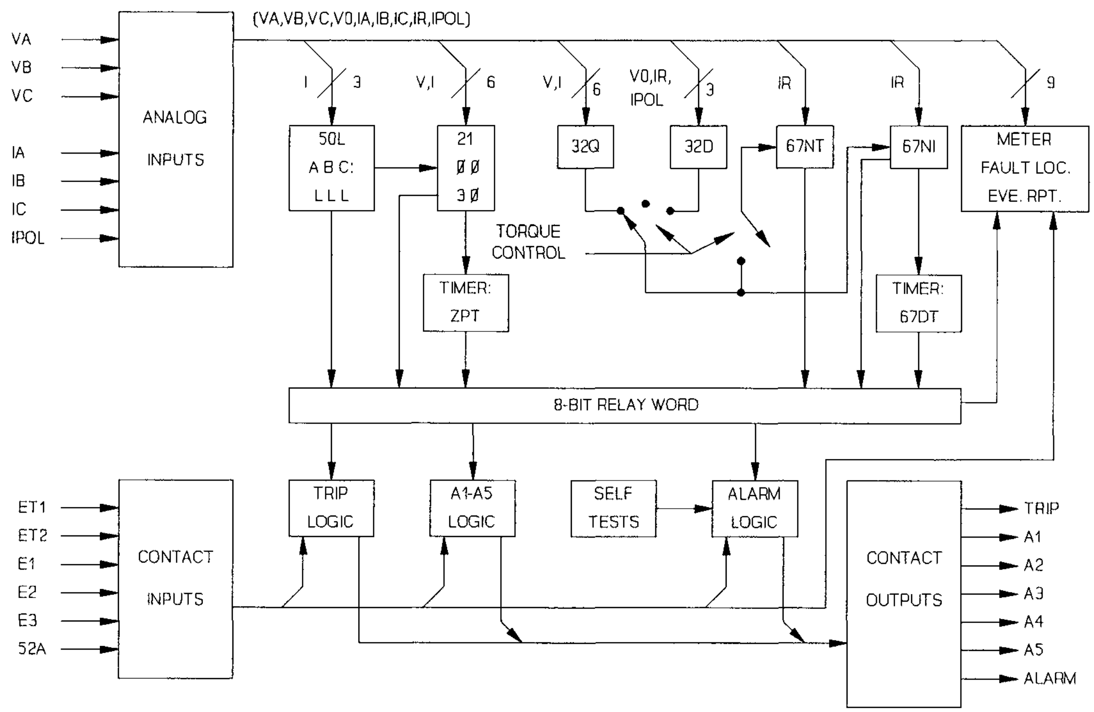


Figure 1.3: Relay Function Block Diagram

Logic for tripping, closing, and other functions uses the Relay Word data. You can program most of this logic through the logic masks.

The following information groups basic protective capabilities and explains them by fault type.

Three-Phase Faults

The relay provides a single-zone three-phase mho relay element.

Three overcurrent elements supervise the three-phase element. All three overcurrent elements must pick up. The relay provides four cycles of memory polarization, allowing positive action for close-in three-phase faults.

Phase-Phase Faults

The compensator-distance principle forms the basis of the phase-phase mho element. This element has no response for three-phase faults. Three overcurrent elements supervise the phase-phase mho element; at least one of these must pick up for the distance element to operate.

The relay provides a timer driven by the phase-phase and three-phase mho elements. You can use it as a zone timer or a backup-coordination timer. You can also set it to zero when no delay is required.

Ground Faults

Ground fault protection consists of an instantaneous residual overcurrent element and a residual time-overcurrent element.

A negative-sequence directional element and a dual polarized zero-sequence element determine directionality. Settings select the negative-sequence element or neither, either, or both sources of zero-sequence polarization. The relay securely discriminates between forward- and reverse-direction faults. The directional elements have a torque threshold which faults must exceed before the relay declares a fault direction.

The curve shape (moderately inverse, inverse, very inverse, extremely inverse) of the time-overcurrent element is user-selectable. This element is either nondirectional or forward-reaching.

HARDWARE DESCRIPTION

The SEL-2PG10 Relay Hardware Block Diagram illustrates the major parts of the relay. Input transformers isolate current and voltage inputs. 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 four times per power-system cycle.

The microcomputer has 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 through loss of power. Input/output (I/O) devices connected to the microcomputer bus provide control over the output relays and targets. These devices can also monitor inputs such as the state of the breaker 52A contact. Other I/O devices provide communications through two EIA RS-232-C ports to allow setting entry and report fault location. The relay also has an input for time code, so the internal clock may be synchronized to an external time code source.

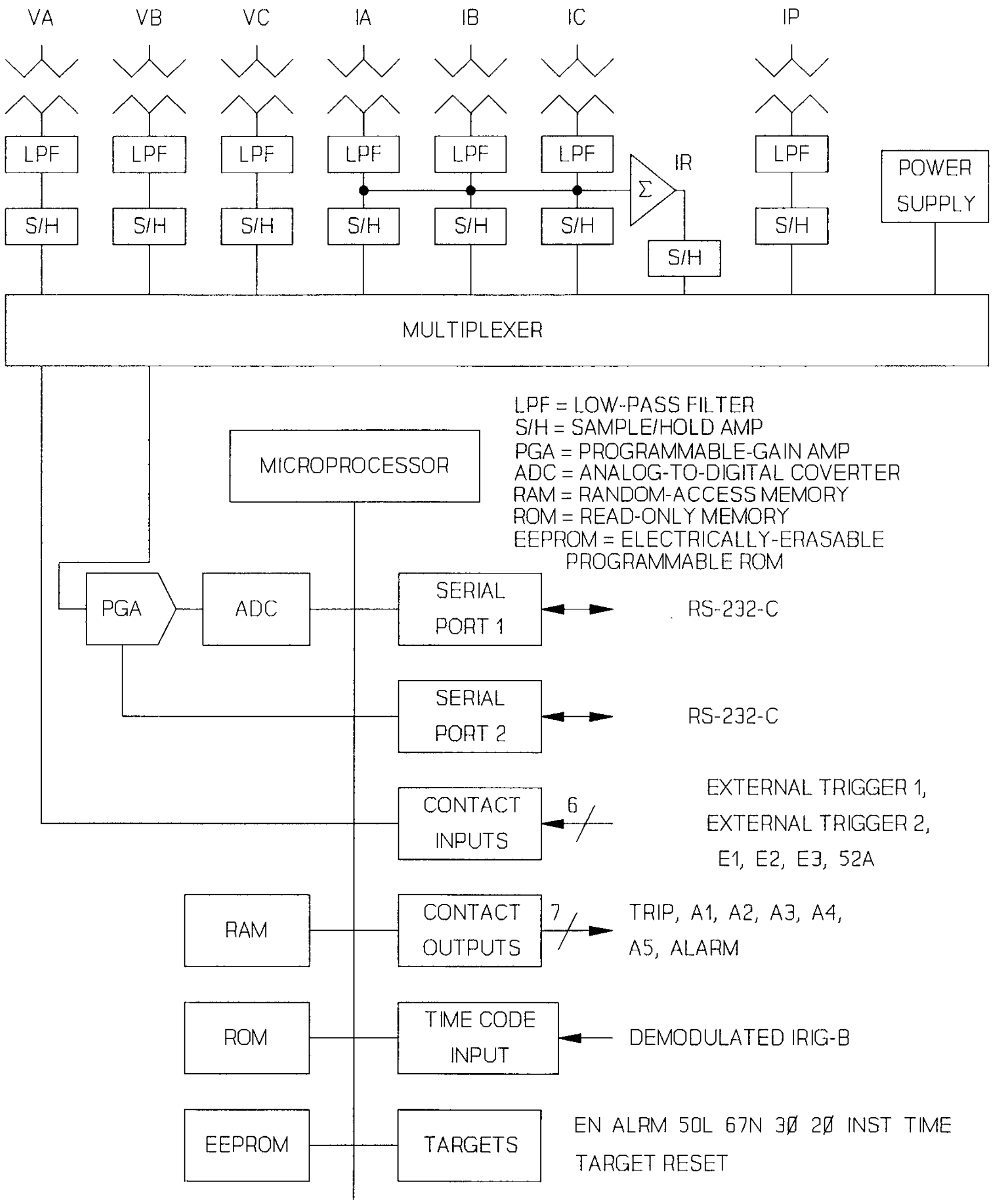


Figure 1.4: Relay Hardware Block Diagram

SIGNAL PROCESSING

The relay derives phasor representations of voltage and current from samples taken four times a cycle. The relay updates the phasors every quarter-cycle. The relaying and fault-locating algorithms subsequently process the phasor quantities.

The digital filters eliminate dc offsets introduced by the analog electronics, reduce the decaying exponential offset on the current data following a fault, and pass power system frequency information to the relay. The digital filters are simple, placing a minimum burden of computation on the microprocessor.

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

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

This filter eliminates dc offsets. When all the samples are set to the same value, the filter output is zero. It also eliminates ramps, which you may verify by setting the samples equal to 1, 2, 3, and 4. Again, the output is zero.

Every quarter-cycle, the relay computes a new value of P for each input. The current value of P combines with the previous (renamed Q) to form a Cartesian-coordinate pair. This pair represents the input signal as a phasor (P, Q). The relay processes these phasor representations of the input signals. They also appear with the relay output after an event. You can use this data to construct phasor diagrams of the voltages and currents.

INITIAL CHECKOUT
TABLE OF CONTENTS

Equipment Required 2-1
Checkout Procedure 2-1

TABLES

Table 2.1: Fault Test Results 2-5

INITIAL CHECKOUT

The initial checkout procedure should 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-2PG10 Relay.

1. Computer terminal with EIA RS-232-C serial interface.
2. Cable connecting terminal and relay.
3. Source of control power.
4. Source of three-phase voltages and at least two current sources.

CHECKOUT PROCEDURE

You will use several relay commands during the Initial Checkout. Section 4: COMMANDS AND SERIAL COMMUNICATIONS provides a full explanation of all commands. However, the following instructions should allow you to complete the checkout without referring to the detailed descriptions.

Note: In this manual, commands to type appear in bold/uppercase: **OTTER**. Keys to press appear in bold/uppercase/brackets: **<ENTER>**.

Relay output appears in the following font:

```
Example Settings            Date: 1/1/92    Time: 01:01:01
```

1. Inspect the instrument for physical damage such as dents or rattles.
2. Connect a computer terminal to PORT 2 on the relay front or rear panel. The terminal should be configured to 2400 baud, eight data bits, two stop bits, and no parity. Section 3: FUNCTIONAL DESCRIPTION provides additional details on the port configu-

rations. Refer to Section 6: INSTALLATION for more information about baud rate selection.

3. Connect a frame ground to terminal marked GND on the rear panel. Connect control power to terminals marked + and -.

4. Turn on the power. The enable target (EN) should illuminate. If not, be sure that power is present and check the fuse(s). The following message should appear on the terminal:

```
Example 230 kV Line              Date: 1/1/92     Time: 01:01:01

SEL-PG10
=
```

The ALARM relay should pull in, holding its "b" contacts open. If the relay pulls in, but no message is displayed, check the terminal configuration. If neither occurs, turn off the power and refer to the Troubleshooting Guide in Section 7: MAINTENANCE AND TESTING.

The = prompt indicates that communications with the relay are at Access Level 0, the first of three levels. The only command accepted at this level is ACCESS, which opens communications on Access Level 1, as described below.

5. Type **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. Inspect the demonstration settings entered at the factory. Type **SHOWSET** and press **<ENTER>** to display these settings. The terminal should display the following:

```
=>SHOWSET <ENTER>

Settings for:  Example 230 kV Line

R1   =13.90    X1   =79.96    R0  =41.50   X0   =248.57  LL=100.0
CTR  =200.00   PTR  =2000.00  MTA =80.80   LOCAT=Y
Z%   =80.00    PTMR =0.00     50L =100.00
67NP =100.00   67NTD=3.00     67NC=2       67NTC=Y
67NIP=1000.00  GTMR =0.00
32QE =N        32VE =Y        32IE=Y
TIME1=5        TIME2=0        AUTO=2       RINGS=3

Logic settings:

MT    MA1    MA2    MA3    MA4    MA5
66     40     20     08     04     02
```

A brief 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, and fault locator enable.

Line 3: Single-zone reach as a percent of the line impedance, time delay for phase faults, and phase-overcurrent fault detector element pickup.

Line 4: Residual time-overcurrent pickup, time dial, curve, and torque control enable.

Line 5: Residual instantaneous-overcurrent element pickup threshold and time delay for ground faults.

Line 6: Enables for the negative-sequence directional, voltage polarized zero-sequence directional, and current polarized zero-sequence directional elements.

Line 7: PORT 1 and 2 timeouts, autoport for automatically transmitted messages, and number of rings after which the external modem automatically answers.

The SET command description includes complete information about the relay settings.

See the LOGIC Command Description in Section 4: COMMANDS AND SERIAL COMMUNICATIONS for 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: 50L ZABC ZP ZPT 67NP 67NT 67NI 67DT

Logic settings appear in hexadecimal format. The SHOWSET command description in Section 4: COMMANDS AND SERIAL COMMUNICATIONS provides a table and example of hexadecimal to binary conversion.

7. Turn the power off and connect a source of three-phase voltages to the relay at terminals marked VA, VB, VC, and VN. 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.

   Connect both undotted A and B current input terminals to the undotted C current input terminal. Connect the dotted C current input terminal to both the A and B current source returns.

   Set the A-phase current source to 2 amperes at the same angle as the A-phase voltage. Set the B-phase current source to 2 amperes at the same angle as the B-phase voltage.

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

9. Now use the METER command to measure the voltages and currents. With applied voltages of 67 volts per phase and a potential transformer ratio of 2000, displayed voltages should be 134 kV. With applied currents of 2.0 amperes per phase and a current transformer ratio of 200, displayed currents should be 400 amperes. 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 below. SEL obtained these figures assuming a source impedance of 0.2 times the total 100-mile line impedance and single-end feed for faults at the indicated locations and types. The appendices include a BASIC program which may be useful in computing the test set settings.

LOCATION	TYPE	VA	VB	VC	IA	IB	IC	UNITS
75 miles	AG	52.89 0	70.12 -124	70.06 124	5.11 -80	0	0	V or A Degrees
	BC	67.00 0	56.75 -126	56.75 126	0	7.53 -170	7.53 10	V or A Degrees
85 miles	AG	54.24 0	69.81 -124	69.76 124	4.62 -80	0	0	V or A Degrees
	BC	67.00 0	57.69 -125	57.69 125	0	6.81 -170	6.81 10	V or A Degrees
125 miles	AG	57.76 0	69.00 -123	68.97 123	3.35 -80	0	0	V or A Degrees
	BC	67.00 0	60.20 -124	60.20 124	0	4.93 -170	4.93 10	V or A Degrees

Faults at 75 miles are within the reach of the relay based on two factors. The mho element reach is set to 80.0% (see Z% in the settings) of a 100-mile line (BC fault) and the ground-overcurrent thresholds (See 67NP and 67NIP in the settings) are less than the fault current (AG fault). The BC faults at 85 and 125 miles are beyond the reach of the relay, so it should not respond to these faults. The AG faults at 85 and 125 miles will not cause the instantaneous residual-overcurrent element to pick up, but will pick up the residual time-overcurrent element. Therefore, these ground faults will generate a response from the relay.

The faults listed above should close certain output relay combinations and illuminate front panel LEDs while a fault condition persists. Results appear in the following table.

Table 2.1: Fault Test Results

Location	Type	Output Relays	Target LED's
75 miles	AG	TRIP, A3, A4, A5	50L, 67N, INST
75 miles	BC	TRIP, A2	50L, ∅-∅
85 miles	AG	TRIP, A3, A4	50L, 67N, TIME
85 miles	BC	NONE	50L
125 miles	AG	TRIP, A3, A4	50L, 67N, TIME
125 miles	BC	NONE	50L

The TRIP output relay is set to assert for phase faults, ground time-overcurrent element timeout, and instantaneous ground-overcurrent pickup. This information appears in the MT column of the previous display (see LOGIC Command Description in Section 4: COMMAND AND SERIAL COMMUNICATIONS for details). In the table, the TRIP output relay closes for all faults except phase faults outside the phase-phase mho element set reach.

The A2 output relay is set to monitor phase-phase mho element pickup. Therefore, the A2 output operates only for the phase-phase fault within reach of the element (BC fault at 75 miles).

Output relays A3 and A4 monitor residual time-overcurrent pick up and trip. These output relays operate for any ground fault in the first table because the fault current level is above 67NP pick up. However, the fault condition must persist longer than the time delay as determined by the settings. If the fault clears before the time elapses, 67NT should not assert the A4 output.

The A5 output relay monitors the instantaneous residual-overcurrent. This output asserts only for the ground fault at 75 miles because the residual fault current is above the instantaneous ground-overcurrent pick up.

The LOGIC command description explains the programming of output relays A1-A5 and the MT logic mask.

The 50L target follows pick up of the phase-overcurrent relay element. The 67N target follows pick up of the instantaneous ground-overcurrent element. These two targets show the pick up and drop out of these elements without respect to TRIP.

The last four targets in the display are generally trip targets. They illuminate at tripping. These targets show which elements actually caused the TRIP, even though other elements may time out after that.

Each fault generates a short event report. Type **EVENT 1** and press **<ENTER>** to display a full event report for the latest fault. The report provides an eleven cycle record of the currents, voltages, relay element states, and input/output contact states. The relay saves the last twelve reports.

This checkout procedure demonstrates only a few of the relay features. Study Sections 3, 4 and 5 for more information about the capabilities of this relay. Refer to the appendices for more test procedures.

FUNCTIONAL DESCRIPTION
TABLE OF CONTENTS

Introduction 3-1
Inputs and Outputs 3-1
Definition of Logic Variables 3-4
Intermediate Logic 3-5
Relay Word 3-6
Output Equations 3-7
Targets 3-7
Self-Tests 3-8
Setting Procedure 3-10
Event Report and Fault Locator 3-10
Mho Units 3-13
Directional Elements 3-14
Time-Overcurrent Element 3-14
Time-Overcurrent Curve Equations 3-15

TABLES

Table 3.1: Relay Word Bit Summary Table 3-6
Table 3.2: Power Supply Self-Test Limits 3-9

FIGURES

Figure 3.1: Residual Time-Overcurrent Element Moderately Inverse Time Characteristic (Curve 1) 3-16
Figure 3.2: Residual Time-Overcurrent Element Inverse Time Characteristic (Curve 2) . . . 3-17
Figure 3.3: Residual Time-Overcurrent Element Very Inverse Time Characteristic (Curve 3) 3-18
Figure 3.4: Residual Time-Overcurrent Element Extremely Inverse Time Characteristic (Curve 4) 3-19

FUNCTIONAL DESCRIPTION

INTRODUCTION

This section describes all inputs and outputs, relay elements, and the logic equations which relate them. It also describes self-tests and how they affect system operation.

INPUTS AND OUTPUTS

Serial Interfaces

The SEL-2PG10 Relay is equipped with two EIA RS-232-C serial communication ports. Port 2 has 9-pin connectors on both the front and rear panels, designated Port 2F and Port 2R, respectively.

Port 2R, located on the relay rear panel, is typically used with an SEL-DTA Display/-Transducer Adapter, SEL-RD Relay Display, or local printer. Port 2F is always available for short term local communications with a portable computer or printing terminal. Simply plug the device into the front panel port. The relay automatically discontinues communications with Port 2R and addresses Port 2F. When testing or data retrieval is complete, unplug the temporary device from Port 2F. The relay automatically resumes communication with the device connected to Port 2R.

Serial communications Port 1 and the Auxiliary Input for demodulated IRIG-B time code input remain on the relay rear panel.

The baud rate for each port is set by jumpers near the front of the main board. You can access these jumpers by removing either the top cover or front panel. Available baud rates are 300, 600, 1200, 2400, 4800, or 9600.

Caution: Do not select two baud rates for the same port as this can damage the relay baud rate generator. The relay is shipped with Port 1 set to 300 baud and Port 2 set to 2400 baud.

The serial data format is:

Eight data bits
Two stop bits
No parity

This format may not be changed. The serial communications protocol appears in Section 4: COMMANDS AND SERIAL COMMUNICATIONS.

