

SEL-321-5 Relay
Phase and Ground Distance Relay
Directional Overcurrent Relay
Fault Locator

Instruction Manual

20211203

SEL SCHWEITZER ENGINEERING LABORATORIES





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.



AVERTISSEMENT: 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.

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SEL-321-5 INSTRUCTION MANUAL

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MANUAL CHANGE INFORMATION

The date code at the bottom of each page of this manual reflects the creation or revision date. Date codes are changed only on pages that have been revised and any following pages affected by the revisions (i.e., pagination). If significant revisions are made to a section, the date code on all pages of the section will be changed to reflect the revision date.

Each time revisions are made, both the main table of contents and the affected individual section table of contents are regenerated and the date code is changed to reflect the revision date.

Changes in this manual to date are summarized below (most recent revisions listed at the top).

Revision Date	Summary of Revisions
20211203	Section 2 <ul style="list-style-type: none">– Added <i>Emissions to General Specifications</i>.
20190809	Section 2 <ul style="list-style-type: none">– Added a description to specify the time-overcurrent element behavior when the electromechanical reset setting is set to OFF.– Updated Figure 2.24: Phase Time-Overcurrent Element Logic, Figure 2.25: Negative-Sequence Time-Overcurrent Element Logic, and Figure 2.26: Residual Time-Overcurrent Element Logic. Command Summary <ul style="list-style-type: none">– Updated the definition for EVENT. Appendix E <ul style="list-style-type: none">– Added appendix.
20151118	Section 7 <ul style="list-style-type: none">– Removed firmware upgrade instructions. They are now included in firmware upgrade kits.
20121106	Section 2 <ul style="list-style-type: none">– Updated <i>Figure 2.4: Logic Symbol Legend</i> and <i>Figure 2.47: Trip Decision Logic for Phase A</i>. Specifications <ul style="list-style-type: none">– Added <i>Terminal Connections</i> in <i>General Specifications</i>. Section 7 <ul style="list-style-type: none">– Updated <i>Factory Assistance</i> block.– Corrected symbol in <i>Equation 7.8</i>.
20120127	Section 3 <ul style="list-style-type: none">– Added CALIBRATION command.

Revision Date	Summary of Revisions
20010215	<p>Reissued entire manual to reflect the following changes:</p> <p>Updated to new manual format.</p> <p>Section 2</p> <ul style="list-style-type: none"> – Updated <i>Power Supply</i> information.
20000209	<p>Section 3</p> <ul style="list-style-type: none"> – Reissued entire section to correct pagination errors.
990614	<p>Updated MIRRORED BITS™ format throughout to reflect new trademark.</p> <p>Section 2</p> <ul style="list-style-type: none"> – Deleted the optional jumper-selectable inputs. <p>Section 6</p> <ul style="list-style-type: none"> – Deleted the <i>Configure the Control Input Voltage</i> subsection and reference to the control input voltage under the <i>Set Jumpers</i> subsection. <p>Appendix J</p> <ul style="list-style-type: none"> – Deleted the <i>Control Input Voltage</i> subsection and renumbered figures.
990331	<p>Section 1</p> <ul style="list-style-type: none"> – Corrected spelling error in caption for <i>Figure 1.3: SEL-321-5 Rear Panel (Two I/O Board Version)</i>. <p>Section 3</p> <ul style="list-style-type: none"> – Updated <i>Table 3.11: SET P Fail Messages</i> and <i>Table 3.12: SET P and SHOWSET P Description</i> to include MB8 protocol. – Changed → to ↓ on page 3-48. <p>Section 6</p> <ul style="list-style-type: none"> – Updated figure captions for <i>Figure 6.2: SEL-321-5 Relay Horizontal Front and Rear Panel Drawings</i> and <i>Figure 6.4: SEL-321-5 Relay Horizontal Front and Rear Panel Drawings</i>. <p>Appendix H</p> <ul style="list-style-type: none"> – Updated to include MB8 protocol. <p>Appendix J</p> <ul style="list-style-type: none"> – Replaced <i>Figure J.10: Interface Board 5 Component Layout (Screw Terminal)</i>.