The SEL-PG10 Relay does not include a front panel serial data interface.

Input Power

Terminals marked + and - should be connected to a source of control voltage. Polarity of dc power is unimportant. Power requirement is approximately 12 watts. Terminal marked GND should be wired to the relay rack ground reference for grounding the instrument frame.

Contact Inputs

The relay has six input circuits. The following list shows the input circuits.

External Trigger 1, ET1	Event 2, E2
External Trigger 2, ET2	Event 3, E3
Event 1, E1	52A Monitor, 52A

To assert an input, apply nominal control voltage to the appropriate terminal pair. Polarity is not important.

Input Functions:

External Trigger inputs for Event Report (ET1, ET2): asserting either external trigger input triggers an event report. Assertion does not affect protective functions.

Event inputs (E1, E2, E3): these inputs can monitor any type of external event. Assertion does not affect protective functions.

Circuit Breaker Monitor (52A): the 52A input indicates the state of the breaker; the tripping function uses this input.

Relay Outputs

Seven output relays are provided. They following list shows output relays with contact types.

TRIP	a
A1	a or b
A2	a or b
A3	a or b
A4	a or b
A5	a or b
ALARM	a or b

All relay contacts are rated for circuit breaker tripping duty.

TRIP Output:

This output closes for any number of conditions selected by the user. You select closure conditions with the logic mask MT (mask for TRIPPING). The TRIP output never closes for less than 60 ms. After this interval, it opens when the fault condition vanishes and the breaker appears open, as judged by the 52A input.

ALARM Output:

This 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 depending on which self-test fails

The ALARM output also closes momentarily when you change settings or passwords or enter a new date, if the year stored in EEPROM differs from the year entered (see the DATE command).

Programmable Outputs (A1, A2, A3, A4, A5):

These five 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 primaries connected in a grounded-wye and secondaries connected in four-wire wye. The relay contains a set of three input transformers connected in four-wire wye. Because the relay includes zero-sequence voltage polarization, you must connect the neutral input terminal to the star point of the PT secondaries. The 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.

Current Inputs

Input transformer rating in the relay is 15 amperes continuous, 500 amperes for one second.

IRIG-B Input Description

The J201/AUX INPUT port is for the demodulated IRIG-B input.

The 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 put approximately 10 mA through the diode when "on."

The IRIG-B serial format is a one-second frame containing 100 pulses and divided into fields. The relay decodes second, minute, hour, and day fields and sets the relay clock accordingly.

When IRIG-B data acquisition is activated either manually (with the IRIG command) or automatically, the relay reads two consecutive frames. It updates the older frame by one second and compares the frames. If they do not agree, the relay considers the data erroneous and discards it.

The relay reads the time code automatically about once every five minutes. Near midnight on New Year's Eve, IRIG-B data acquisition stops briefly so the relay clock may implement the year change without interference from the IRIG-B clock.

DEFINITION OF LOGIC VARIABLES

The SEL-2PG10 Relay logic consists of relay elements, timers, and combinations of conditions. Many of these are recorded in the Relay Word, which forms the heart of the programmable mask logic of this relay. Elements and other quantities available in the Relay Word are indicated in boldface type in this section.

Since the logic uses so many binary variables, we define the functioning with Boolean logic equations. Definitions of the logic variables appear below.

Relay Elements

Single-phase overcurrent relays	50A 50B 50C	(phase fault detectors)
Three-phase mho distance	21ABC	
Line-line mho distance	21P	
Residual time-overcurrent pickup	**67NP**	T.C. or nondirectional
Residual time-overcurrent trip	**67NT**	T.C. or nondirectional
Residual inst-overcurrent	67N	T.C.
Negative-sequence directional	32Q	32QF = forward
Zero-sequence dual pol directional	32D	32DF = forward

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

Timers

GTMR Ground timer for definite-time ground overcurrent element
PTMR Phase-phase and three-phase fault timer

Enables From Setting Procedure

32QE	Enables 32Q
32VE	Enables voltage polarization of 32D
32IE	Enables current polarization of 32D
67NTC	Selects directional torque control for time-overcurrent relay

Contact Inputs

EXT1	External trigger 1 for event report
EXT2	External trigger 2 for event report
E1	Event 1
E2	Event 2
E3	Event 3
52A	Circuit breaker monitor

Contact Outputs

TRIP	Circuit breaker trip
A1	Programmable output 1
A2	Programmable output 2
A3	Programmable output 3
A4	Programmable output 4
A5	Programmable output 5
ALARM	System alarm

INTERMEDIATE LOGIC

The logic equations below represent combinations of the relay elements and other conditions. "*" indicates the logical "and" operator; "+" indicates the logical "or" operator.

50L	= 50A + 50B + 50C	Phase fault current supervision
3P50	= 50A * 50B * 50C	Three-phase fault current supervision
ZABC	= 21ABC * 3P50	Three-phase fault
ZP	= 21P * 50L	Phase-to-phase fault
DF	= 32QF * 32QE + 32DF * 32IE + 32DF * 32VE + NOT(32QE + 32VE + 32IE)	Forward direction

(If 32QE=32VE=32IE=N then DF=1, i.e., disabling the directional elements makes the ground elements nondirectional.)

67NI = 67N * DF	
ZPT = (**ZABC** + **ZP**) * PTMR	Phase-to-phase or three-phase fault timeout
67DT = **67NI** * GTMR	Definite-time ground timeout

RELAY WORD

The eight-bit Relay Word contains relay elements and intermediate logic results. You can select bits in this word to perform desired functions for tripping or controlling the five programmable outputs. Selected bits are stored in masks for each function. You can program the bits in these masks with the LOGIC command.

Relay Word

50L ZABC ZP ZPT 67NP 67NT 67NI 67DT

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

Table 3.1: Relay Word Bit Summary Table

50L	-	Phase fault current supervision
ZABC	-	Three-phase mho element
ZP	-	Phase-to-phase mho element
ZPT	-	Phase or three-phase fault timeout
67NP	-	Residual time-overcurrent pickup
67NT	-	Residual time-overcurrent trip
67NI	-	Residual instantaneous-overcurrent (directional or nondirectional)
67DT	-	Definite-time ground timeout

The Relay Word and programmable masks provide great application flexibility. SEL-2PG10 relay protection can be modified without rewiring panels or changing jumpers on circuit boards.

OUTPUT EQUATIONS

Programmable logic controlling the TRIP output and five output relays (A1-A5) increases flexibility and eases testing. Programming requires setting masks for various conditions. The masks are applied to the general Relay Word.

General forms for each of the output equations:

Let R = Relay Word

MT = mask for trip

Then: TRIP = R * MT

close TRIP = TRIP
open TRIP = NOT(TRIP) * NOT(52A + TARGET RESET button pushed)
* (60 ms minimum TRIP)

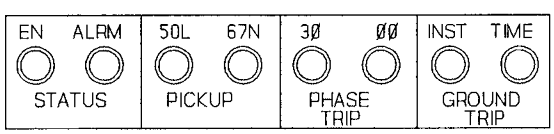
A1 = R * MA1
A2 = R * MA2
A3 = R * MA3
A4 = R * MA4
A5 = R * MA5

"*" indicates the logical "and" operator; "+" indicates the logical "or" operator.

The ALARM output relay function is fixed. It responds to self-test failures, setting changes, and password violations.

TARGETS

Front-panel targets appear below:



The first two LEDs indicate relay status. The enable light (EN) signifies normal operation. The ALARM LED (ALRM) warns that an alarm condition has occurred.

The next two indicators show instantaneous phase overcurrent element (50L) pickup and instantaneous ground overcurrent element or ground time-overcurrent element pickup (67NI + 67NP). These two LEDs illuminate when their respective elements assert.

The next two LEDs indicate three-phase and phase-phase fault trip targets. They illuminate when the phase fault timer expires.

The remaining two LEDs indicate the ground trip targets. The display shows the instantaneous ground-overcurrent element trip (67NI + 67NP) target first, followed by the ground element timeout trip (67DT + 67NT) target.

When you press the TARGET RESET button, all eight indicators illuminate for a one-second lamp test. The fault targets clear and the Enable light shows that the relay is operating again. Targets also clear before presentation of new targets when a fault occurs.

Pressing the TARGET RESET button also unlatches the TRIP output from the 52A input. This feature is useful during relay testing, and minimizes the risk of reinstalling the relay with the TRIP output asserted.

SELF-TESTS

The relay runs a variety of self-tests to ensure reliable operation. Some tests have warning and failure states; others only have failure states. The relay generates a status report if any self-test warning or failure occurs.

The relay closes the ALARM contacts and illuminates the ALRM LED after any self-test fails. When it detects certain failures, the relay disables control functions and places the output relay driver port in an input mode. No A-contact outputs may be asserted with the instrument in this configuration. The relay runs all self-tests on power up, after setting changes, and every few minutes during normal operation.

Offset

The relay measures the offset voltage of each analog input channel and compares the value against fixed limits. If an offset measurement is outside the fixed limits, the relay declares a warning or failure. Offset measurements exceeding 50 millivolts in any channel result in a warning. The relay declares a failure when offset exceeds 75 millivolts. All data acquisition/relay functions and control functions remain enabled. The ALARM relay pulses closed for one second when this test fails. The ALRM LED illuminates momentarily.

Power Supply

Power supply voltages are limit-checked. The table below summarizes the voltage limits.

Table 3.2: Power Supply Self-Test Limits

Supply	Warning Thresholds		Failure Thresholds	
+5 V	5.3 V	4.7 V	5.4 V	4.6 V
+15 V	15.8 V	14.2 V	16.2 V	13.8 V
-15 V	-15.8 V	-14.2 V	-16.2 V	-13.8 V

The relay transmits a STATUS command response for any failure or warning. +5 volt supply failure de-energizes all output relays and blocks them from operation. Failure of the ±15 volt supplies disables protective relay functions, but control functions remain intact. The ALARM relay remains closed. The ALRM (alarm) LED illuminates for a power supply failure unless the +5 volt supply output fails completely.

Random-Access Memory

The relay periodically checks random-access memory (RAM) to ensure that each byte can be written to and read from. There is no warning state for this test. If the relay detects a problem, it transmits a STATUS command message with the socket designation of the affected RAM IC. RAM failure disables protective and control functions, closes the ALARM output relay contacts, and illuminates the ALRM (alarm) LED.

Read-Only Memory

The relay tests read-only memory (ROM) by computing a checksum. If the computed value does not agree with the stored value, the relay declares a ROM failure. It transmits a STATUS command response and disables all protective and control functions. The ALRM (alarm) LED illuminates and the ALARM relay contacts close.

Analog-to-Digital Converter

The analog-to-digital converter (A/D) changes voltage signals into numbers for processing by the microcomputer. The test verifies converter function by checking A/D conversion time. The test fails if conversion time is excessive or a conversion starts and never finishes. There is no warning state for this test. A/D failure disables protective functions; control functions remain intact. The relay transmits a STATUS command response, illuminates the ALRM (alarm) LED and closes the ALARM relay contacts.

Master Offset Test

The multiplexer selects a zero volt input to test the master offset (MOF). The test fails if the offset is greater than 75 mV. Failure disables the offset and master offset tests. Data acquisition, relay, and control functions remain intact. The ALARM relay pulses closed for one second and the ALRM LED pulses on momentarily.

Settings

The relay stores two images of the relay settings in nonvolatile memory. It compares these images after you enter the initial settings and periodically thereafter. If the images disagree, the setting test fails. The relay disables all protective and control function and transmits a STATUS message. The ALARM relay remains closed and the ALRM LED stays illuminated.

SETTING PROCEDURE

You can enter relay settings with the SET and LOGIC commands through either serial interface port. The relay stores settings in nonvolatile memory and retains them when the power is off.

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

EVENT REPORT AND FAULT LOCATOR

The relay records an eleven-cycle event report following any of these events:

1. Instantaneous operation of directional ground-overcurrent element (67NI).
2. Pickup of residual time-overcurrent element (67NP).
3. Pickup of three-phase and phase-phase mho elements (ZABC and ZP).
4. Assertion of External Trigger 1 and External Trigger 2 inputs.
5. Execution of Trigger command.

Trip and External Trigger (ET1 or ET2) events are rising-edge sensitive. For these events, additional reports are generated even while any or all relay elements remain picked up. The relay triggers a second report for the same fault if the trip occurs after the first report expires. Thus, the relay records the beginning and end of each fault for which it trips. A second event report is not provided if the TRIP output first asserts at or less than seven cycles after the first report is triggered.

Triggering is recorded 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. The system also allows you to determine the duration of a long fault which triggers two event reports. Simply calculate the time difference between the report generated at fault inception and the report generated at the TRIP.

The relay stores the last twelve reports in memory; you may retrieve reports with the EVENT command. The HISTORY command displays a short history of the last twelve events.

Several events automatically trigger the fault locator. These include: pickup of certain relay elements, assertion of certain contact inputs or outputs, and user entered commands. You can enable or disable the fault locator with the LOCAT setting in the setting procedure.

Triggering events are:

(1) RELAY ELEMENTS (high-level trigger)
Three-phase distance element
Two-phase distance element
Ground overcurrent 67NI and 67NP pickup

(2) CONTACT INPUTS (rising-edge trigger)
External Trigger 1
External Trigger 2

(3) CONTACT OUTPUTS (rising-edge trigger)
TRIP

(4) USER ENTERED COMMANDS (rising-edge trigger)
Trigger

The relay elements trigger the fault locator in a level sensitive manner. The relay does not generate additional event reports when additional relay elements pick up. Only the first relay element of any continuous sequence triggers an event report.

All triggering relay elements must drop out for at least four cycles before they can initiate another event report. This helps eliminate multiple records for boundary faults.

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

The relay always determines fault location for event records if any of the triggering relay elements are picked up, unless they are picked up in the first seven rows of prefault data or only in the last five rows of the event report. Whenever the locator is able to determine the fault location, it labels the corresponding record according to fault type, regardless of what actually triggered the event report. Event records taken with no triggering relay elements picked up have the following label:

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

The actual fault location algorithm has two steps. The relay determines fault type, then calculates location.

For the event reports, the relay determines fault type independently of relay element operations. Fault current comparison determines the involved phases. This differs from the TARGET data, which is completely derived from relay element operations.

The report compares currents taken from the two middle rows of the stored fault data. If the uncompensated current magnitudes are in large ratios between phases (4:1 or more), the relay lists fault type 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), fault type is listed as single- or two-phase. If all ratios are less than 1.5, the relay lists fault type as three-phase. Explicit fault classification logic is as follows (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 relay determines fault type, the fault locator uses the Takagi algorithm to locate the fault. Using prefault and fault data, it compensates for errors fault resistance introduces in the presence of load flow. If the event record provides no prefault data, the 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:

1. Instrument transformer ratio errors due to overburden by other devices.

2. Capacitive potential transformer capacitor value.

3. Transmission line parameter errors.

Although the fault-location computation takes several seconds, the relay can handle several faults in quick succession. The relay stores all fault data, then processes each fault in turn. Suppose three faults occur in a few seconds. The relay stores data from each as it occurs. The fault-location computations begin with the first (oldest) fault and proceed until all three are processed. The relay transmits each summary event report when the corresponding fault location is available.

The relay does not consider shunt capacitance of the transmission line. The capacitance causes the fault location to appear more remote by a factor of approximately 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:

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

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 you apply shunt reactor compensation and measured current at the relay equals reactor plus line current, the fault locator is not affected by distributed capacitance. This is because the effect of the capacitance is reduced by the shunt reactor.

When series capacitor compensation is used, accurate performance is obtained for faults between the relay and the capacitors, and beyond the capacitors if the capacitor protective gaps flash. If the gaps do not flash, the measured impedance includes the line impedance and the capacitance impedance, and the errors can be substantial. This problem is aggravated by high-speed clearing and the excitation of eigenmodes or resonances of the line-capacitor system, which may not be much removed from 60 Hz. On the other hand, we have had success in cases where series capacitor gaps did not flash, by recomputing the fault location from the event report data, using a voltage equal to the measured voltage minus the capacitor voltage drop. The latter is computed from the capacitance value and the measured current.

MHO UNITS

The following settings affect mho circles: maximum torque angle, set reach, and transmission line impedance. The circles pass through the impedance-plane origin; the diameter passing through the origin is at an angle of MTA (maximum torque angle) with respect to the resistance axis. The chord passing through the origin at the positive-sequence impedance (Z1) angle of the transmission line equals the length of the set reach. Therefore the mho circle diameter is:

DIAMETER = [SET REACH]/[cos(T. L. ANGLE - MTA)]

The mho elements are based on the general principles of operation presented in "Compensator Distance Relaying." by W. K. Sonnemann and H. W. Lensner (AIEE Transactions, Part III, vol. 77, pp 372-382, June 1958). These principles have been applied successfully in the electromechanical and solid-state designs of several manufacturers. Electromechanical versions use induction cylinders for a product-type phase comparison between the measurands. Solid-state analog designs use coincident-timing phase comparators. In the SEL-2PG10 Relay, phasor multiplication in the microprocessor performs the phase comparison.

Phase comparator inputs for the various distance functions are:

FUNCTION	INPUT A	INPUT B
phase-phase	Vab - Z1xIab	Vbc - Z1xIbc
three-phase	Vab - Z1xIab	-jVab - Vc (memory)

The constant Z1 is the reach of the relay element in positive-sequence ohms.

DIRECTIONAL ELEMENTS

You can enable either the negative-sequence or zero-sequence directional element to provide directional supervision of the residual overcurrent elements.

When no directional elements are enabled, the direction forward (DF) condition is always set and the residual overcurrent elements are nondirectional.

Directional elements are phasor-product derived. For the negative-sequence element (32Q), the product is negative-sequence voltage times negative-sequence current adjusted by the maximum torque angle setting. The relay declares a fault forward when I2 leads V2 ± 90 degrees from the maximum torque angle.

For the zero-sequence directional element (32D), the product is the residual current adjusted by the MTA setting times the sum of the residual voltage, plus the polarizing current shifted in phase by the MTA setting. The result is a dual polarized zero-sequence directional element.

If you enable the zero-sequence voltage polarizing method (32VE = Y), the relay declares a fault forward when I0 leads V0 ± 90 degrees from the maximum torque angle.

If you enable the zero-sequence current polarizing method (32IE = Y), the relay declares a fault forward when the residual current from the faulted line is ± 90 degrees from the current measured in the Ipol input. The current in the Ipol input is typically derived from grounded-wye transformer neutrals or a transformer bank tertiary.

Table 3.3 shows the equations the relay uses to express the sensitivity of the directional elements in units of torque. These equations are useful in determining directional element sensitivities for fault angles which may differ from the MTA.

Table 3.3: Directional Element Torque Equations

$$32Q:\ T \equiv |V2| x |I2| x[\cos(\angle -V2 - (\angle I2 + MTA))]$$
$$32V:\ T \equiv |V0| x |IR| x[\cos(\angle -V0 - (\angle IR + MTA))]$$
$$32I:\ T \equiv |Ipol| x |IR| x[\cos(\angle Ipol - \angle IR)]$$

Where:

T ≡ Torque, positive for a forward fault
V2 ≡ Negative-sequence secondary voltage
I2 ≡ Negative-sequence secondary current
V0 ≡ Zero-sequence secondary voltage
IR ≡ Residual secondary current
Ipol ≡ Secondary current at Ipol input

TIME-OVERCURRENT ELEMENT

The 67N time-overcurrent element provides directional-forward or nondirectional protection. Its pickup (67NP) and trip (67NT) states are both available in the Relay Word for programming into any mask.

You can select the time dial and the curve shape in the setting procedure. Four curve shapes are available. This section includes the curves and their equations.

The 67N time-overcurrent characteristic is formed by a simple delay (modelling the inertia of an overcurrent relay disk) followed by a recursive sum of the magnitude or magnitude-squared of the residual current, adjusted by the pickup setting.

The time dial setting determines the limit the recursive sum must reach for a trip. The current is scaled to handle the pickup setting.

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

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

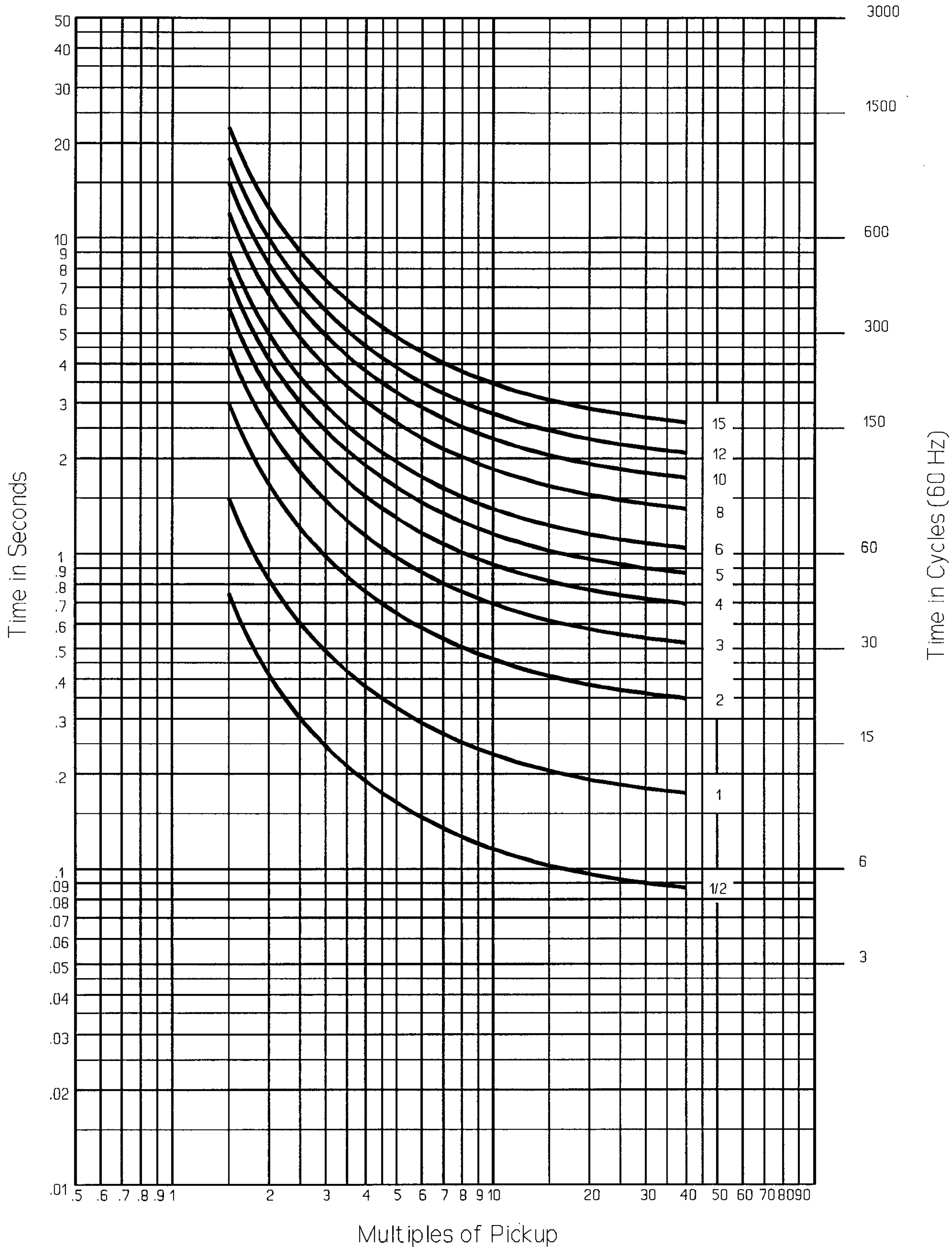


Figure 3.1: Residual Time-Overcurrent Element Moderately Inverse Time Characteristic (Curve 1)

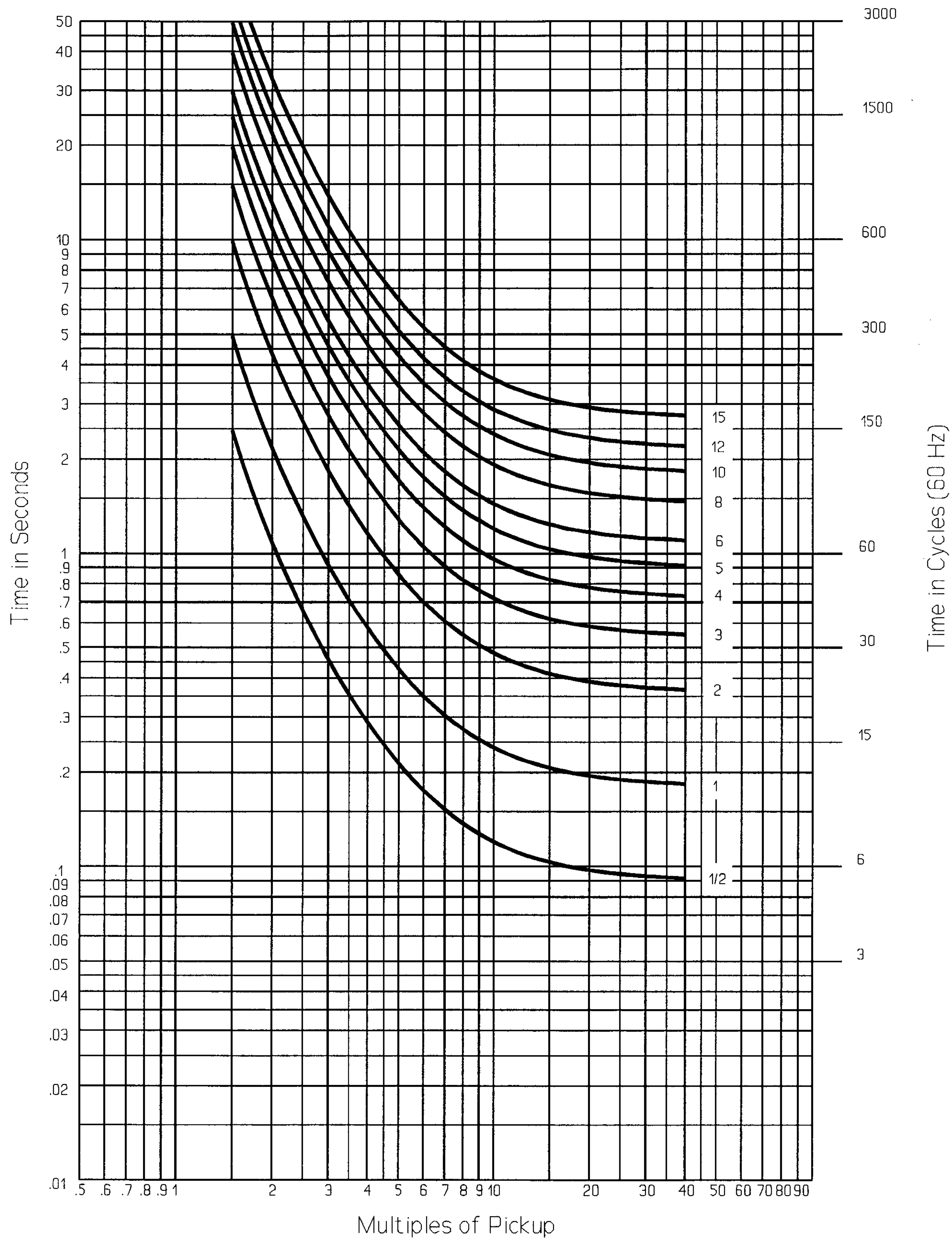


Figure 3.2: Residual Time-Overcurrent Element Inverse Time Characteristic (Curve 2)

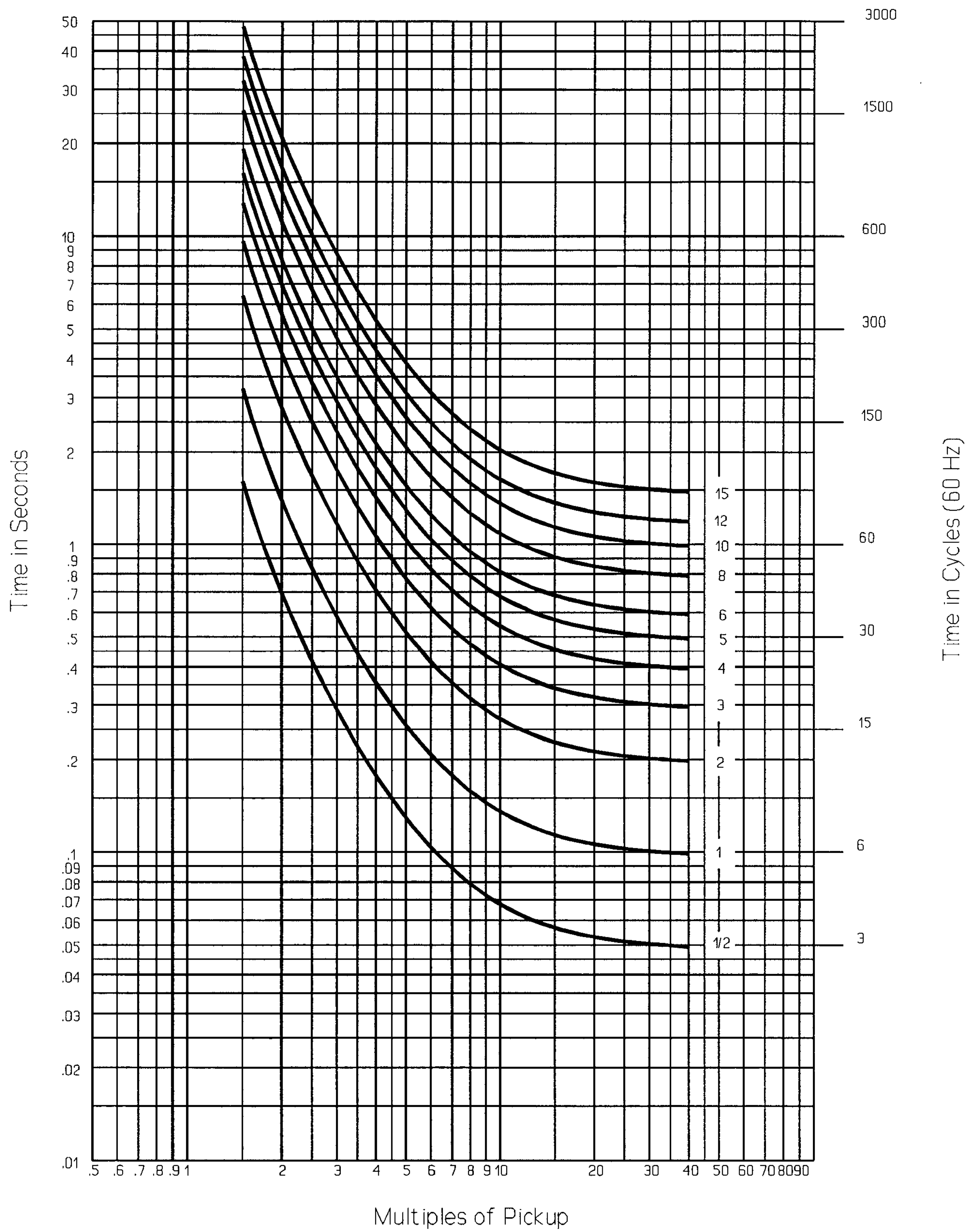


Figure 3.3: Residual Time-Overcurrent Element Very Inverse Time Characteristic (Curve 3)

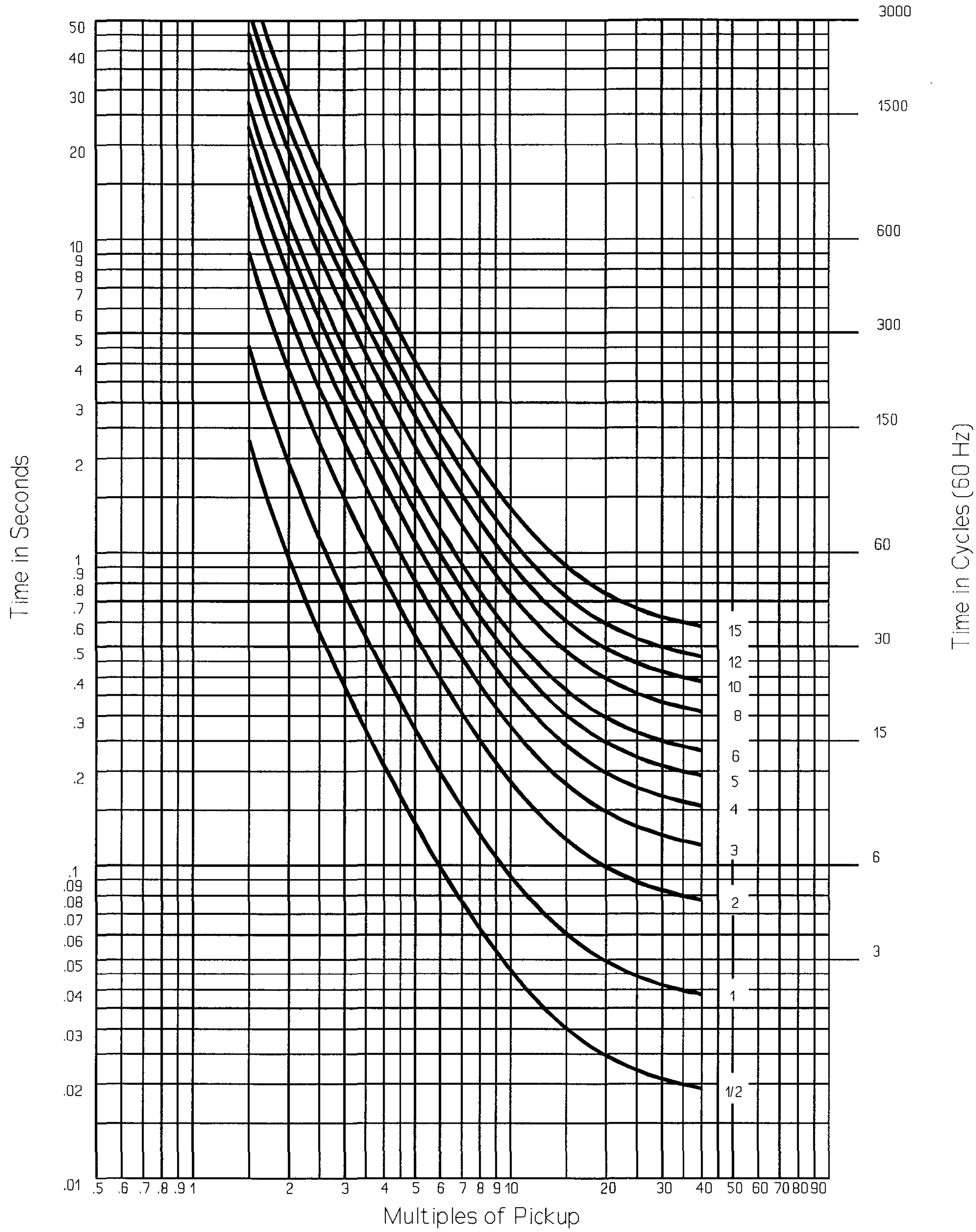


Figure 3.4: Residual Time-Overcurrent Element Extremely Inverse Time Characteristic (Curve 4)

COMMANDS AND SERIAL COMMUNICATIONS
TABLE OF CONTENTS

Introduction 4-1
Serial Port Connections and Configurations 4-2
Communications Protocol 4-4
Command Characteristics 4-6
Command Descriptions 4-8
SEL-2PG10 Distance Relay/Fault Locator Command Summary 4-23

TABLES

Table 4.1: SEL-2PG10 Relay Serial Port Connector Pin Assignments 4-3
Table 4.2: SEL-PG10 Relay Serial Port Connector Pin Assignments 4-4
Table 4.3: Hexadecimal/Binary Conversion 4-14
Table 4.4: Self-Test Summary 4-16
Table 4.5: Target LED Assignment 4-16

FIGURES

Figure 4.1: SEL-2PG10 Relay 9-Pin Connector Pin Number Convention 4-2
Figure 4.2: SEL-PG10 Relay 9-Pin Connector Pin Number Convention 4-3

COMMANDS AND SERIAL COMMUNICATIONS

INTRODUCTION

The SEL-2PG10 Relay is set and operated via serial communications interfaces. These interfaces connect to a computer terminal and/or a modem, or the SEL Protective Relay Terminal Unit. Communication serves these purposes:

1. The relay responds to commands spanning all functions; setting, metering, and control operations.

2. The relay generates an event record for any of the following conditions:

    a) a fault
    b) assertion of EXTERNAL TRIGGER 1 input
    c) assertion of EXTERNAL TRIGGER 2 input
    d) in response to TRIGGER command
    e) assertion of TRIP output

    The relay does not record an event record for assertion of the E1, E2, E3, or 52A inputs.

3. The relay responds to changes in system status, such as self-test warnings.

Two password protected access levels provide security against unauthorized access and setting changes.

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

Note: In this manual, commands to type appear in bold/uppercase: **OTTER**. Keys to press appear in bold/uppercase/brackets: **<ENTER>**.

Relay output appears in the following font:

```
Example Settings          Date: 1/1/92    Time: 01:01:01
```

SERIAL PORT CONNECTIONS AND CONFIGURATIONS

The SEL-2PG10 Relay is equipped with two EIA RS-232-C serial communications ports. Port 2 has 9-pin connectors on both the front and rear panels, designated Port 2F and Port 2R, respectively.

Port 2R, located on the relay rear panel, is typically used with an SEL-DTA Display/-Transducer Adapter, SEL-RD Relay Display, or local printer. Port 2F is always available for short term local communications with a portable computer or printing terminal. Simply plug the device into the front panel port. The relay automatically discontinues communications with Port 2R and addresses Port 2F. When testing or data retrieval is complete, unplug the temporary device from Port 2F. The relay automatically resumes communication with the device connected to Port 2R.

Serial communications Port 1 and the Auxiliary Input for demodulated IRIG-B time code input remain on the relay rear panel.

Communications port baud rate jumpers are located along the front edge of the circuit board. To select a baud rate for Port 1 or Ports 2, remove the relay front panel. The jumpers are visible near the center of the relay drawout assembly, to the right of the target LEDs. Carefully move the jumpers using needle-nosed pliers. Available rates are 300, 600, 1200, 2400, 4800, and 9600 baud.

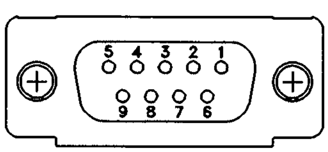
Caution: Do not select two baud rates for the same port as this can damage the relay baud rate generator. The relay is shipped with Port 1 set to 300 baud and Port 2 set to 2400 baud.

The serial data format is:

Eight data bits
Two stop bits
No parity bit

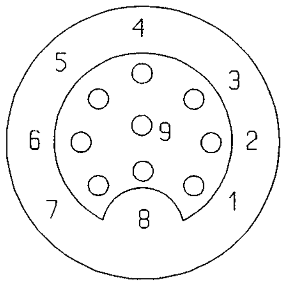
This format cannot be altered.

The SEL-PG10 Relay does not include a front panel serial interface port.



(female chassis connector, as viewed from outside panel)

Figure 4.1: SEL-2PG10 Relay 9-Pin Connector Pin Number Convention



(female chassis connector, as viewed from outside rear panel)

Figure 4.2: SEL-PG10 Relay 9-Pin Connector Pin Number Convention

Table 4.1 lists SEL-2PG10 Relay port pin assignments and signal definitions.

Table 4.1: SEL-2PG10 Relay Serial Port Connector Pin Assignments

Pin	Port 1, Port 2R	Port 2F	Description
1	+5 Vdc	N/C	
2	RXD	RXD	Receive data input.
3	TXD	TXD	Transmit data output.
4	+12 Vdc	N/C	
5	GND	GND	
6	-12 Vdc	N/C	
7	RTS	RTS	The relay asserts this line under normal conditions. When its received-data buffer is full, the line is de-asserted, 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.
8	CTS	CTS	The relay monitors CTS, and transmits characters only if CTS is asserted.
9	GND	GND	Ground for ground wires and shields

Table 4.2 lists SEL-PG10 Relay port pin assignments and signal definitions.