Revision Date	Summary of Revisions
981030	<p>Updated format in <i>Table of Contents</i> in <i>Sections 2–5</i>.</p> <p>Section 1</p> <ul style="list-style-type: none"> – Updated <i>Figure 1.3: SEL-321-5 Rear Panel (Two I/O Board Version)</i>. <p>Section 2</p> <ul style="list-style-type: none"> – Updated <i>Figure 2.5: Zone 1 Mho Phase Distance Element Logic</i>– <i>Figure 2.8: Zone 4 Mho Phase Distance Element Logic</i>. <p>Section 5</p> <ul style="list-style-type: none"> – Current Transformer Ratio updated – all calculations based on CTR updated; all element settings based on CTR calculation updated. – Settings Z2F and Z2R updated under <i>Negative-Sequence Directional Element Settings</i>. – Corrected omission of OFF option to EBLKD and ETDPUs settings under <i>Permissive Overreaching Scheme Settings</i> in <i>Settings Sheets</i>. <p>Section 6</p> <ul style="list-style-type: none"> – Removed connectorized references and renumbered figures. – Added clarifying Note under <i>Modems in Communications</i>. – Updated <i>Figure 6.10: Relay Dimensions and Drill Plan (Conventional Terminal Block Version)</i>. <p>Appendix B</p> <ul style="list-style-type: none"> – Updated <i>Figure B.1: SEL-321-5 Main Board Jumper, Connector, and Socket Locations</i>. <p>Appendix I</p> <ul style="list-style-type: none"> – Reformatted <i>Table I.1: FIDS Enable Settings</i> (no date code change).
980812	<p>Appendix A</p> <ul style="list-style-type: none"> – Updated and improved diagnostics.
980514	<p>Section 2</p> <ul style="list-style-type: none"> – Added CBAD, RBAD, and LBOK elements to element tables. – MB protocol replaces R protocol in <i>Communications Ports Specifications</i>. – Corrected <i>Figures 2.5, 2.6, 2.7, 2.8, 2.25, 2.26, 2.31, 2.32, and 2.41</i>. <p>Section 3</p> <ul style="list-style-type: none"> – COMM and LOOP commands added and ERESTART setting added to SET G command. <p>Section 5</p> <ul style="list-style-type: none"> – <i>Settings Sheets</i> modified. <p>Section 6</p> <ul style="list-style-type: none"> – Clarified and expanded. <p>Appendix F</p> <ul style="list-style-type: none"> – Corrected <i>Figure F.1: Scheme 1 Trip Decision Logic for Phase A</i>. <p>Appendix I</p> <ul style="list-style-type: none"> – Changed previous <i>Appendix H: SEL-321-1 Relay Factory Settings</i> to <i>Appendix I</i>.

Revision Date	Summary of Revisions
	<p>Appendix H – Added new <i>Appendix H: Mirrored Bits</i>.</p> <p>Appendix J – Added new <i>Appendix J: Interface Board Specifications</i>.</p>

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SECTION 1: INTRODUCTION

GETTING STARTED

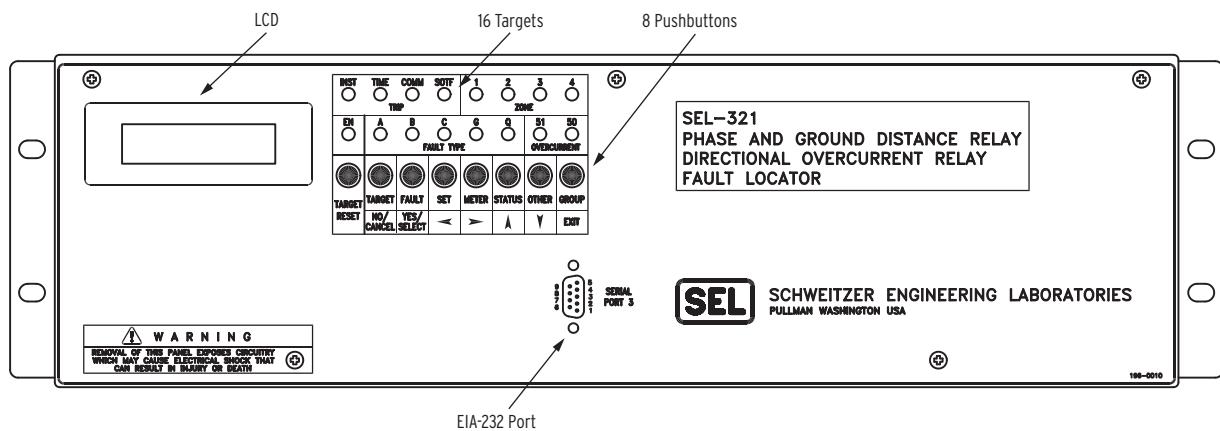
This instruction manual provides descriptive information and instructions for the SEL-321-5 Relay. The instructions in this manual are designed for use by personnel with a background in power engineering and experience in protective relay applications. A detailed technical description of the relay and examples of its application are included. While reasonable examples and illustrations of relay uses are given, sound judgment must be exercised at all times in its application.

The manual is divided into sections with the following information:

Section 1: Introduction	General information
Section 2: Specifications	Detailed technical description of each feature
Section 3: Communications	User interface and protocol
Section 4: Event Reporting	Describes content and use
Section 5: Applications	How to apply and set
Section 6: Installation	Wiring and configuration
Section 7: Maintenance and Testing	Initial checkout and tests
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OVERVIEW

The following pages present a brief overview of the functions and characteristics of the relay.



From Front Panel

- Set relay
- Read meter and other data
- Switch setting groups
- Password protection

Figure 1.1: SEL-321-5 Front Panel (One I/O Board Version)

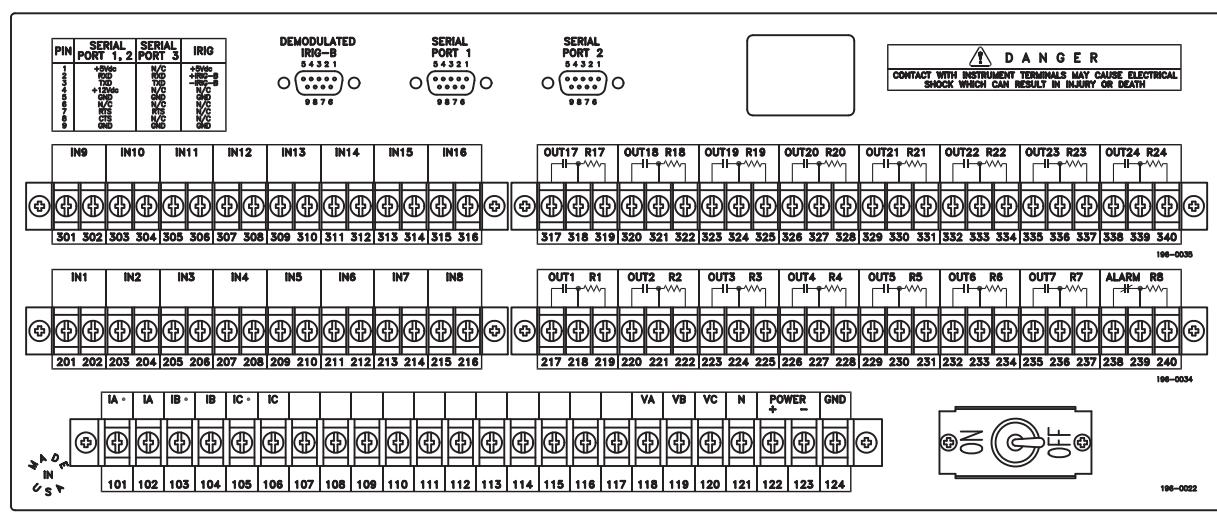
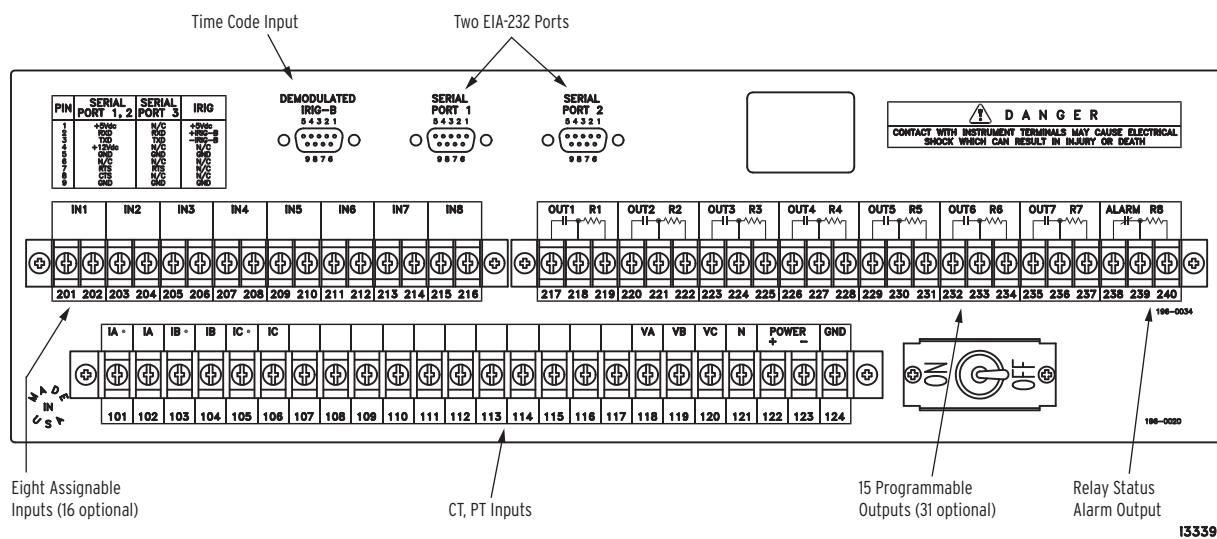
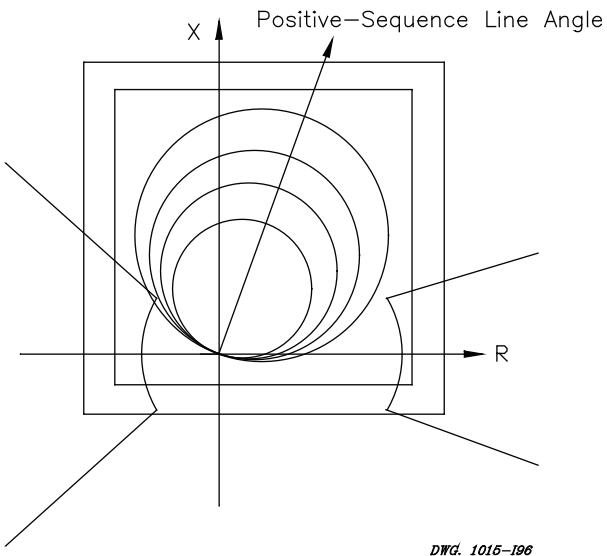
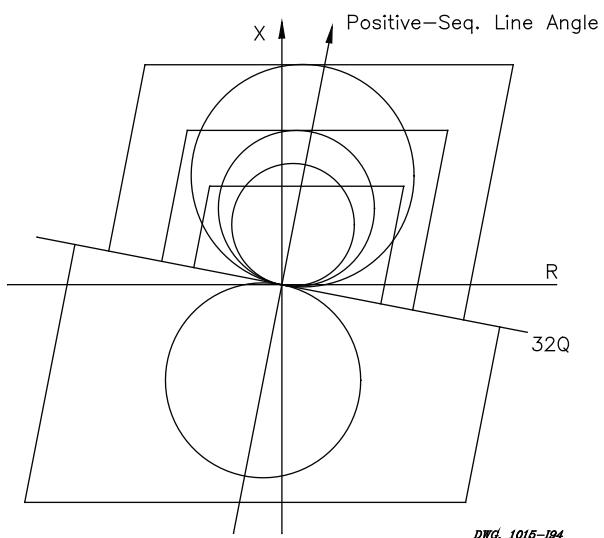


Figure 1.3: SEL-321-5 Rear Panel (Two I/O Board Version)



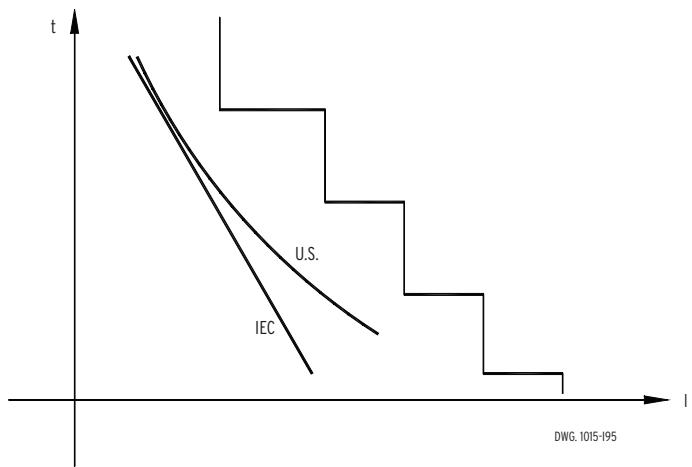
- Four mho zones
- Two quadrilateral zones for OOS
- Two load zones
- Set only characteristics you need
- All zones reversible