Table 4.2: SEL-PG10 Relay Serial Port Connector Pin Assignments

Pin	Name	Description
2	TXD	Transmit data output.
3	RTS	The relay asserts this line under normal conditions. When its received-data buffer is full, the line deasserts until the buffer has room to receive more data. Connected devices should monitor RTS (usually with their CTS input) and stop transmitting characters whenever the line deasserts. If transmission continues, data may be lost.
4	RXD	Receive date input
5	CTS	The 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

The communications protocol consists of hardware and software features. Hardware protocol includes the control line functions described above. The following software protocol is designed for manual and automatic communications.

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

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

   Commands transmitted to the relay should consist of the command name followed by a carriage return or a carriage return and line feed. You may truncate commands to the first three letters. For example, shorten **EVENT 1 <ENTER>** to **EVE 1 <ENTER>**. You may use upper and lower case characters without distinction, except in passwords.

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.

2. The relay transmits all messages in the following format:

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

   Each line of the message ends with a carriage return and line feed.

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

   The relay transmits XON (ASCII hex 11) and asserts the RTS output when the buffer drops below ¼ full.

   The relay transmits XOFF (ASCII hex 13) when the buffer is over ¾ full. It deasserts the RTS output when the buffer is approximately 95% full. Automatic transmission sources should monitor for the XOFF character so they do not overwrite the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and may resume when the relay sends XON.

4. You can use an XON/XOFF procedure to control the relay during data transmission. When the relay receives XOFF during transmission, it pauses until it receives XON. If there is no message in progress when the relay receives XOFF, it blocks transmission of any message presented to its buffer. Messages will be accepted after the relay receives XON.

   The CAN character (ASCII hex 18) aborts a pending transmission. This is useful in terminating an unwanted transmission.

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

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

COMMAND CHARACTERISTICS

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

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

You can enter Access Level 1 with the ACCESS command and the first password. The Level 1 password is factory-set to OTTER and may be changed with the PASSWORD command in Access Level 2. Most commands may be used in Access Level 1.

Critical commands such as SET operate only in Access Level 2. You can enter Access Level 2 with 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

Immediately after power is applied, the relay transmits the following message to the port(s) designated automatic:

```
Example 230 kV Line                 DATE: 1/1/92       TIME: 01:01:01


SEL-PG10
=
```

The ALARM relay should pull in, opening its "b" contact. The = represents the Access Level 0 prompt.

The relays are shipped with PORT 2 designated automatic; you may use the SET command to change this designation (see SET command, AUTO setting). The setting allows you to select PORT 1, PORT 2, or both ports to transmit automatic responses from the relay.

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 **OTTER** and press **<ENTER>**. The response is:

```
Example 230 kV Line                 DATE: 1/1/92        TIME: 01:01:44

Level 1
=>
```

The Access Level 1 prompt is =>. Now you can execute any Level 1 command.

Use a similar procedure to enter Access Level 2:

Type **2ACCESS <ENTER>**. The relay pulses the ALARM relay contact closed for one second and illuminates the ALRM LED, indicating an attempt to enter Access Level 2. Enter the proper password (TAIL) when prompted. After receiving the second password, the relay opens access to Level 2, as indicated by the following message and Level 2 prompt (=>>):

```
Example 230 kV Line                Date: 1/1/92         Time: 01:01:50

Level 2
=>>
```

You can enter any command at this prompt.

Command Format

Commands consist of three or more characters; only the first three characters of any command are required. You may use upper or lower case characters without distinction, except in passwords.

You must separate arguments from the command with spaces, commas, semicolons, colons, or slashes.

You can enter commands any time after the terminal displays an appropriate prompt.

COMMAND DESCRIPTIONS

Access Level 0 Command

ACCESS

ACCESS allows you to enter Access Level 1. The password is required unless you install jumper JMP103. The first password is set to OTTER at the factory; use the Level 2 command PASSWORD to change passwords.

The following display indicates successful access:

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


Example 230 kV Line                    Date: 1/1/92     Time: 01:02:05

Level 1
=>
```

The => prompt indicates Access Level 1.

If a user enters wrong passwords in three consecutive attempts, the ALARM relay contacts pulse closed and the relay briefly illuminates the ALRM target LED (unless an alarm condition exists). If the ALARM contact is connected to a monitoring system this feature can alert personnel to possible unauthorized access attempts.

Access Level 1 Commands

2ACCESS

2ACCESS allows you to enter Access Level 2. The password is required unless you install jumper JMP103. The second password is set to TAIL at the factory; use the Level 2 command PASSWORD to change passwords.

The following display indicates successful access:

```
=>2ACCESS
Password: ? @@@@@@

Example 230 kV Line              Date: 1/1/92          Time: 01:02:13
Level 2
=>>
```

You may use any command from the =>> prompt. After any Level 2 access attempt, the relay pulses the ALARM contacts closed and illuminates the ALRM target LED briefly (if no alarm condition exists).

DATE mm/dd/yy

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

To set the date to June 20, 1990, enter:

```
DATE 6/20/90 <ENTER>
```

The SEL-2PG10 Relay sets the date, pulses the ALARM relay closed, illuminates the ALRM target LED as the year is stored in EEPROM (if the year input differs from the year stored), and displays the new date.

EVENT n

EVENT displays an event report. Type **EVENT n <ENTER>** to display an event report for the nth event. The parameter n ranges from 1 for the newest event through 12 for the oldest event stored in the relay memory. If n is not specified, the default value is 1 and the relay displays the newest event report.

To inspect the newest report type **EVENT 1 <ENTER>** or **EVE <ENTER>**. The report provides the relay identifier string and 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, and for faults, the location, duration, and current. Relay and logic settings appear at the end of the report.

You can control transmissions from the relay with the following keystrokes:

- **<CTRL>S** Pause transmission
- **<CTRL>Q** Continue transmission
- **<CTRL>X** Terminate command

All event data are lost when the event buffers are cleared. If an event buffer is empty when you request an event, the relay returns an error message:

```
=> EVENT 12 <ENTER>
Invalid event
=>
```

Section 5: EVENT REPORTING includes a sample event report.

HISTORY

HISTORY displays the date, time, and type of event for each of the last twelve events. If the event is a fault, the distance, duration, and current are also shown.

```
Example 230 kV Line                 Date: 2/28/92      Time: 01:45:40

#    DATE         TIME        TYPE  DIST   DUR   CURR

1   7/28/88   09:03:01.092  AG    100.21 7.25  798.1
2   7/28/88   09:02:11.167  AG    74.97  4.00  1022.0
3   7/28/88   09:02:10.962  AG    25.21  7.25  2120.9
4   7/28/88   09:00:13.345  BC    25.52  7.25  3167.6
5
6
7
8
9
10
11
12
```

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

The time is saved 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. If a long fault triggers two events, you can still determine its duration. Simply calculate the time difference between the report generated at fault inception and the report generated at the TRIP.

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

For faults, the TYPE indication shows phase-involvement information. The phase-involvement is determined independently from the relay elements picked up in the event report. The relay determines phase-involvement using only uncompensated and load compensated current magnitudes. These magnitudes are taken from 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 relay trips for a BG fault after the initial report was completed, the second report shows "BGT" for TYPE.

For events other than faults, the TYPE indication is "EXT." "EXT" indicates a report generated in response to external stimulus, such as assertion of the EXT1 (EXTERNAL TRIGGER 1) or EXT2 (EXTERNAL TRIGGER 2) or TRIGGER command execution.

The DIST column lists the equivalent distance to a fault in miles. The relay calculates fault location with the Takagi algorithm or a reactance measurement, depending on the availability of prefault data in the event report. When relay element operation is sporadic, the fault locator may not be able to locate every fault for boundary faults of long duration. The DIST column may contain "999999" in such cases. While this behavior can be contrived under test conditions, it is extremely rare in actual practice.

The DUR column gives a measurement of the fault duration. This is timed from the first pickup of the ZABC, ZP, 67NP, or 67NI relay element to the first dropout of all said relay elements. It is the duration of the first contiguous pickup of relay elements 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.

IRIG

IRIG directs the relay to read the demodulated IRIG-B time code input at J201 on the rear panel, if a time code signal is input.

If the relay reads the time code successfully, it updates the internal clock/calendar time and date to the time code reading. The relay transmits a message with the relay ID string, date, and time.

If no signal is present or the time code cannot be read successfully, the relay sends the error message "IRIGB DATA ERROR."

Note: Normally, it is not necessary to synchronize using this command because the relay performs it automatically every few minutes. The command is provided to prevent delays during testing and installation.

METER n

METER displays the voltages, currents, and real and reactive power in primary quantities of amperes, kilovolts, megawatts, and megavars.

```
Example 230 kV Line                   Date:  7/28/92      Time: 13:27:05

                 A          B          C         AB        BC       CA
I (A)          994        995        994       1723      1724     1724
V (kV)       134.4      134.3      134.2      233.1     232.8    232.9

P (MW)      350.91
Q (MVAR)     67.82
```

P and Q are positive when the power flow is in the direction of the relay reach; i.e., out from the bus and into the line.

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

QUIT

QUIT returns control to Access Level 0 from Level 1 or 2 and resets targets to the Relay Targets (TAR 0). The command displays the relay I.D., date, and time of QUIT command execution.

Use this command when you finish communicating with the relay to prevent unauthorized access. Control automatically returns to Access Level 0 after a settable interval of no activity (see the TIME1 and TIME2 settings of the SET command).

SHOWSET

SHOWSET displays the current relay settings. You cannot enter or modify settings with this command. See the SET command description for information about setting entry.

SHOWSET display example:

```
Settings for:  Example 230 kV Line

R1   =13.90    X1   =79.96     R0  =41.50   X0   =248.57   LL=100.00
CTR  =200.00   PTR  =2000.00   MTA =80.80   LOCAT=Y
Z%   =80.00    PTMR =0.00      50L =100.00
67NP =100.00   67NTD=3.00      67NC=2       67NTC=Y
67NIP=1000.00  GTMR =0.00
32QE =N        32VE =Y         32IE=Y
TIME1=5        TIME2=0         AUTO=2       RINGS=3

Logic settings:

MT    MA1    MA2    MA3    MA4    MA5
66     40     20     08     04     02
```

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 impedances are given.

Line 2: Current and voltage transformer ratios, maximum torque angle, and fault locator enable.

Line 3: Single-zone reach as a percent of the line, time delay for phase faults and phase overcurrent element.

Line 4: Residual time-overcurrent pickup, time dial, curve, and torque control enable.

Line 5: Residual instantaneous-overcurrent element pickup threshold and time delay for ground faults.

Line 6: Enables for the negative-sequence directional, voltage polarized zero-sequence directional, and current polarized zero-sequence directional elements.

Line 7: Port 1 and 2 timeouts, the autoport for automatically transmitted messages, and the number of rings after which the modem automatically answers.

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

Row 1: 50L ZABC ZP ZPT 67NP 67NT 67NI 67DT

Logic settings appear in hexadecimal format. The following table provides equivalencies between hexadecimal (hex) and binary numbers. Use the table when you examine the logic settings display.

Table 4.3: Hexadecimal/Binary Conversion

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

For example, consider Row 1 of mask MT, which is set to 66 hex format. Using the table, convert 66 to binary:

66 -> 0110 0110.

Now, build the Relay Word for Row 1 of mask MT as follows:

```
50L   ZABC  ZP    ZPT   67NP  67NT  67NI  67DT
 0     1     1     0     0     1     1     0
 _______  6 _______    _______  6 _______
```

STATUS

STATUS allows inspection of self-test status. The relay automatically executes the STATUS command whenever a self-test enters a warning or failure state. If this occurs, the relay also transmits a STATUS report from the port designated automatic (see SET command, AUTO setting).

The STATUS report format:

```
Example 230 kV Line                  Date: 7/28/92        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.

W (warning) or F (failure) suffixes indicate out-of-tolerance values.

The PS row indicates voltages for the three power supplies. W or F suffixes indicate warning or failure states of the 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 of five tests. If a RAM or ROM test fails, the report lists the IC socket number of the defective part instead of OK.

The A/D self-test checks A/D conversion time. If it exceeds a threshold, the test fails and the relay disables protective functions. 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. SET indicates the state of the self-test which compares two copies of the settings stored in nonvolatile memory. Failure of this test disables relay and control functions.

Table 4.4 shows relay actions for any self-test condition: warning (W) or failure (F).

Table 4.4: Self-Test Summary

Self-Test	Limits	Status Message	Protection Disabled	Control Disabled	Alarm Output
RAM	----	F	YES	YES	permanent contact closure
ROM	----	F	YES	YES	permanent contact closure
SETTINGS	----	F	YES	YES	permanent contact closure
A/D	----	F	YES	NO	permanent contact closure
+5 V	±0.3 V	W	NO	NO	no ALARM contact closure
	±0.4 V	F	YES	YES	permanent contact closure
±15 V	±0.8 V	W	NO	NO	no ALARM contact closure
	±1.2 V	F	YES	NO	permanent contact closure
CHANNEL	50 mV	W	NO	NO	no ALARM contact closure
OFFSETS	75 mV	F	NO	NO	four second contact pulse
MASTER	50 mV	W	NO	NO	no ALARM contact closure
OFFSET	75 mV	F	NO	NO	four second contact pulse

TARGETS n k

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

When the relay power is on, the LED display indicates the functions marked on the front panel. The default display shows fault information from the RELAY TARGETS row of Table 4.5.

Using the TARGET command, you may select one of the following three sets of data to print and display on the LEDs.

Table 4.5: Target LED Assignment

LED:	1	2	3	4	5	6	7	8	
0	EN	ALRM	50L	67N	3PH	2PH	INST	TIME	RELAY TARGETS
1	50L	ZABC	ZP	ZPT	67NP	67NT	67NI	67DT	RELAY WORD #1
2			52A	E3	E2	E1	EXT2	EXT1	CONTACT INPUTS
3		TRIP	A1	A2	A3	A4	A5	ALRM	CONTACT OUTPUTS

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

The ALRM (alarm) bit in target 3 (contact outputs) asserts for the ACCESS command, 2ACCESS command, and self-test failures. It does not assert for the SET, LOGIC, DATE, or PASSWORD commands. This differs from the ALARM output relay, which asserts for all the above conditions.

The optional parameter k selects the number of times the relay displays target data for parameter n. To display a series of ten target readings of target number one, type **TARGET 1 10 <ENTER>**.

When finished, type **TAR 0 <ENTER>**. This returns the display to fault targets so field personnel do not misinterpret displayed data. The relay target status automatically returns to TAR 0 when the relay returns to Access Level 0. You can accomplish this with the QUIT command.

Press the TARGET RESET button on the front panel to clear the TAR 0 data and illuminate all target LEDs for a one second lamp test. Pressing TARGET RESET also unlatches the TRIP output from the 52A input. This feature is useful during relay testing and minimizes the possibility of reinstalling the relay with the TRIP output asserted.

You can reset the front panel targets to TAR 0 and clear them remotely or locally with the TARGET command. Type **TARGET R <ENTER>** to reset and clear the targets.

TIME hh:mm:ss

TIME checks the internal clock. To set the clock, type TIME and the desired setting, then press **<ENTER>**. Separate the hours, minutes and seconds with colons, semicolons, spaces, commas or slashes. To set the clock to 23:30:00, enter:

```
TIME 23 30 00 <ENTER> or TIME 23:30:00 <ENTER>
```

A quartz crystal oscillator provides the time base for the internal clock. You can set the time clock automatically with the relay time code input and a source of demodulated IRIG-B time code.

TRIGGER

TRIGGER generates an event record. After command entry, the relay responds "Triggered." The computer formats the record during a short delay and sends a record summary for display or printout to the port(s) designated automatic.

Use TRIGGER to inspect phasor voltages and currents. Immediately after installation, execute the TRIGGER command and draw the phasors (Section 5: EVENT REPORTING explains how to do this). Check for the proper polarity and phase-sequence of the inputs.

Event records can also be generated without control action by asserting the EXTERNAL TRIGGER 1 or EXTERNAL TRIGGER 2 input.

Access Level 2 Commands

While all commands are available from Access Level 2, the commands below are available ONLY from Access Level 2. Remember: the ALARM relay pulses closed and the ALRM (ALARM) LED illuminates briefly after any Level 2 access attempt.

LOGIC n

The logic command programs the masks which control outputs and reclosing operations.

The parameter n specifies a mask to program where n can be any of the following:

MT - Mask for trip
MA1 - Mask for A1 relay control
MA2 - Mask for A2 relay control
MA3 - Mask for A3 relay control
MA4 - Mask for A4 relay control
MA5 - Mask for A5 relay control

The logic programming procedure requires you to enter changes to the mask or press **<ENTER>** to indicate no change. Each mask listed above has one line which corresponds to Relay Word one (1) as follows:

Relay Word: `50L   ZABC  ZP    ZPT   67NP  67NT  67NI  67DT`

When you have entered all data for the Relay Word, the terminal displays the new settings and prompts you to approve the new logic settings. **Y** enters the new data, clears the event buffers, pulses the ALARM contact closed and illuminates the ALRM target LED briefly. **N** retains the old settings.

The LOGIC command displays a header (as shown above) and the present logic mask for the Relay Word. Next, the terminal displays a question mark prompt and waits for input. Enter only ones and zeros as input; one selects and zero de-selects a member of the Relay Word. Press **<ENTER>** when a group is satisfactory. If you wish to change any member of a group, you must re-enter all eight members, even if some remain the same. The relay displays existing settings and question mark prompt after entry to allow corrections.

The following masks represent those present at shipping.

The first mask controls the TRIP output.

```
=>> LOG MT <ENTER>

50L  ZABC ZP   ZPT  67NP 67NT 67NI 67DT
 0    1    1    0    0    1    1    0
```

The mask for trip (MT) selects tripping by the instantaneous three-phase mho element, phase-phase mho element, instantaneous residual overcurrent element, and by timeout of the residual time-overcurrent element.

The last five masks control the programmable output relays A1-A5.

```
=>> LOG MA1 <ENTER>

50L  ZABC ZP   ZPT  67NP 67NT 67NI 67DT
 0    1    0    0    0    0    0    0
```

Output relay A1 selects three-phase faults for monitoring.

```
=>> LOG MA2 <ENTER>

50L  ZABC ZP   ZPT  67NP 67NT 67NI 67DT
 0    0    1    0    0    0    0    0
```

MA2 selects phase-phase faults to monitor with output relay A2.

```
=>> LOG MA3 <ENTER>

50L  ZABC ZP   ZPT  67NP 67NT 67NI 67DT
 0    0    0    0    1    0    0    0
```

MA3 selects the pick up of the residual time-overcurrent relay alone.

```
=>> LOG MA4 <ENTER>

50L  ZABC ZP   ZPT  67NP 67NT 67NI 67DT
 0    0    0    0    0    1    0    0
```

MA4 selects the time-out of the residual time-overcurrent relay.

```
=>> LOG MA5 <ENTER>

50L  ZABC ZP   ZPT  67NP 67NT 67NI 67DT
 0    0    0    0    0    0    1    0
```

MA5 selects the instantaneous residual overcurrent relay pick up for monitoring ground faults with output relay A5.

Programmable masks enable you to use the outputs for any function. Examples include separating outputs for phase and ground faults or by relay element.

PASSWORD (1 or 2) password

PASSWORD allows you to inspect or change existing passwords. To inspect passwords, type **PASSWORD <ENTER>**.

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

PASSWORD 1 BIKE <ENTER>

The relay sets the password, pulses closed the ALARM contacts, and transmits the response "Set."

After entering new passwords, type **PAS <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 relay without the passwords.

Passwords can be any length up to six numbers, letters, or any other printable characters except 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-PG10 123456 12345. 12345 ab1CDE

If passwords are lost or you wish to operate the relay without password protection, install JMP103 on the main board. With no password protection, you can gain access without the passwords and view or change them.

SET

SET allows you to enter relay settings. At the setting procedure prompts, enter new data or press **<ENTER>** to indicate no change.

When you finish entering setting changes, it is not necessary to scroll through the remaining settings. Type **END** after the last change to display the new settings and enable prompt. Do not use the END statement at the relay I.D. setting; press **<CTRL>X** to abort the set procedure from this point.

After you enter all data, the relay displays the new settings and prompts for approval to enable them. Error messages notify you when entries result in out-of-range settings. If all settings are acceptable, the relay enables them, briefly closes the ALARM contacts, illuminates the ALRM target LED momentarily, and clears the event buffers.

The following data are required to set the relay:

R1, X1	Pos.-seq. primary impedance of line 0-9999 ohms
R0, X0	Zero-seq. primary impedance of line 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 mho elements (47°-90°)
LOCAT	Do you want the fault locator enabled? (Y or N)
Z%	Reach of mho elements (percent of line impedance: 0 to 2000%)
PTMR	Delay for phase and three-phase faults (0-2000 cycles in quarter-cycle steps)
50L	Phase overcurrent element low pickup (0.25-50,000 primary amperes)
67NP	Residual time-overcurrent pickup (0.25-50,000 primary amperes)
67NTD	Residual time-overcurrent time dial (0.5-15)
67NC	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
67NTC	Do you want residual time-overcurrent torque control? (Y or N)
67NIP	Residual instantaneous overcurrent (0.25-50,000 primary amperes)
GTMR	Delay for ground faults (0-2000 cycles in quarter-cycle steps)
32QE	Do you want negative-sequence directional supervision of the ground overcurrent elements? (Y or N)
32VE	Do you want voltage polarization for the zero-sequence directional element enabled? (Y or N)
32IE	Do you want current polarization for the zero-sequence 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	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.

As you enter settings, the relay checks them against the limits above. It computes internal settings from your entries and checks to be sure they fall within the specified range.

For example, let CTR = 1000 and 67NIP = 1. These settings are admissible alone, but combining them results in an out of range secondary pickup setting: 1 mA. Error messages indicate these problems immediately after you enable the new settings (refer to Specifications in Section 1: INTRODUCTION for the secondary ranges of the relay elements).

Reach value is the reach of the mho units for a zero-resistance fault on the transmission line. The maximum torque angle (MTA) for the mho circles is independently set. The circle diameter is expanded to keep the reach setting in the direction of the transmission line impedance constant as the maximum torque angle is separated from the transmission line angle. Thus the maximum torque angle setting does not affect the reach in the direction of the transmission line. The mho circle diameter relates to the set reach and the difference between the transmission line angle and the MTA by the expression below.

DIAMETER = [SET REACH] / [cos (T. L. ANGLE - MTA)]

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

Auto Setting	Automatic Message Destination Port
1	1
2	2
3	1 and 2

EVENT REPORTING
TABLE OF CONTENTS

Introduction 5-1
Example Event Report 5-2
Interpretation of Voltage and Current Data 5-2
Relay Elements Status Indicators 5-4
Firmware Identification 5-6
Sample Event Report 5-7

EVENT REPORTING

INTRODUCTION

The relay transmits a summary event report after events and saves a full event report in 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 also includes distance to the fault, impedance to the fault (along the line) in secondary ohms, duration, and a fault current measurement (the LOCAT setting allows you to disable the fault locator).

The relay automatically transmits the summary from the port(s) designated automatic (refer to AUTO setting), as long as the port has not timed out. Report transmission occurs regardless of access level. If automatic transmissions are monitored by a dedicated channel or printed on a dedicated printer, set the port timeout interval to zero for the appropriate port (refer to TIME1, TIME2 settings).

The full report contains current and voltage information you can use to construct phasor diagrams of the prefault, fault, and postfault conditions. 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, etc.

Due to the length of the full report, it is not automatically transmitted. You can display the full report with the EVENT command.

The relay stores the last twelve events in volatile memory and retains the data as long as control power remains on. This differs from relay settings, which are stored in nonvolatile memory. The relay retains settings until they are changed with the SET command, regardless of control power cycling. Use the HISTORY command to review the stored events.

The relay generates an event report in response to the following:

- Any fault
- Execution of TRIGGER command
- Assertion of EXTERNAL TRIGGER 1 Input
- Assertion of EXTERNAL TRIGGER 2 Input

One fault can trigger a second event report if the trip occurs after the end of the first report.

Changes to the 52A input do not trigger an event report.

See FAULT LOCATOR in Section 3: FUNCTIONAL DESCRIPTION for more information on event report triggering.

EXAMPLE EVENT REPORT

A full report appears at the end of this section. The report was generated in response to a simulated fault on the Example 230 kV Line described in Section 2: INITIAL CHECKOUT. Simulation used an A-to-ground fault 50 miles away; test settings were computed with the BASIC program in the appendices. Calculations assumed a source impedance of 0.2 of the total line impedance. A Doble F-2000 Test System provided the relay currents and voltages for this test. The test used a latching relay to simulate the circuit breaker action and provide a contact whose state is sensed by the relay 52A input.

The actual test settings appear below.

VA	VB	VC	IA	
47.86	71.31	71.24	6.93	volts or amps
0	-126	126	-80	degrees

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

VA	VB	VC	IA	
95.7	142.6	142.5	1386	kilovolts or amperes

These were obtained using the potential and current transformer ratios assumed in the Example 230 kV Line. Note that these ratios are displayed at the end of the report:

PTR = 2000   CTR = 200.

The following paragraphs describe the relay response to the simulated fault using information from the full event report.

INTERPRETATION OF VOLTAGE AND CURRENT DATA

The relay receives voltage and current data via the rear panel, completes the processes listed below, and uses the data for event reporting.

1. Two-pole low-pass filters with cutoff frequencies of about 85 Hz filter input analog signals.

2. Filtered analog signals are sampled four times per power system cycle and converted to numeric values.

3. Digital filters process the sampled data and remove dc and ramp components. The unit sample response of these filters is:

1, -1, -1, 1

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

4. Digital filter output data are scaled into primary quantities using current and potential transformer ratios entered during the setting procedure. Samples are taken four times per power-system cycle. The latest four samples are processed through the digital filter every quarter-cycle, and successive filter outputs arrive every 90°. 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°.

These filter output values can 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 having zero phase shift with respect to t=0 and a peak amplitude of 1. Now consider two samples, one taken at t=0, the other taken 90° 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 t=0 and t+90° are 1 and 0; its phasor representation is (0,1). The phasor (0,1) leads the phasor (1,0) by 90°. This coincides with the 90° lead of the cosine function over the sine function.

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

Note that moving forward one quarter-cycle rotates all phasors 90°. You can verify this by plotting the phasor diagram with rows 1 and 2, then rows 2 and 3.

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

	Currents				Voltages			
IPOL	IR	IA	IB	IC	VA	VB	VC	
0	1329	1318	0	0	-11.7	125.2	-104.2	(Y-component)
0	-402	-396	0	0	-94.7	67.6	96.6	(X-component)

These appear near the "middle" of the fault, as shown by 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	1388	1376	0	0	95.4	142.3	142.1	(magnitude)
0	107	107	0	0	-173	62	-47	(angle)
0	280	280	0	0	0	-125	126	(angle + 173)

The third row adds 173° to all angles of the second row. This assigns the phase-A voltage phasor as the 0° reference. Compare the magnitude and shifted angles to the test settings above. Angle measurement errors are 1° or less; magnitude errors are less than 1%.

The event report indicates a fault current of 1382.3 amperes primary, which agrees with the 1386-ampere test set current referred to primary.

The indicated fault location is 50.06 miles. The "actual" fault location is 50.00 miles. The error is 50.06 - 50.00, or 0.06 miles, less than 1.0% of the set reach for this example.

RELAY ELEMENTS STATUS INDICATORS

The six columns headed "Relays" indicate the states of all relay elements. Designator symbols indicate active states of various relay elements. These symbols correspond with the relay element names. Periods placed in the corresponding columns indicate inactive states. Columns for active relay elements read as follows:

50P : Phase overcurrent element : * = 50L pick up

213 : Three-phase distance unit : * = pick up

21P : Two-phase distance unit : * = pick up

67I : Residual overcurrent unit : * = 67NI pick up

67T : Residual time-overcurrent : P = 67NP, pick up threshold reached
T = 67NT, trip threshold reached

The groups of columns headed "Outputs" and "Inputs" show states of all output and input contacts. An asterisk (*) indicates assertion of any output or input contact; a period indicates deassertion. The columns read:

OUTPUTS

TP : TRIP output
A1 : PROGRAMMABLE output #1
A2 : PROGRAMMABLE output #2
A3 : PROGRAMMABLE output #3
A4 : PROGRAMMABLE output #4
A5 : PROGRAMMABLE output #5
AL : ALARM output

INPUTS

ET1 : EXTERNAL TRIGGER 1 (for event report) input
ET2 : EXTERNAL TRIGGER 2 (for event report) input
E1 : EVENT 1 input
E2 : EVENT 2 input
E3 : EVENT 3 input
52A : BREAKER AUXILIARY 52A SWITCH input

The example event report shows the phase-overcurrent element (50L) picked up for load current, as indicated by the "*" in the 50P column.

The residual time-overcurrent element (67NT) is the first to pick up for the fault. This is indicated by the "P" in the 67T column in the last quarter-cycle of the fourth cycle of the event report. The A3 output asserts in the same quarter-cycle, since A3 was programmed to follow the 67NT pickup (67NP). For almost every actual fault, the first element(s) to pick up are shown in the sixteenth row of data.

In the nineteenth quarter-cycle, the instantaneous residual-overcurrent element (67NI) picks up, indicated by the "*" in the 67I column. In response, the TRIP output and programmable output A5 asserts. The TRIP output asserts because the 67NI element was incorporated into the TRIP MASK (MT) of the LOGIC settings. The A5 output also asserts due to mask incorporation. The programmable output A5 was set to follow the 67NI pickup via the A5 MASK (MA5) of the logic settings.

The 52A contact input monitored the latching relay (circuit breaker simulator) state. This input deasserts in the 22nd row of the report, indicating that the latching relay changed to the "open" state about one cycle after tripping was initiated.

You can estimate fault duration from the total time relay elements were picked up. They were picked up for a total of 24 quarter-cycles, or 6.00 cycles. This value appears near the bottom of the report: Duration: 6.00.

For additional information about this report, see the HISTORY command description.

FIRMWARE IDENTIFICATION

The relay provides a means of interpreting Firmware Identification Data (FID). The FID string appears near the top of each long event report. The string format is:

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

Where:

[PN] = Product Name (eg: SEL-PG10)

[RN] = Revision Number (eg: 100)

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

[RD] = Release Date (eg: YYMMDD = 880724)

FID string example:

FID = SEL-PG10-R100-V656mpr-D880724

For the SEL-PG10 family of relays, interpret version specifications 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	c, r	cumulative, recent	Target LED Update Logic

Please contact Schweitzer Engineering Laboratories, Inc. for the available versions of the SEL-2PG10 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 230 kV Line Date: 8/13/90 Time: 11:22:11.329

FID=SEL-PG10-R100-V656mpr-D880724

	Currents (amps)				Voltages (kV)			Relays	Outputs	Inputs
								52266	TAAAAAA	EEEEE5
IPOL	IR	IA	IB	IC	VA	VB	VC	01177	P12345L	TT1232
								P3PIT		12 A
3	0	799	-305	-481	132.8	-52.1	-80.8	*....	....	.....*
-3	4	-101	736	-632	-16.0	123.0	-106.7	*....	....	.....*
-3	0	-796	302	485	-132.8	52.0	80.9	*....	....	.....*
0	-3	98	-739	626	16.0	-123.0	106.7	*....	....	.....*
6	-1	796	-302	-481	132.9	-52.0	-80.9	*....	....	.....*
0	3	-101	739	-629	-16.1	123.0	-106.5	*....	....	.....*
-3	1	-793	305	481	-132.8	52.1	80.9	*....	....	.....*
0	-4	104	-736	636	16.1	-123.3	106.3	*....	....	.....*
-3	1	787	-308	-488	132.9	-51.8	-80.7	*....	....	.....*
3	4	-98	736	-629	-16.2	123.2	-106.5	*....	....	.....*
3	-2	-790	308	488	-132.9	51.8	80.8	*....	....	.....*
-3	-3	98	-739	626	16.2	-123.1	106.6	*....	....	.....*
0	1	793	-305	-485	132.8	-51.9	-80.9	*....	....	.....*
-3	93	3	683	-591	-16.7	122.8	-106.7	*....	....	.....*
3	45	-551	160	440	-122.4	56.3	85.2	*....	....	.....*
3	-620	-591	-374	349	14.2	-123.9	105.7	*...P	...*...	.....*
-6	129	349	-13	-223	104.6	-63.6	-92.5	*...P	...*...	.....*
3	1173	1186	69	-79	-11.4	125.2	-104.5	*...P	...*...	.....*
3	-371	-396	3	25	-96.1	67.1	96.2	*..*P	*..*.*.	.....*
-3	-1309	-1306	-6	9	11.6	-125.1	104.4	*..*P	*..*.*.	.....*
0	397	400	3	-6	94.9	-67.6	-96.7	*..*P	*..*.*.	.....*
0	1329	1318	0	0	-11.7	125.2	-104.2	*..*P	*..*.*.	.....*
0	-402	-396	0	0	-94.7	67.6	96.6	*..*P	*..*.*.	.....*
3	-1330	-1325	3	-3	11.7	-125.3	104.2	*..*P	*..*.*.	.....*
0	403	400	0	0	94.7	-67.5	-96.6	*..*P	*..*.*.	.....*
3	1328	1328	0	3	-11.6	125.3	-104.2	*..*P	*..*.*.	.....*
0	-402	-406	0	-3	-94.8	67.5	96.7	*..*P	*..*.*.	.....*
-3	-1329	-1321	3	-6	11.7	-125.2	104.0	*..*P	*..*.*.	.....*
0	402	406	-3	6	94.8	-67.5	-96.6	*..*P	*..*.*.	.....*
0	1330	1318	0	6	-11.9	125.2	-104.1	*..*P	*..*.*.	.....*
0	-402	-406	0	-6	-94.7	67.4	96.6	*..*P	*..*.*.	.....*
0	-1330	-1318	-3	-3	11.8	-125.3	104.2	*..*P	*..*.*.	.....*
-3	403	400	3	3	94.9	-67.3	-96.6	*..*P	*..*.*.	.....*
0	1238	1230	0	0	-11.4	125.4	-103.9	*..*P	*..*.*.	.....*
6	-449	-440	0	3	-105.1	63.2	92.3	*..*P	*..*.*.	.....*
0	-711	-705	0	0	13.9	-124.3	105.2	*...P	...*...	.....*
-6	276	271	3	-3	122.6	-56.0	-85.2	*...P	...*...	.....*
3	155	151	0	0	-16.6	123.2	-106.5	*...P	...*...	......
0	-32	-28	-6	-3	-131.5	52.4	81.8	*...P	...*...	......
-3	-20	-25	0	0	16.5	-123.4	106.3	.....	....	......
6	3	6	3	3	132.7	-51.7	-81.3	.....	....	......
-3	2	6	0	0	-16.5	123.5	-106.1	.....	....	......
-3	1	-3	0	0	-132.8	51.4	81.2	.....	....	......
6	-1	3	3	-3	16.6	-123.3	106.0	.....	....	......

Event AG Location 50.06 mi 4.06 ohms sec
Duration 6.00 Flt Current 1382.3

R1 =13.90	X1 =79.96	R0 =41.50	X0 =248.57	LL=100.00
CTR =200.00	PTR =2000.00	MTA =80.80	LOCAT=Y	
Z% =80.00	PTMR =0.00	50L =100.00		
67NP =100.00	67NTD=3.00	67NC=2	67NTC=N	
67NIP=1000.00	GTMR =0.00			
32QE =N	32VE =Y	32IE=Y		
TIME1=0	TIME2=0	AUTO=2	RINGS=3	

Logic settings

MT	MA1	MA2	MA3	MA4	MA5
66	40	20	08	04	02

INSTALLATION
TABLE OF CONTENTS

Mounting . . . 6-1
Frame Ground Connection . . . 6-1
Power Connections . . . 6-1
Secondary Circuits . . . 6-1
Control Circuits . . . 6-2
Communications Circuits . . . 6-2
Jumper Selection . . . 6-2
EIA RS-232-C and IRIG-B Installation . . . 6-4
Initial Checkout . . . 6-5
SEL Direction and Polarity Check Form . . . 6-12

FIGURES

Figure 6.1: 9-Pin Female Chassis Connector Pin Number Convention . . . 6-4
Figure 6.2: Horizontal Front and Rear Panel Drawings . . . 6-7
Figure 6.3: Relay Dimensions, Panel Cutout, and Drill Plan . . . 6-8
Figure 6.4: Communications and Clock Connections - One Unit at One Location . . . 6-9
Figure 6.5: Communications and Clock Connections - Multiple Units at One Location . . . 6-9
Figure 6.6: SEL Relay Communications Diagram for Connection to the SEL-DTA . . . 6-10
Figure 6.7: External AC Current and Voltage Connections . . . 6-10
Figure 6.8: External DC Connection Diagram (Typical) . . . 6-11
SEL Direction and Polarity Check Form . . . 6-12

INSTALLATION

MOUNTING

The relay is designed for mounting by its front vertical flanges in a 19" vertical relay rack. It may also be mounted semi-flush in a switchboard panel. Use four #10 screws for mounting. Front and rear panel drawings are included in this manual.

FRAME GROUND CONNECTION

Terminal 46 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 44 and 45 on the rear panel must be connected to a source of control voltage. Control power passes through these terminals to the fuse(s) and a toggle switch, if installed. The power continues through a surge filter and connects to the switching power supply and output relay control circuits. The control power circuitry is isolated from the frame ground.

SECONDARY CIRCUITS

The relay presents a very low burden to the secondary current and potential circuits. Each current circuit is independent of the other circuits. There is no interconnection of current circuits inside the instrument. When current polarization is not desired or required, terminals 33 and 34 may be left open-circuited.

Since it includes ground relaying functions, the relay requires four-wire wye potentials. It is not possible to apply the relay directly to circuits where line-to-line potential transformers are used. Please consider the SEL-221D Relay for such applications.

CONTROL CIRCUITS

The control inputs are dry. To assert the 52A input, you must apply control voltage 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. A metal-oxide varistor protects each contact.

COMMUNICATIONS CIRCUITS

Connections to the two EIA RS-232-C serial communications ports are made via three 9-pin connectors labeled PORT 1 and PORT 2R on the rear panel and PORT 2F on the front panel. Pins 5 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. You can minimize communications-circuit difficulties by keeping the length of the EIA RS-232-C cables as short as possible. Lengths of twelve feet or less are recommended; cable lengths should never exceed 100 feet. Use shielded communications cable for lengths greater than ten 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. If these wires are bundled, switching spikes and surges can cause noise in the communications wiring. This noise could exceed communications logic thresholds and introduce errors. The IRIG-B clock cable should also be routed away from the control wiring and secondary circuits.

JUMPER SELECTION

Jumpers JMP103, J104, and J6 are on the front edge of the main board. They are easily accessed by removing the front panel. Jumpers JMP3 and soldered wire jumpers JMP4 through JMP11 are toward the back of the main board and are accessed by removing the top cover, or removing the front panel and withdrawing the main board.

EIA RS-232-C Jumpers

Jumper J6 provides for EIA RS-232-C baud rate selection. 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 a 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.

OPEN/CLOSE Command Enable Jumper

Jumper JMP104 performs no function since there is not an OPEN or CLOSE command in the SEL-2PG10 Relay.

Password Protection Jumpers

Put JMP103 in place to disable password protection. This feature is useful if passwords are not required or when passwords are forgotten.

A5 Output Contact Jumper

With JMP3 in the A4 position, the A5 output contact operates per the MA5 logic mask setting. With jumper JMP3 in the ALARM position, the A5 output contact operates with the ALARM output contact.

Communication Port External Power Jumpers

DC power is available from Port 1 and Port 2R to power external devices. Jumpers must be selected to route dc power to the rear panel connectors. The internal jumpers are near Port 1 and are labeled as follows: JMP12 = +5 V; JMP13= +12 V; JMP14 = -12 V. Use caution to ensure the dc current requirement of the external equipment does not exceed the relay power supply specifications. Only route dc power to the rear ports if required for your application.