Figure 1.4: Three-Phase and Phase-to-Phase Distance Characteristics



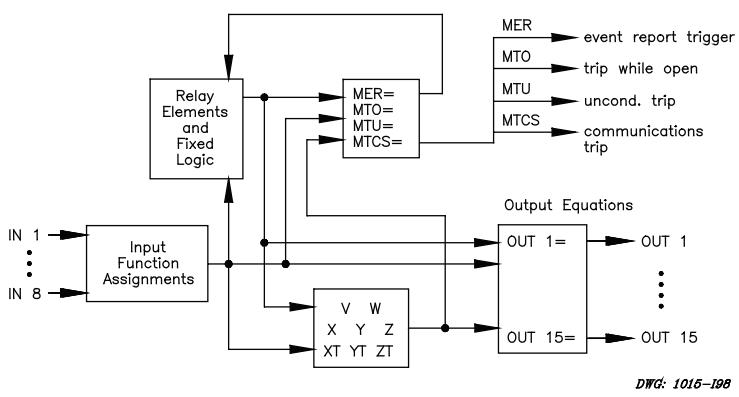
- Four mho zones
- Four quadrilateral zones
- User quadrilateral, mho, none, or both

Figure 1.5: Ground-Distance Characteristics



- Four US, four IEC curve families
- Phase, residual, and negative-sequence elements
- Torque-controllable by distance and directional elements
- One-cycle or electro-mechanical reset characteristics
- Four instantaneous/definite-time elements for negative-sequence and for residual overcurrent

Figure 1.6: Instantaneous, Definite-Time, and Time-Overcurrent Characteristics



- Assign input functions
- Create output functions specific to any applications
- Design unique trip and control schemes
- Minimize external timers, auxiliary relays, wiring, and panel space
- Event reporting records all logic

Figure 1.7: SELOGIC® Control Equations Programmable Control Logic

Event Reporting

Provides four types of event reports:

- Automatic summary report with abbreviated information
- Default report is 11-cycles duration, 4 samples/cycle
- Long event report is 11-cycles duration, 16 samples/cycle
- Unfiltered report for computer analysis of data
- Forty summaries are stored in nonvolatile memory

Application Highlights

A list of applications and key specifications:

Applications	Key Specifications
Single-Pole Tripping	<ul style="list-style-type: none">• Advanced phase-selection methods• Secure protection during open-pole interval• Pole-discordance logic trips three-pole for excessive single-pole-open events
Multiple-Breaker Applications	<ul style="list-style-type: none">• SPT one; 3PT other• SPT both; 3PT both• Trip coil monitors for up to six poles• Stub protection
Long Lines	<ul style="list-style-type: none">• Load-encroachment elements prevent unwanted trips on load• Voltage elements detect local and remote bus overvoltages• Sensitive negative-sequence and residual overcurrent elements provide sensitive backup protection
Tapped and Three-Terminal Lines	<ul style="list-style-type: none">• Four zones• Two zero-sequence compensation factors for more accurate ground-distance reach on either side of the tap• Independent reach settings for phase, ground mho, and ground reactance elements• Multiple setting groups cover any switching configurations• Multiple setting groups<ul style="list-style-type: none">◆ Match relay settings group to each line substitution◆ Eliminate current reversing switches
Bus-Tie Breakers	<ul style="list-style-type: none">• Local or remote operator switches the setting groups
Subtransmission Lines	<ul style="list-style-type: none">• Time-stepped distance• Ground directional overcurrent protection• Torque-controlled time-overcurrent elements
Lines with Transformers	<ul style="list-style-type: none">• Negative-sequence overcurrent protection