Output Contact Soldered Wire Jumpers

All the output contacts can be configured as "a" or "b" contacts with soldered wire jumpers JMP4 through JMP11 (each jumper has positions A and B). The output contact/soldered wire jumper correspondence is as follows:

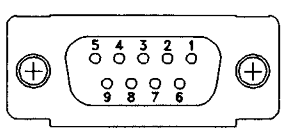
Output Contact	Jumper
TRIP (terminals 1,2)	JMP11
TRIP (terminals 3,4)	JMP10
A1	JMP9
A2	JMP8
A3	JMP7
A4	JMP6
A5	JMP5
ALARM	JMP4

EIA 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 is a 56-ohm resistor in series with the photodiode input of an optical isolator. The photodiode has a forward voltage drop of about 1.5 volts. The output of a TTL-level driver with sufficient current capability can drive the input directly. Inputs can also be driven in a current loop from a higher-voltage driver.

A pin definition of the 9-pin port connectors and cabling information for the EIA RS-232-C ports appears below. The table shows several types of EIA RS-232-C cables. 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 for more information.



(as viewed from the relay rear panel)

Figure 6.1: 9-Pin Female Chassis Connector Pin Number Convention

EIA RS-232-C cables

```
SEL-2PG10                  9-Pin *DTE DEVICE

GND  5 ------------------ 5   GND
TXD  3 ------------------ 2   RXD
RXD  2 ------------------ 3   TXD        (SEL  CABLE 234)
RTS  7 -┐
        │ Jumper
CTS  8 -┘
                       ┌─ 1   DCD
                       ├─ 4   DTR
                Jumper ├─ 6   DSR
                       └─ 8   CTS
                          9   RI

SEL-2PG10                  **DCE DEVICE

GND   5 ----------------- 7   GND
TXD   3 ----------------- 2   RXD
RTS   7 ----------------- 20  DTR        (SEL  CABLE 222)
RXD   2 ----------------- 3   TXD
CTS   8 ----------------- 8   CD
GND   9 ----------------- 1   GND

PRTU                       SEL-2PG10

GND   1 ----------------- 5   GND
TXD   2 ----------------- 2   RXD
RXD   4 ----------------- 3   TXD        (SEL  CABLE 231)
CTS   5 ----------------- 7   RTS
+12   7 ----------------- 8   CTS
GND   9 ----------------- 9   GND
```

* DTE = Data Terminal Equipment (terminals, printers, computers, etc.)
** DCE = Data Communications Equipment (modems, etc.)

INITIAL CHECKOUT

You can follow the suggestions below or combine them with your normal practice. Never implement recommendations prohibited by the rules of your normal practice.

A portable terminal or computer provides convenient local communications with the relay during field checkout. Connect the device to PORT 2 for checkout, with PORT 2 designated automatic (see AUTO setting under SET command).

1. Apply control power and make sure the terminal displays the startup message. If not, set AUTO = 2 with the SET command in Access Level 2. Check the settings with the ACCESS and SHOWSET commands. Use SET to change the TIME2 setting if necessary. Use 2ACCESS and TIME to set the clock.

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

3. Use the TRIGGER command to save an event record. Type **EVENT 1 <ENTER>** and examine the triggered event record. Refer 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° apart, of reasonable magnitudes, and rotating in the positive-sequence direction. Zero-sequence voltage Y and X components (times a factor of three) are the sum of the three Y components and the three X components of voltage. 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. Type **TARGET 2 <ENTER>**. If the connections are made to the circuit breaker 52A contact and the circuit breaker is closed, the TARGET command with option 2 should read "1" under the 52A heading.

5. Proceed to Access Level 2 using the 2ACCESS command and second password. When you execute 2ACCESS, the ALARM relay contacts should close and open and the ALRM LED should illuminate. The ALARM pulse cannot be detected if the contacts are closed by an alarm condition.

6. Test the tripping function. Apply voltages and currents which represent a fault condition for which the relay should trip. Here, the TRIP relay closes regardless of the 52A contact state. It opens when the 52A input deasserts AND fault conditions no longer exist. The TRIP output always remains closed for at least 60 ms.

7. Asserting either EXTERNAL TRIGGER input (EXTERNAL TRIGGER 1 or EXTERNAL TRIGGER 2) should trigger the relay to record an event record. These inputs do not affect the protective relaying functions in any way.

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

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

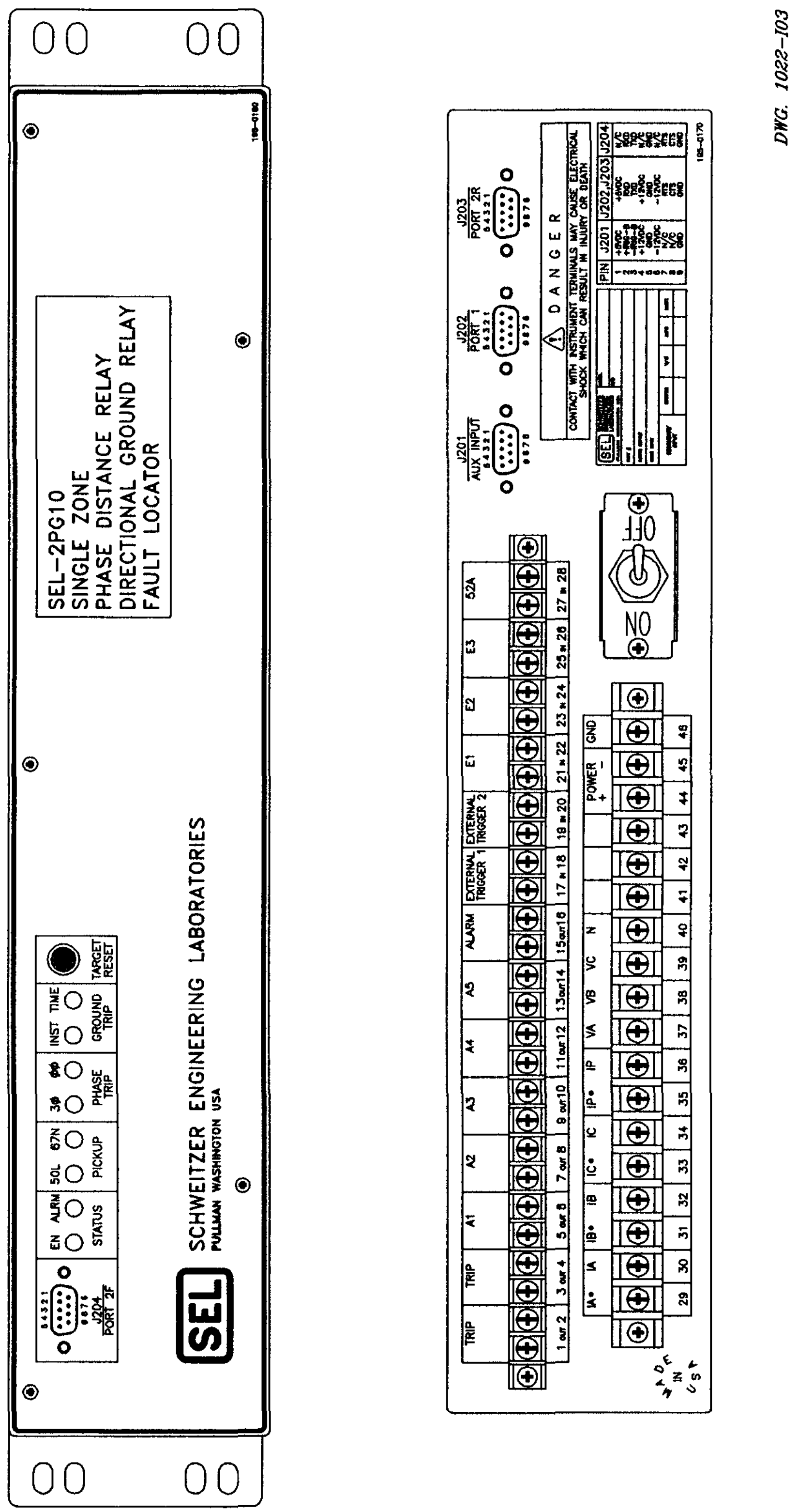


Figure 6.2: Horizontal Front and Rear Panel Drawings

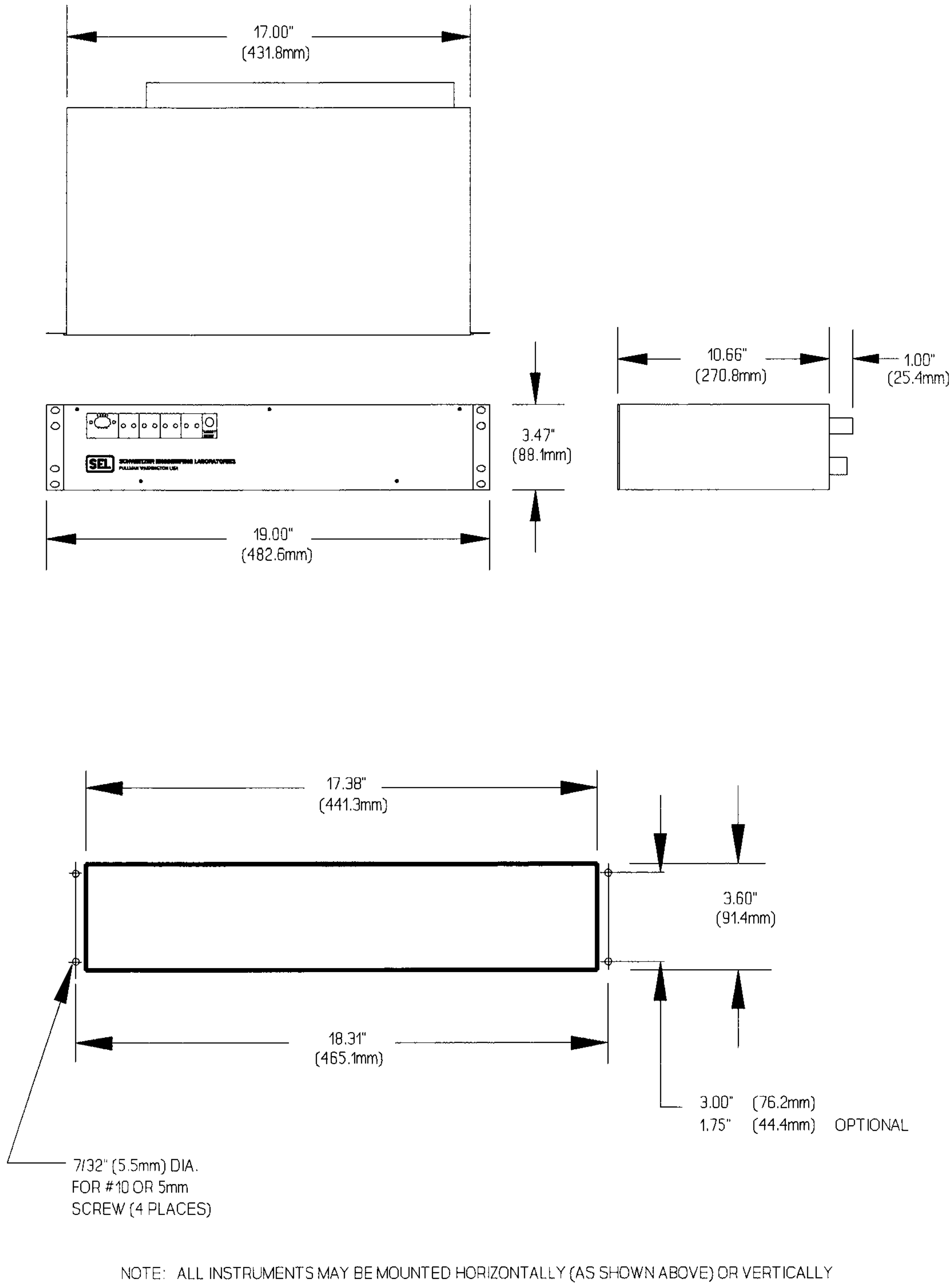


Figure 6.3: Relay Dimensions, Panel Cutout, and Drill Plan

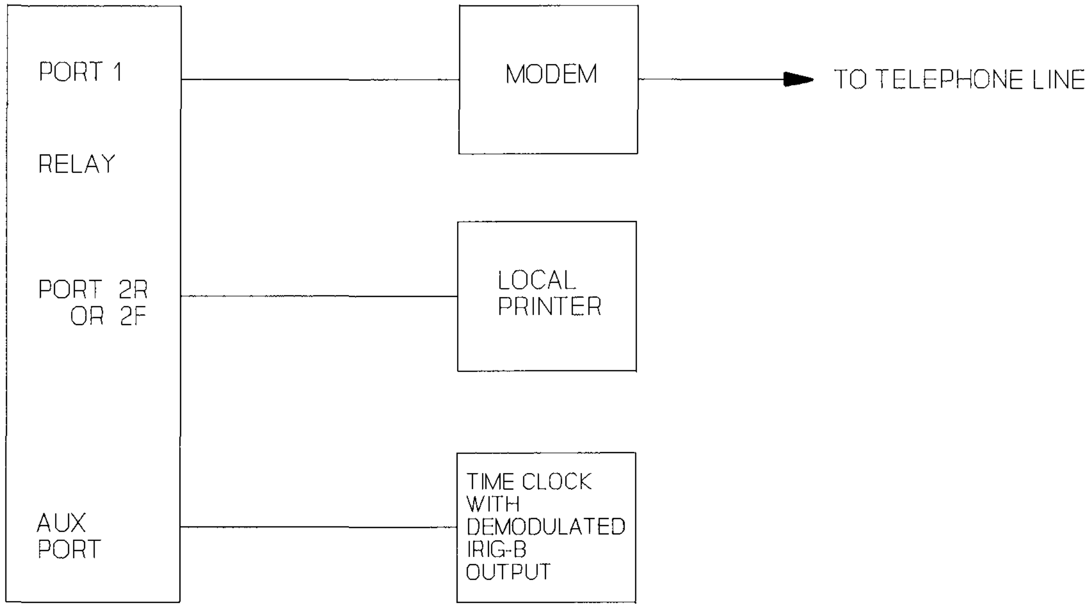


Figure 6.4: Communications and Clock Connections - One Unit at One Location

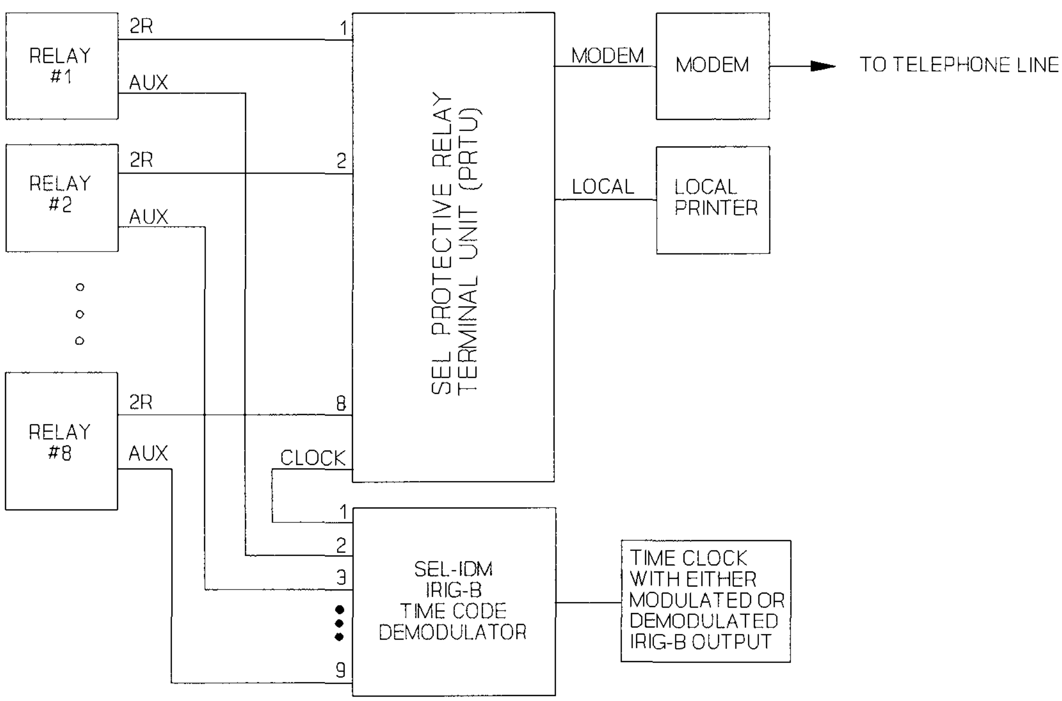


Figure 6.5: Communications and Clock Connections - Multiple Units at One Location

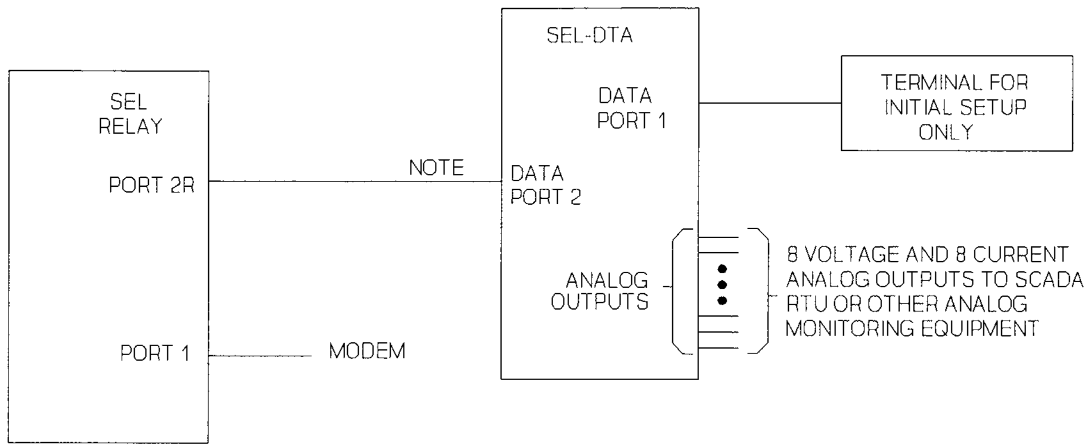


Figure 6.6: SEL Relay Communications Diagram for Connection to the SEL-DTA

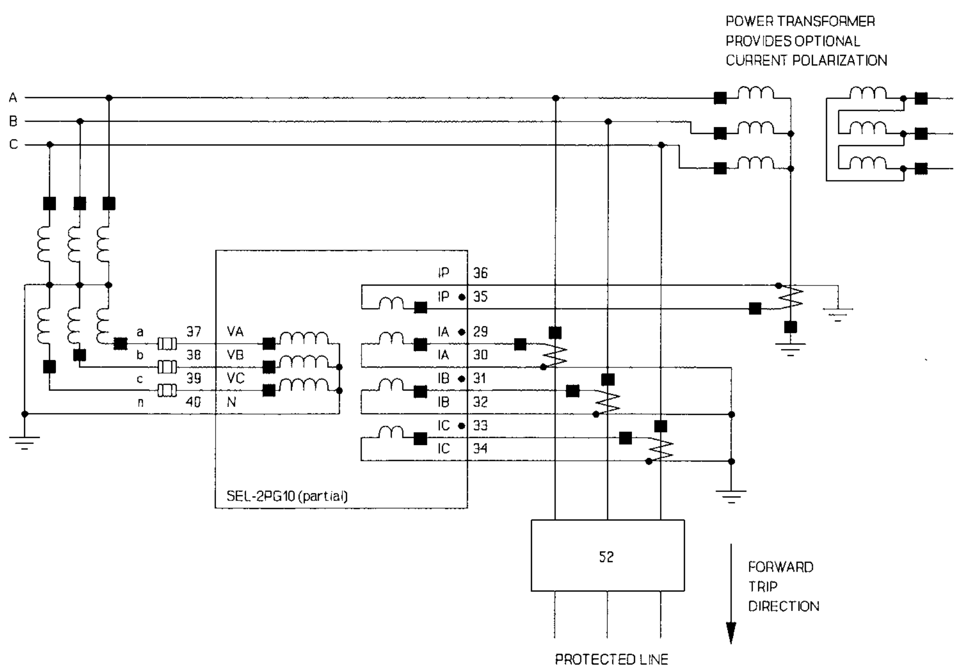


Figure 6.7: External AC Current and Voltage Connections

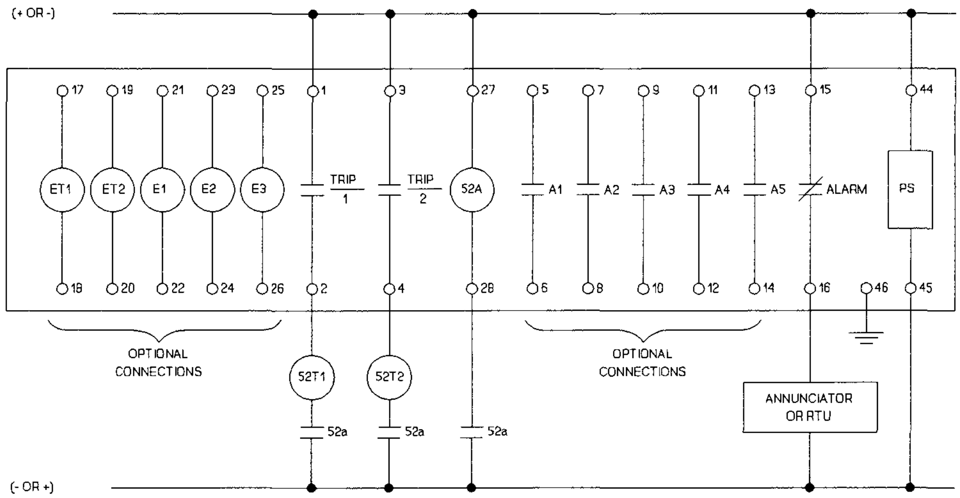


Figure 6.8: External DC Connection Diagram (Typical)

SEL DIRECTION AND POLARITY CHECK FORM

STATION ______________________ DATE: ___/___/___ TESTED BY ______________

SWITCH NO. ______________ EQUIPMENT ______________________

INSTALLATION ________ ROUTINE ________ OTHER ______________________

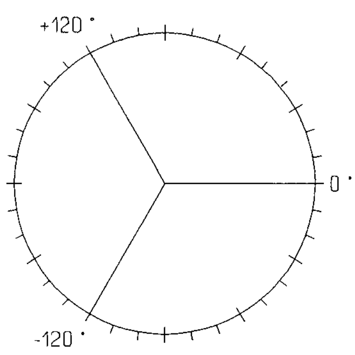
LOAD CONDITIONS:

STATION READINGS: ________ MW (OUT)(IN) ________ MVAR (OUT)(IN) ________ VOLTS ________ AMPS

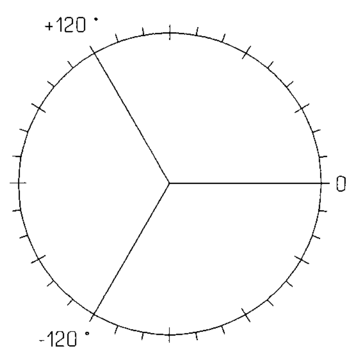
SEL READINGS: ________ MW (+)(-) ________ MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I( )	I( )	I( )	V( )	V( )	V( )	
1st LINE CHOSEN (Y COMPONENT)							
2nd LINE CHOSEN (X COMPONENT)							
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$							ROW 1
ANGLE IN DEGREES ARCTAN Y/X							
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0							
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM							ROW 2

USE THE VALUES IN ROWS 1 AND 2 ABOVE TO DRAW PHASOR DIAGRAMS BELOW



CURRENTS



VOLTAGES

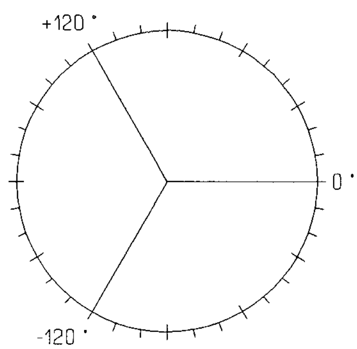
SEL DIRECTION AND POLARITY CHECK FORM

STATION ______________________ DATE: ___/___/___ TESTED BY ______________
SWITCH NO. ______________ EQUIPMENT ______________
INSTALLATION ________ ROUTINE ________ OTHER ______________

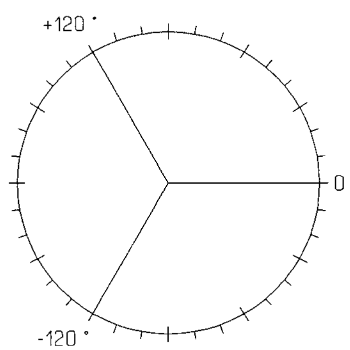
LOAD CONDITIONS:
STATION READINGS: ________ MW (OUT)(IN) ________ MVAR (OUT)(IN) ________ VOLTS ________ AMPS
SEL READINGS: ________ MW (+)(-) ________ MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I( )	I( )	I( )	V( )	V( )	V( )	
1st LINE CHOSEN (Y COMPONENT)							
2nd LINE CHOSEN (X COMPONENT)							
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$							ROW 1
ANGLE IN DEGREES ARCTAN Y/X							
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0							
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM							ROW 2

USE THE VALUES IN ROWS 1 AND 2 ABOVE TO DRAW PHASOR DIAGRAMS BELOW



CURRENTS



VOLTAGES

MAINTENANCE & TESTING
TABLE OF CONTENTS

Test Procedure 7-1
Removal of Front Panel and Drawout Assembly 7-6
Calibration 7-6
Troubleshooting Guide 7-6
Program to Compute Test Set Settings for Testing Distance Relays 7-11

MAINTENANCE AND TESTING

TEST PROCEDURE

Testing the relay requires that you complete Section 2: INITIAL CHECKOUT as well as the steps below.

Initial Checkout

Finish the Initial Checkout before using the following tests. Initial checkout makes it easy to set up the relay for testing and ensures proper functioning.

Setting Test

This test ensures that the relay accepts settings.

1. Move to Access Level 2 (see Access and 2Access commands).
2. Type **SET** and press **<ENTER>**.
3. Change one setting. For example, change the line length from 100 to 102 miles.
4. After the change, type **END <ENTER>** to display the new settings and enable prompt. Press **Y** to approve the settings. The ALARM contact closes and the ALRM target LED illuminates briefly while the relay computes internal settings.
5. Use SHOWSET to inspect the settings and ensure that your change was accepted.
6. Use SET and SHOWSET again to restore and check the original settings.
7. Type **LOG MA1 <ENTER>**.
8. Change one bit.
9. Complete the logic setting procedure.
10. Type **LOG MA1 <ENTER>** again and make sure the bit change is present. Restore the setting and repeat the command to check the restored setting.

METER Test

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

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 five ampere current through the three inputs. You can use a resistor and a stepdown transformer energized from the same source to derive this current without a test set. When the instruments provide 50 Vac input to the voltage inputs, the phase angle between the current and 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 230 kV Line settings, you should obtain:

$$VA = VB = VC = 50 \times 2000 = 100 \text{ kV}. \quad (\pm 0.5\ \%)$$

Voltages VAB, VBC, and VCA should be less than 1.5 kV.

Similarly, currents IA, IB, and IC should equal the applied current times the current transformer ratio. With the Example 230 kV Line settings, you should obtain:

$$IA = IB = IC = 5 \times 200 = 1000 \text{ A}. \quad (\pm 1\ \%)$$

Difference currents IAB, IBC, and ICA should be less than 20 amperes.

The power reading should be:

$$VA \times IA + VB \times IB + VC \times IC = 300 \text{ MW}.$$

The reactive power reading should be less than 5 MVAR.

Mho Relay Testing

SEL recommends the three-phase test described below. You can display mho element status with the TARGETS command. Use a programmable output relay to observe the total mho output. Set the logic mask for that relay to observe the selected element.

The following steps outline the mho relay test procedure.

1. Connect the relay to a test set capable of providing four-wire voltages and at least one current. To test the phase element (ZP), connect the current source so the current enters the dotted end of one phase and exits the dotted end of the other phase. For a BC test, inject the current into B-dot, connect the undotted B and C current terminals, and connect C-dot to the current source return terminal.

2. Calculate the voltages and currents required for a fault on the boundary at the maximum-reach point of the relay. The BASIC program in Appendix C provides a simple, convenient method for determining these figures. Using zero source impedance further simplifies the test. Enter Z0=Z1 to use the single-phase fault current calculation for phase A as the three-phase fault current calculation.

   For example, using the Example 230 kV Line settings, the CT/PT ratio is 0.1. Secondary-ohm line data to enter into the BASIC program are:

   $$Z1 = 1.39 + j\ 7.996 \quad \text{ohms}$$

   $$Z0 = 1.39 + j\ 7.996 \quad \text{ohms}$$

   Enter 0 for ground fault resistance.

   Enter 0 source-to-bus impedance.

   To test the mho element (set to 80% of the line), enter 0.8 for the per-unit distance from the bus to the fault. The program will compute the test set voltages and currents for AG and BC faults 0.8 pu or 80 miles away from the bus. Since the 80.8° MTA setting places the mho circle diameter on the transmission line positive-sequence impedance characteristic, computed voltages and currents test the mho characteristic at the point of maximum reach along its maximum torque angle.

   The terminal displays the voltages and current for a phase-A-to-ground fault on a system with Z0=Z1. IA is the same for a three-phase fault. IB and IC are equal in magnitude to IA, but at angles of ±120° from IA.

   The screen also shows the voltages and currents for a BC fault.

   Using the example settings, the display for the boundary conditions is:

VA	VB	VC	IA	IB	IC	
67	67	67	10.3	0	0	A-G
0	-120	+120	-80	0	0	
67	67	67		8.9	8.9	B-C
0	-120	+120	0	-170	+10	

   Thus, for a three-phase boundary fault, the test would be set for 67 volts and 10.3 amps per phase, with currents lagging voltages by 80°.

3. For two other convenient test points, consider a square inscribed in a mho circle with one diagonal as the diameter along the MTA. The two corners of the square on the other diagonal are reached by increasing the current by a factor of 1.414 at angles of ±45° away from the angle obtained from the BASIC program.

For our three-phase example, the required currents are 10.3 * 1.414 = 14.6 amperes at the angles listed below:

IA	IB	IC	
-35°	-155°	85°	(MTA + 45°)
-125°	115°	-5°	(MTA - 45°)

4. Test the relay at the three current settings (MTA, MTA + 45, MTA - 45).

Directional Element Checking

Type **TAR 1** (Access Level 2 command) to observe the Relay Word with the 67NI bit (r1). The second target LED from the right displays the 67NI bit status.

Check both the negative-sequence element and voltage-polarized part of the zero-sequence element with the following instructions.

Apply VA= 30 volts, VB = 0, VC = 0. This results in an applied V2 = V0 = 10 volts.

Apply IA = 6 amperes corresponding to negative- and zero-sequence currents of 2 amperes.

Move the phase of the current with respect to the voltage, and observe the boundary of the directional element (observe the pickup and dropout of the 67NI relay element) at MTA ±90°.

You can check current polarization 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 0°, so you should observe the boundary of the characteristic at ±90°.

Overcurrent Element Checking

You can easily check pickup of the 67NI and 67NP residual overcurrent elements. Type **TARGET 1** (Access Level 2 command) to display Relay Word 1 with overcurrent element bits on the target LEDs. Disable all directional functions for this test (set 51NTC, 32QE, 32VE, and 32IE = N). Apply current to one phase and observe the pickup and dropout of each element.

Check the pickup and dropout of the phase overcurrent element the same way. Type **TARGET 0** or **TARGET 1** to display the 50L bit on the LEDs. Apply current to one phase and observe the pickup and dropout of the element.

Testing the Input Circuits

1. Set the LEDs to follow the contact inputs. Type **TAR 2 <ENTER>** (Access Level 2 command).

2. As you apply control voltage to each input, the corresponding target LED turns on. Energizing the EXT1 and EXT2 inputs triggers an event report.

Testing the Serial Ports

The Initial Checkout assumes that you connect a terminal to PORT 2. Set the baud rate of PORT 1 to the same value as PORT 2 and switch your terminal from PORT 2 to PORT 1. Make sure you can communicate through this port. If your relay includes front and rear panel serial ports, ensure that both ports operate correctly.

Testing the IRIG-B Time Code Input

1. Connect a source of demodulated IRIG-B time code to the Auxiliary Port. Use a series resistor to monitor the current. Adjust the source to produce an "ON" current of about 10 mA.

2. Use IRIG (Access Level 2 command) to make sure the relay clock displays the correct date and time.

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

Testing the Power Supply Voltages

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

2. Use a voltmeter to read the +5 and ±12 volt outputs at the Auxiliary Port. 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; both readings should be within 0.15 volts of 5 volts.

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

REMOVAL OF FRONT PANEL AND DRAWOUT ASSEMBLY

To prevent shock hazard, disconnect power to the relay before removing the front panel assembly.

1. Disconnect external power source.
2. Remove the front panel screws.
3. You can 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 under the forward outside edges of drawout assembly.
5. Disconnect the analog input connector from the main board (P 104). It is the right-most connector. If your relay is an SEL-2PG10 Relay, disconnect the analog signal and power supply connectors from the underside of the drawout assembly.
6. Remove the drawout assembly. Use your index fingers to pull the spacers located on the tray bottom.

CALIBRATION

The SEL-2PG10 Relay is factory calibrated. If you suspect that the relay is out of calibration, please contact the factory.

TROUBLESHOOTING GUIDE

Inspection Procedure

Complete the following inspection procedure before disturbing the system. After you finish the inspection, proceed to the TROUBLESHOOTING TABLE.

1. Measure and record control power voltage present at terminals marked + and -.
2. Check to see that the power is on, but do not turn the 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 a communications device is connected to at least one communications port.

Troubleshooting Table

All Front Panel LEDs Dark

1. Power is off.
2. Blown fuse.
3. Input power not present.
4. Self-test failure.
5. Target command improperly set.

Note: The ALARM relay contacts should be closed for 1, 2, 3, and 4. The ALRM LED should illuminate for 4.

System Does Not Respond to Commands

1. Communications device not connected to system.
2. 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 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 **<CTRL>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. Interface board failure.

No Prompting Message Issued to Terminal upon Power-Up

1. Terminal not connected to system.
2. Wrong baud rate.
3. Terminal improperly connected to system.

4. Other port designated automatic. See AUTO setting in the SET command.
5. Port timeout interval set to a value other than zero.
6. Main board or interface board failure.

System Does Not Respond to Faults

1. Improper relay settings. Review settings with SET and LOGIC commands.
2. Improper test settings.
3. CT or PT input cable wiring error.
4. Analog input cable between transformer-termination and main board loose or defective.
5. Check self-test status with STATUS command.
6. Check input voltages and currents with METER command and TRIGGER and EVENT sequence.

Terminal Displays Meaningless Characters

1. Baud rate incorrectly set.
2. Check terminal configuration. See Section 4: COMMANDS AND SERIAL COMMUNICATIONS.

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 between transformers and 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.

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).

```
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$="A-G"
320     GOSUB 4041
500     REM  B-C FAULT
510     AR=1: AI=0
520     BR=2*R1*(S+F):BI=2*S1*(S+F)
530     GOSUB 2000
540     I=RR:J=RI
550     IA=0:JA=0
560     AR=I:AI=J:BR=0:BI=-67*SQR(3)
570     GOSUB 1000
580     IB=RR:JB=RI:IC=-IB:JC=-JB
590     UA=67:VA=0
600     AR=I:AI=J:BR=S*R1:BI=S*S1
610     GOSUB 1000
620     AR=RR:AI=RI:BR=0:BI=SQR(3)
630     GOSUB 1000
635     TR=RR:TS=RI
640     UB=67*(-0.5+TR)
650     VB=67*(-SQR(3)/2+TS)
660     UC=67*(-0.5-TR)
670     VC=67*(0.5*SQR(3)-TS)
675     FF$="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
```

APPENDICES
TABLE OF CONTENTS

Firmware Versions A-1
Parts Placement Diagram B-1
Settings Sheets C-1

APPENDIX A - FIRMWARE VERSIONS

This manual covers SEL relays that contain firmware bearing the following part numbers and revision numbers:

Firmware Part/Revision No.	Description of Firmware
Firmware Revision 1, PG10 Mainboard Configurations	
	This firmware differes from previous versions as follows: - Re-enabled CONNECT command.
SEL-PG10-R106 SEL-PG10-R204 SEL-PG10-R104	60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, kilometers, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator
	This firmware differs from previous versions as follows: - The relay does not echo the Fast Meter command while a Fast Meter command is in progress. - Improved clock accuracy during fast meter operations. - The relay issues one prompt when responding to a "Carriage Return, Line Feed" combination.
SEL-PG10-R105 SEL-PG10-R203 SEL-PG10-7-R103	60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, kilometers, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator
	This firmware differs from previous versions as follows: - Trip is cleared by dropout of the trip condition or 60 ms, whichever is longer. - Only latch the targets on the rising edge of trip. - Correct the scaling calculation. - Added directional elements. - Fast meter added. - Control characters in the ID string no longer cause setting problems. - Correct year rollover problem. - Correct Irig sync delay.
SEL-PG10-R104 SEL-PG10-R202 SEL-PG10-7-R102	60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, kilometers, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator

	This firmware differs from previous versions as follows: - There are no notable changes between the remaining versions.
SEL-PG10-R103 SEL-PG10-R201 SEL-PG10-7-R101	60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, kilometers, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator
SEL-PG10-R102 SEL-PG10-R200 SEL-PG10-7-R100	60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, kilometers, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator
SEL-PG10-R101	60 Hz, 5 Amps, miles, ABC rotation
SEL-PG10-R100	60 Hz, 5 Amps, miles, ABC rotation
Firmware Revision 4, PG10/2PG10 Mainboard Configurations	
	This firmware differs from previous versions as follows: - Re-enabled CONNECT command.
SEL-PG10-R404 SEL-PG10-R504 SEL-PG10-R603 SEL-PG10-7-R403 SEL-PG10-8-R403	60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, kilometers, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator 60 Hz, 5 Amps, miles, ABC rotation, modified levels for commands
	This firmware differs from previous versions as follows: - The relay does not echo the Fast Meter command while a Fast Meter command is in progress. - Improved clock accuracy during fast meter operations. - The relay issues one prompt when responding to a "Carriage Return, Line Feed" combination. - Added fast meter to the negative-sequence rotation version.
SEL-PG10-R403 SEL-PG10-R503 SEL-PG10-R602 SEL-PG10-7-R402 SEL-PG10-8-R402	60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, kilometers, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation 60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator 60 Hz, 5 Amps, miles, ABC rotation, modified levels for commands