Applications	Key Specifications
Lines with Reactors	<ul style="list-style-type: none"> Overvoltage elements control reactor insertion and tripping
Short Transmission Lines	<ul style="list-style-type: none"> Twenty-cycle polarizing memory duration
Permissive Overreaching Transfer Tripping Schemes (POTT)	<ul style="list-style-type: none"> Current reversal guard logic Open breaker echo keying logic Weak- and zero-infeed logic Time-step distance backup
Directional Comparison Unblocking Tripping Schemes (DCUB)	<ul style="list-style-type: none"> Includes all POTT logic All loss-of-channel logic inside the relay Time-step backup
Permissive Underreaching Transfer Tripping Schemes (PUTT)	<ul style="list-style-type: none"> Supported by POTT logic Time-step backup
Directional Comparison Blocking Trip Scheme (DCB)	<ul style="list-style-type: none"> Current reversal guard logic Carrier coordinating timers Carrier send and receive extend logic
Zone 1 Extension Schemes	<ul style="list-style-type: none"> Zone 3 latch eliminates the need for offset three-phase distance elements Time-step backup
Direct Underreaching Transfer Tripping Schemes (DUTT)	<ul style="list-style-type: none"> Settable Zone 1 extension multiplier Settable Zone 1 extension enable delay
	<ul style="list-style-type: none"> SELOGIC control equations program which elements key direct trip

Other Features

- Fault Locator
- Metering
- Automatic Self-testing
- Forty event report summaries stored in nonvolatile memory
- Three general purpose timers
- Five choices for controlling the trip circuits
- Trip circuit monitoring

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SECTION 2: SPECIFICATIONS

OVERVIEW

The relay contains protection elements, many logic schemes, programmable I/O and logic, event recording, fault locating, metering, and other functions.

Outputs from all of the protection elements, logic schemes, etc. are available to the programmable logic (SELOGIC® control equations) for tripping, alarming, keying communications, and any other desired functions.

The relay includes three serial communications ports and a front-panel user-interface for entering settings, reviewing operations, checking metering, and other functions.

SETTING STRUCTURE

The relay has four types of settings, as shown in Table 2.1.

Table 2.1: Relay Setting Structure

Communications Port Settings (SET P command) Assign the parameters of the three EIA-232 ports
Global Settings (SET G command) Assign contact inputs, LCD illumination time-out, and setting group switch delay
Logic Settings (SET L command) Program tripping functions and output contacts using SELOGIC control equations
All Remaining Settings (SET command) Select and set protective element boundaries and thresholds, communications-assisted trip, and other schemes

The setting procedure has enables for each group of features and characteristics. If you do not select a feature (e.g., out-of-step protection), the relay does not prompt you for those settings.

The following information is set using the **SET** command for each of the six setting groups.

LINE AND RELAY TERMINAL INFORMATION

The relay accepts information that describes the line section in terms of positive- and zero-sequence secondary impedances. The fault location algorithm uses these replica impedances directly. The distance elements use the positive-sequence impedance angle for calculations.

Other terminal information includes:

- Fault location option (Y = Two-terminal, R = Radial, N = Disable)
- Line length (LL)
- Current and potential transformer ratios (for presenting metering and event report data in primary values)

ENABLING DISTANCE ZONES

Zero to four zones of phase mho, ground mho, and ground quadrilateral protection can be individually selected. Use the PMHOZ, GMHOZ, and QUADZ settings to specify how many zones of each type of distance element you need.

Element Label Comment

Elements with zone labels are associated with distance elements. Elements with level labels are associated with negative-sequence and residual overcurrent elements.

SETTING THE DIRECTION OF ZONES AND OVERCURRENT ELEMENTS

The DIR1 through DIR4 settings establish the direction of characteristics associated with Zones and Levels 1–4. Table 2.2 shows which elements are affected by DIR1 through DIR4.

Table 2.2: Zone and Level Elements Affected by DIR1 through DIR4

Setting (F/R)	Affected Characteristics			
	Phase Mho	Ground Mho and Quad	$I_R >>$	$3I_2 >>$
DIR1	M1P	Z1G	67N1	67Q1
DIR2	M2P	Z2G	67N2	67Q2
DIR3	M3P	Z3G	67N3	67Q3
DIR4	M4P	Z4G	67N4	67Q4

(F = Forward; R = Reverse)

PHASE MHO DISTANCE CHARACTERISTICS

Each phase mho zone has independent phase-to-phase overcurrent supervision. All instantaneous and time-delayed outputs can be used in the programmable logic to create control, alarm, and indication schemes.

<u>Settings</u>	<u>Zone 1</u>	<u>Zone 2</u>	<u>Zone 3</u>	<u>Zone 4</u>
Zone Reach	Z1P	Z2P	Z3P	Z4P
O/C Supervisory	50PP1	50PP2	50PP3	50PP4
<u>Outputs</u>				
Instantaneous	M1P	M2P	M3P	M4P
Time Delayed		M2PT	M3PT	M4PT

Supporting Drawings: Figure 2.5 through Figure 2.9.

GROUND MHO AND QUADRILATERAL DISTANCE CHARACTERISTICS

Each zone has separate phase and residual overcurrent supervision. The Zone 1 zero-sequence compensation factor (k_{01}) is independent from the compensation factor (k_0) used for all other zones.

<u>Settings</u>	<u>Zone 1</u>	<u>Zone 2</u>	<u>Zone 3</u>	<u>Zone 4</u>
Mho Reach Z1MG	Z2MG	Z3MG	Z4MG	
Quad Reactance	XG1	XG2	XG3	XG4
Quad Resistance	RG1	RG2	RG3	RG4
Phase O/C Sup.	50L1 ¹	50L2	50L3	50L4
Res. O/C Sup. 50G1	50G2	50G3	50G4	
k0 Magnitude k01M	k0M	k0M	k0M	
k0 Angle k01A	k0A	k0A	k0A	
<u>Outputs</u>				
Instantaneous Z1G	Z2G	Z3G	Z4G	
Time Delayed	Z2GT	Z3GT	Z4GT	

¹ 50L1 is also used for open pole logic and trip unlatch logic if no zones of ground distance are enabled.

(The mho and quadrilateral characteristics share the same logical outputs Z1G–Z4G.)

Supporting Drawings: Figure 2.10 through Figure 2.19.

OUT-OF-STEP (OOS) CHARACTERISTICS

The rectangular impedance-plane characteristics use positive-sequence impedance and overcurrent supervision.

When the impedance remains between Zones 5 and 6 longer than the OOS blocking delay (OSBD), the relay logic prevents designated zones from tripping for up to two seconds.

Negative-sequence overcurrent conditions, detected by the 50Q1–50Q4 elements, remove OOS blocking to permit tripping for unbalanced faults, which may occur during swings.

A narrow rectangular impedance-plane characteristic centered around the line angle (specified by Z1ANG setting) is used to remove OOS blocking to permit tripping for three-phase faults (Patent Pending), which may occur during swings.

Zone Blocking Enable Settings	OOSB1–OOSB4			
<u>Timer Settings</u>				
OOS Blocking Delay	OSBD			
OOS Tripping Delay	OSTD			
Rectangular OOS				
<u>Characteristic Settings</u>	<u>Top</u>	<u>Bottom</u>	<u>Right</u>	<u>Left</u>
Zone 5 X1T5	X1B5	R1R5	R1L5	
Zone 6 X1T6	X1B6	R1R6	R1L6	
Overcurrent Supervision Setting	50ABC 50Q1 for removing OSB1 condition in the M1P logic 50Q2 for removing OSB2 condition in the M2P logic 50Q3 for removing OSB3 condition in the M3P logic 50Q4 for removing OSB4 condition in the M4P logic			
Maximum Time of Block	2 seconds			
<u>Outputs</u>				
Zone 5 Element	X5ABC			
Zone 6 Element	X6ABC			
Overcurrent Element	50ABC			
Out-of-Step Block Condition	OSB			
Zone 1–4 Blocked	OSB1 OSB2 OSB3 OSB4			
Out-of-Step Trip Initiated	OSTI			
Out-of-Step Trip Condition	OST			

These outputs may be used for alarming or controlling other equipment.

Supporting Drawings: Figure 2.20 and Figure 2.21.

LOAD-ENCROACHMENT CHARACTERISTICS

The load-encroachment feature permits setting the distance protection independent of the line loading.

Two independent positive-sequence impedance characteristics monitor load conditions. When load is in either of these characteristics, and the load-encroachment logic is enabled (ELE = Y), then the three-phase distance elements are blocked.

One characteristic monitors load-flow out, and the other monitors load-flow in. The settings are load impedance magnitude and angle limits. Normally, these characteristics are set to accommodate maximum load (minimum load impedance), and some margin, to ensure heavy loads remain inside the load characteristic.