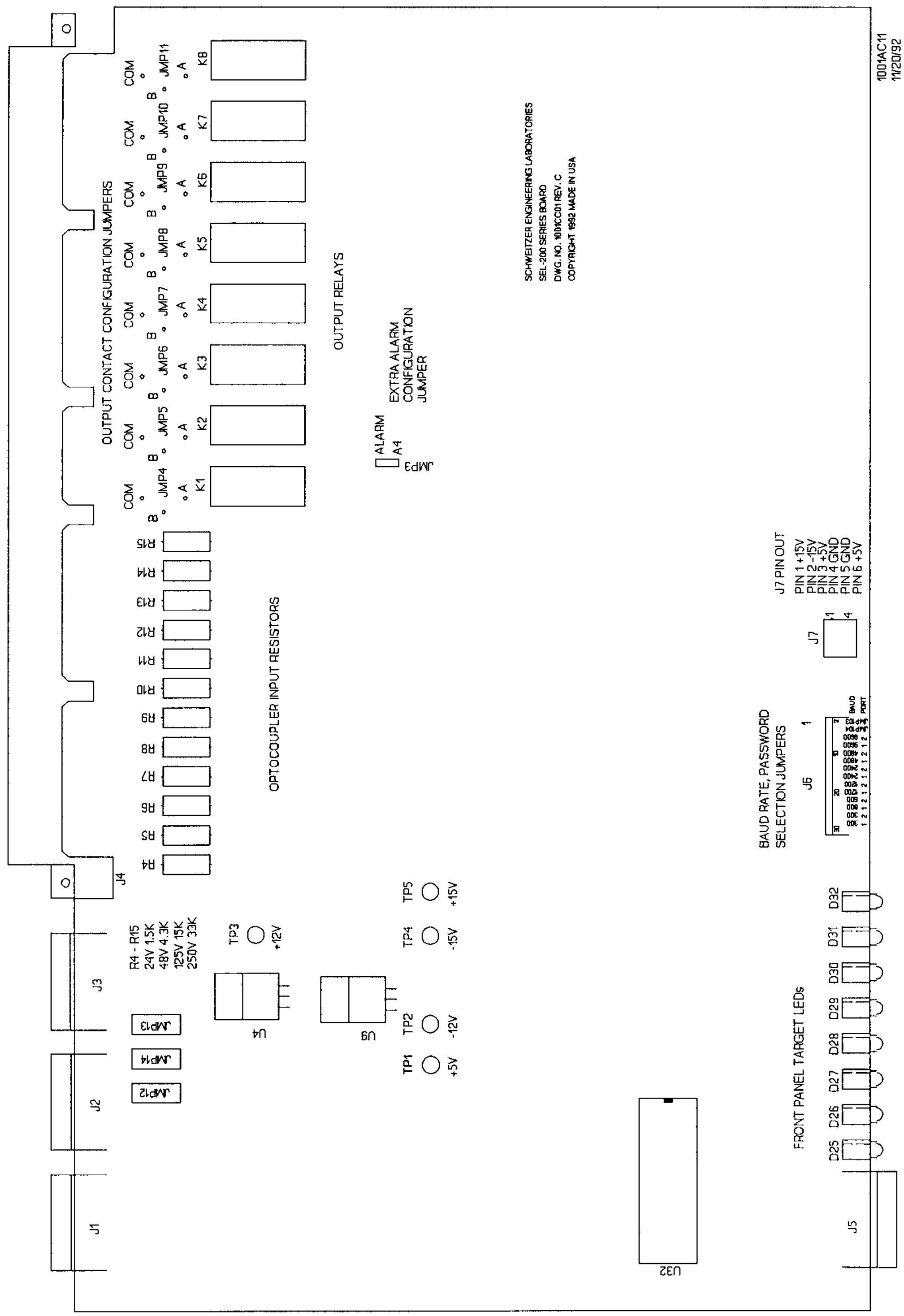
	This firmware differs from previous versions as follows: - Trip is cleared by dropout of the trip condition or 60 ms, whichever is longer. - Only latch the targets on the rising edge of trip. - Correct the scaling calculation. - Added directional elements. - Fast meter added. (Positive-sequence versions only). - Control characters in the ID string no longer cause setting problems. - Correct year rollover problem. - Correct Irig sync delay.
SEL-PG10-R402	60 Hz, 5 Amps, miles, ABC rotation
SEL-PG10-R502	60 Hz, 5 Amps, kilometers, ABC rotation
SEL-PG10-R601	60 Hz, 5 Amps, miles, ABC rotation
SEL-PG10-7-R401	60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator
SEL-PG10-8-R401	60 Hz, 5 Amps, miles, ABC rotation, modified levels for commands
	This firmware differs from previous versions as follows: - There are no notable changes between the remaining versions.
SEL-PG10-R401	60 Hz, 5 Amps, miles, ABC rotation
SEL-PG10-R501	60 Hz, 5 Amps, kilometers, ABC rotation
SEL-PG10-R600	60 Hz, 5 Amps, miles, ABC rotation
SEL-PG10-7-R400	60 Hz, 5 Amps, miles, ABC rotation, radial compensated fault locator
SEL-PG10-8-R400	60 Hz, 5 Amps, miles, ABC rotation, modified levels for commands
SEL-PG10-R400	60 Hz, 5 Amps, miles, ABC rotation
SEL-PG10-R500	60 Hz, 5 Amps, kilometers, ABC rotation

To find the firmware revision number in your relay, obtain an event report (which identifies the firmware) using the EVENT command. This is an FID number with the Part/Revision number in bold:

FID=**SEL-PG10-R402**-656mpruS2-D930830

For a detailed explanation of the Firmware Identification Number (FID) refer to Section 5: EVENT REPORTING.

APPENDIX B - PARTS PLACEMENT DIAGRAM



SEL-200 Series Main Board Troubleshooting Test Points and Jumper Locations

APPENDIX C - SETTINGS SHEETS

SETTINGS SHEET
FOR SEL-2PG10 RELAY

DATE ________

SUBSTATION ____________ CIRCUIT ____________________

BREAKER ____________ DEVICE NO. ____________________

MAKE ____________ C.T. SETTING ____________________

MODEL/STYLE NO. _____ P.T. SETTING ____________________

SERIAL #________ POWER SUPPLY ______ VOLTS ac/dc LOGIC INPUT ____ Vdc

SECONDARY INPUTS: V/ϕ = 67L-N, NOMINAL AMPS = 5, Hz = 60

HEXADECIMAL REPRESENTATION

MASK: MT (TRIP)

ROW #1: RELAY WORD BINARY REPRESENTATION	50L	ZABC	ZP	ZPT	67NP	67NT	67NI	67DT	SETTING

MASK: MA1 (A1 CONTACT)

ROW #1: RELAY WORD BINARY REPRESENTATION	50L	ZABC	ZP	ZPT	67NP	67NT	67NI	67DT	SETTING

MASK: MA2 (A2 CONTACT)

ROW #1: RELAY WORD BINARY REPRESENTATION	50L	ZABC	ZP	ZPT	67NP	67NT	67NI	67DT	SETTING

MASK: MA3 (A3 CONTACT)

ROW #1: RELAY WORD BINARY REPRESENTATION	50L	ZABC	ZP	ZPT	67NP	67NT	67NI	67DT	SETTING

MASK: MA4 (A4 CONTACT)

ROW #1: RELAY WORD BINARY REPRESENTATION	50L	ZABC	ZP	ZPT	67NP	67NT	67NI	67DT	SETTING

SETTINGS SHEET
FOR SEL-2PG10 RELAY

DATE ________

MASK: MA5 (A5 CONTACT)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	50L	ZABC	ZP	ZPT	67NP	67NT	67NI	67DT	

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

ACCESS Command passwords: (6 Characters excluding "SPACE, COMMA, SEMI-COLON and SLASH")

LEVEL 0: "=" **ACCESS <ENTER>**
PASSWORD: ________

LEVEL 1: "=>" **2ACCESS <ENTER>**
PASSWORD: ________

LEVEL 2: "=>>" ENTER SETTINGS PER MATRIX TABLE

Note: FOR NEW RELAYS BEGIN WITH LEVEL 1 PASSWORD = OTTER AND LEVEL 2 PASSWORD = TAIL. WHEN IN LEVEL 2 MODIFY PASSWORDS VIA PASSWORD 1 AND 2 COMMANDS.

SETTINGS SHEET
FOR SEL-2PG10 RELAY

DATE ________

DESCRIP. / RANGE	POS-SEQ. IMPEDANCE 0-9999 (PRI. OHMS)		ZERO-SEQ. IMPEDANCE 0-9999 (PRI. OHMS)		LINE LENGTH* 0.1-999 MILES
ABBREV. SETTING	**R1**	**X1**	**R0**	**X0**	**LL**
DESCRIP. / RANGE	C. T. RATIO 1-5000:1	P. T. RATIO 1-10,000:1	MAX. TORQUE ANGLE 47°-90°	ENABLE FAULT LOCATOR (Y OR N)	
ABBREV. SETTING	**CTR**	**PTR**	**MTA**	**LOCAT**	
DESCRIP. / RANGE	ZONE REACH (0.125-32Ω SEC) 0-2000% OF R1+jX1	PHASE TIME DELAY 0-2000 Cycles	ϕ O/C LOW SET PICKUP (0.5-40A SEC.) 0.25-50,000 AMP PRI.		
ABBREV. SETTING	**Z%**	**PTMR**	**50L**		
DESCR. / RANGE	GND TIME O/C PICKUP (0.25-6.3A SEC) 0.25-50,000 AMP PRI.	GND TIME O/C TIME DIAL 0.5-15 (0.01 STEPS)	GND TIME O/C CURVE SHAPE 1, 2, 3, OR 4	GND TIME O/C TORQUE CONTROL (Y OR N)	
ABBREV. SETTING	**67NP**	**67NTD**	**67NC**	**67NTC**	
DESCR. / RANGE	GND INST. O/C (0.25A-48x51NP) 0.25-50,000 AMP PRI.	GND O/C DELAY 0-2000 Cycles			
ABBREV. SETTING	**67NI**	**GTMR**			
DESCR. / RANGE	GND O/C NEGATIVE-SEQ. POLAR. (Y OR N)	GND O/C ZERO-SEQ. VOLTAGE POLAR. (Y OR N)	GND O/C ZERO-SEQ. CURRENT POLAR. (Y OR N)		
ABBREV. SETTING	**32QE**	**32VE**	**32IE**		
DESCR. / RANGE	SEL-2PG10 PORT #1 TIMEOUT 0-30 MINUTES	SEL-2PG10 PORT #2 TIMEOUT 0-30 MINUTES	AUTOMATIC MESSAGE TRANSMIT AUTOPORT SELECTION PORT 1, 2, OR 3(BOTH)	# RINGS AFTER WHICH MODEM ANSWERS 1-30	
ABBREV. SETTING	**TIME1**	**TIME2**	**AUTO**	**RINGS**	

SETTINGS SHEET
FOR SEL-2PG10 RELAY

DATE ________

* Line Length = Station #1 (relay location) to Station #2; the full distance in miles between stations.

Note: Length can also be represented in metric units, primary or secondary ohms, etc., but conversion to miles would be required.

Comments: ____

____

____

____

____

____

____

____

____

____

Settings recommended by ______________________________

Settings approved by ______________________________

Settings approved by ______________________________

Settings performed by ______________________________

Test printout required ______ Yes ______ No Substation _______

SEL-2PG10 DISTANCE RELAY/FAULT LOCATOR COMMAND SUMMARY

Access Level 0

ACCESS	Answer password prompt (if password protection is enabled) to enter Access Level 1. Three unsuccessful attempts pulse ALARM contacts closed.

Access Level 1

2ACCESS	Answer password prompt (if password protection is enabled) to enter Access Level 2. This command always pulses the ALARM contacts closed.
DATE m/d/y	Shows or sets date. DAT 2/3/90 sets date to Feb. 3, 1990. IRIG-B synchronization overrides this setting. Command pulses ALARM relay contacts closed and briefly illuminates the ALRM LED when year entered differs from year stored.
EVENT	Shows event record. EVE 1 shows long form of latest event.
HISTORY	Shows DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION and CURRENT for the last twelve events.
IRIG	Forces immediate execution of time-code synchronization task.
METER n	Displays primary currents, voltages, real and reactive power. Option n displays meter data n times.
QUIT	Returns control to Access Level 0.
SHOWSET	Shows the relay settings and logic settings: does not affect the settings. Logic settings appear in hexadecimal format.
STATUS	Shows self-test status.
TARGET n k	Shows data and sets target LEDs as follows: TAR 0: Relay Targets TAR 1: Relay Word TAR 2: Contact Inputs TAR 3: 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 h/m/s	Shows or sets time. TIM 13/32/00 sets clock to 1:32:00 PM. IRIG-B synchronization overrides this setting.
TRIGGER	Triggers and saves an event record (event type is EXT).

Access Level 2

LOGIC*	Shows or sets logic masks MT, MA1-MA5.
PASSWORD	Shows or sets passwords. Command pulses ALARM contacts closed and illuminates the ALRM LED 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*	Initiates set procedure.
	Use the following to separate commands and their parameters: space, comma, semicolon, colon, slash.
*	ALARM relay closes and ALRM target LED illuminates briefly as event data buffers are cleared and new settings are stored.

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Pullman, WA 99163-5603
TEL: (509) 332-1890 FAX: (509) 332-7990

EXPLANATION OF EVENT REPORT

```
Example 230 kV Line                       Date: 1/1/92     Time: 11:22:11.329

FID=SEL-PG10-R100-V656mpr-D920101

              Currents                          Voltages        Relays Outputs Inputs
               (amps)                             (kV)
                                                                52266   TAAAAAA EEEEE5
  IPOL      IR      IA      IB      IC      VA      VB      VC  01177   P12345L TT1232
                                                                P3PIT           12   A

     3      45    -551     160     440  -122.4    56.3    85.2  *....   ....... .....*
     3    -620    -591    -374     349    14.2  -123.9   105.7  *...P   ...*... .....*

    -6     129     349     -13    -223   104.6   -63.6   -92.5  *...P   ...*... .....*
     3    1173    1186      69     -79   -11.4   125.2  -104.5  *...P   ...*... .....*
     3    -371    -396       3      25   -96.1    67.1    96.2  *..*P   *..*.*. .....*
    -3   -1309   -1306      -6       9    11.6  -125.1   104.4  *..*P   *..*.*. .....*

Event   : AG      Location   : 50.06  mi  4.06   ohms sec
Duration: 6.00    Flt Current: 1382.3

R1   =13.90     X1   =79.96     R0  =41.50    X0   =248.57    LL=100.00
CTR  =200.00    PTR  =2000.00   MTA =80.80    LOCAT=Y
Z%   =80.00     PTMR =0.00      50L =100.00
67NP =100.00    67NTD=3.00      67NC=2        67NTC=N
67NIP=1000.00   GTMR =0.00
32QE =N         32VE =Y         32IE=Y
TIME1=0         TIME2=0         AUTO=2        RINGS=3

Logic settings:

MT   MA1  MA2  MA3  MA4  MA5
66   40   20   08   04   02

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 = -396, IAX = -1306. Therefore, IA = 1365 amps RMS primary, at an angle
of ATAN(-396/-1306) = -163 degrees, with respect to the sampling clock.

<FID>          Firmware Identification Data
<Relays>       columns show states of internal relay elements  ---> Designators
               50P : phase overcurrent ..... : 50L              ---> *
               213 : 3-phase distance ...... :                  ---> *
               21P : 2-phase distance ...... :                  ---> *
               67N : inst ground overcurrent : 67NI             ---> *
               51N : ground time-overcurrent :                  ---> P,T
<Outputs>      columns show states of output contacts:  ON = "*", OFF = "."
               TP=TRIP, A1-A5=PROGRAMMABLE, AL=ALARM
<Inputs>       columns show states of input contacts: ET1=EXTERNAL TRIGGER 1,
               ET2=EXTERNAL TRIGGER 2, E1-E3=EXTERNAL EVENT, 52A=PCB A-CONTACT
<Event>        Fault type indication is one of the following:
                   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 indication is EXT = externally or otherwise triggered
<Location>     Distance to fault in miles. 999999 is indeterminate distance
<ohms sec>     Distance to fault in secondary ohms. 999999 is indeterminate
<Duration>     Fault duration determined from relay element(s) pickup time
<Flt Current>  Max phase current (primary amps) taken near middle of fault
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 mho elements
LOCAT          Enable or disable fault locator (Y/N)
Z%             Reach of 3- and 2-phase mhos, percent of line impedance
PTMR           Phase fault timer for 3- and 2-phase faults
50L            Phase-overcurrent setting
67NP,TD,C,TC   GND time-overcurrent Pickup, Time-Dial, Curve, Torque Control
67NIP          Ground instantaneous-overcurrent pickup setting
GTMR           Ground timer for ground faults
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 settings
```

SEL-2PG10 DISTANCE RELAY/FAULT LOCATOR COMMAND SUMMARY

Access Level 0

ACCESS	Answer password prompt (if password protection is enabled) to enter Access Level 1. Three unsuccessful attempts pulse ALARM contacts closed.

Access Level 1

2ACCESS	Answer password prompt (if password protection is enabled) to enter Access Level 2. This command always pulses the ALARM contacts closed.
DATE m/d/y	Shows or sets date. DAT 2/3/90 sets date to Feb. 3, 1990. IRIG-B synchronization overrides this setting. Command pulses ALARM relay contacts closed and briefly illuminates the ALRM LED when year entered differs from year stored.
EVENT	Shows event record. EVE 1 shows long form of latest event.
HISTORY	Shows DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION and CURRENT for the last twelve events.
IRIG	Forces immediate execution of time-code synchronization task.
METER n	Displays primary currents, voltages, real and reactive power. Option n displays meter data n times.
QUIT	Returns control to Access Level 0.
SHOWSET	Shows the relay settings and logic settings: does not affect the settings. Logic settings appear in hexadecimal format.
STATUS	Shows self-test status.
TARGET n k	Shows data and sets target LEDs as follows: TAR 0: Relay Targets — TAR 1: Relay Word TAR 2: Contact Inputs — TAR 3: 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 h/m/s	Shows or sets time. TIM 13/32/00 sets clock to 1:32:00 PM. IRIG-B synchronization overrides this setting.
TRIGGER	Triggers and saves an event record (event type is EXT).

Access Level 2

LOGIC*	Shows or sets logic masks MT, MA1-MA5.
PASSWORD	Shows or sets passwords. Command pulses ALARM contacts closed and illuminates the ALRM LED 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*	Initiates set procedure.
	Use the following to separate commands and their parameters: space, comma, semicolon, colon, slash.
*	ALARM relay closes and ALRM target LED illuminates briefly as event data buffers are cleared and new settings are stored.

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EXPLANATION OF EVENT REPORT

```
Example 230 kV Line                         Date: 1/1/92     Time: 11:22:11.329

FID=SEL-PG10-R100-V656mpr-D920101

              Currents                      Voltages       Relays Outputs Inputs
               (amps)                         (kV)
                                                           52266  TAAAAAA EEEEE5
  IPOL     IR      IA      IB      IC      VA      VB      VC  01177  P12345L TT1232
                                                           P3PIT          12   A

     3     45    -551     160     440  -122.4    56.3    85.2  *....  ....... .....*
     3   -620    -591    -374     349    14.2  -123.9   105.7  *...P  ...*... .....*

    -6    129     349     -13    -223   104.6   -63.6   -92.5  *...P  ...*... .....*
     3   1173    1186      69     -79   -11.4   125.2  -104.5  *...P  ...*... .....*
     3   -371    -396       3      25   -96.1    67.1    96.2  *..*P  *..*.*. .....*
    -3  -1309   -1306      -6       9    11.6  -125.1   104.4  *..*P  *..*.*. .....*

Event   : AG      Location   : 50.06  mi  4.06   ohms sec
Duration: 6.00    Flt Current: 1382.3

R1   =13.90     X1   =79.96     R0  =41.50     X0   =248.57    LL=100.00
CTR  =200.00    PTR  =2000.00   MTA =80.80     LOCAT=Y
Z%   =80.00     PTMR =0.00      50L =100.00
67NP =100.00    67NTD=3.00      67NC=2         67NTC=N
67NIP=1000.00   GTMR =0.00
32QE =N         32VE =Y         32IE=Y
TIME1=0         TIME2=0         AUTO=2         RINGS=3

Logic settings:

MT   MA1  MA2  MA3  MA4  MA5
66   40   20   08   04   02
```

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 = -396, IAX = -1306. Therefore, IA = 1365 amps RMS primary, at an angle of ATAN(-396/-1306) = -163 degrees, with respect to the sampling clock.

```
<FID>           Firmware Identification Data
<Relays>        columns show states of internal relay elements  ---> Designators
                50P : phase overcurrent ..... : 50L             ---> *
                213 : 3-phase distance ...... :                 ---> *
                21P : 2-phase distance ...... :                 ---> *
                67N : inst ground overcurrent : 67NI            ---> *
                51N : ground time-overcurrent :                 ---> P,T
<Outputs>       columns show states of output contacts:  ON = "*", OFF = "."
                TP=TRIP, A1-A5=PROGRAMMABLE, AL=ALARM
<Inputs>        columns show states of input contacts: ET1=EXTERNAL TRIGGER 1,
                ET2=EXTERNAL TRIGGER 2, E1-E3=EXTERNAL EVENT, 52A=PCB A-CONTACT
<Event>         Fault type indication is one of the following:
                    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 indication is EXT = externally or otherwise triggered
<Location>      Distance to fault in miles. 999999 is indeterminate distance
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RINGS           Number of rings to wait before modem answers telephone
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```