<u>Settings</u>	<u>Load-Out Region</u>	<u>Load-In Region</u>
Minimum load impedance	ZLF	ZLR
Load-angle limits	PLAF (0° to $+90^\circ$)	PLAR (90° to 180°)
NLAF (-90° to 0°)	NLAR (180° to 270°)	
<u>Output</u>		
Load element asserted	ZLOAD	Load detected in the Load-in or Load-out regions. $ I_1 $ must exceed $0.1 \cdot I_{\text{nom}}$ A.

Supporting Drawing: Figure 2.22.

I_{nom} = Nominal rated current

NEGATIVE-SEQUENCE DIRECTIONAL CHARACTERISTICS (PATENT #5349490)

The negative-sequence directional element characteristics are two settable (one forward and one reverse) negative-sequence reactance characteristics. The reaches of the forward and reverse elements are independently settable and have independently set negative-sequence overcurrent supervision. Thus, forward and reverse sensitivity and selectivity are user-settable.

Both characteristics are supervised by a negative- to positive-sequence current ratio (I_2/I_1) check. This supervision restrains the negative-sequence directional elements for three-phase faults with errant I_2 . The a2 setting determines the minimum (I_2/I_1) ratio where directional elements are calculated.

The negative-sequence directional element supervises the phase distance elements for unbalanced faults. The ground directional element supervises the ground distance and ground overcurrent protection elements.

Ground Directional Element Characteristics

The SEL-321-5 Relay includes an adaptive ground directional element. When there is sufficient negative-sequence current (i.e., if the 50Q element is picked up), the relay uses the negative-sequence directional element described above. If the 50Q element does not pick up, yet the ratio of residual current (I_R) to negative-sequence current (I_2) exceeds 10, the relay enables the zero-sequence directional element. The GDS ground directional selection element picks up to signify this condition. This zero-sequence directional element has the same characteristics as those described above for the negative-sequence directional element:

- Two settable characteristics (one forward, one reverse)
- Independent zero-sequence supervisory overcurrent element (one for the forward element, another for the reverse)
- Ratio supervision (I_R/I_1)

The zero-sequence directional element uses the same threshold settings as those set for the negative-sequence directional element except it substitutes checking zero-sequence quantities for negative-sequence quantities.

Supporting Drawing: Figure 2.23.

TIME-OVERCURRENT ELEMENTS

Phase, negative-sequence, and residual time-overcurrent elements are available as enabled. Both US and IEC curve shapes are supported. The phase element uses the highest measured phase current, while the negative-sequence and residual current elements use $3I_2$ and I_R currents, respectively.

<u>Settings</u>	<u>Phase</u>	<u>Residual</u>	<u>Neg.-Seq.</u>
Pickup	51PP	51NP	51QP
Curve Family (US or IEC)	51PC	51NC	51QC
Time Dial	51PTD	51NTD	51QTD
Reset Delay	51PRS	51NRS	51QRS
Torque Control	51PTC	51NTC	51QTC
Torque Control Options:			
• Zone 2 Phase Mho (M2P)	X		X
• Load Encroachment	X		
• Zone 2 Ground Dist (Z2G)		X	X
• 32QF (forward)		X	X
• 32QR (reverse)		X	X
• Nondirectional	X	X	X

Reset delay setting choices permit one-cycle resetting or slow resetting, which emulates induction disk resetting.

<u>Outputs</u>	<u>Phase</u>	<u>Residual</u>	<u>Neg.-Seq.</u>
Pickup	51PP	51NP	51QP
Timed Out	51PT	51NT	51QT
Reset	51PR	51NR	51QR

Supporting Drawings: Figure 2.24 through Figure 2.26.

Note: The inverse time-overcurrent reset delay settings (51PRS, 51NRS, 51QRS) can be set to OFF. When set to OFF, the overcurrent pickup elements (51PP, 51NP, 51QP) operate as instantaneous overcurrent elements, but the timed out elements (51PT, 51NT, 51QT) are disabled.

INSTANTANEOUS/DEFINITE-TIME OVERCURRENT ELEMENTS: LEVELS 1–4

Zero to four levels of residual and negative-sequence overcurrent protection can be individually selected using the E50N and E50Q settings, respectively.

<u>Settings</u>	<u>Level 1</u>	<u>Level 2</u>	<u>Level 3</u>	<u>Level 4</u>
$I_R >>$	50N1	50N2	50N3	50N4
$3I_2 >>$	50Q1	50Q2	50Q3	50Q4

Instantaneous

Nondirectional Outputs

$I_R >>$	50N1	50N2	50N3	50N4
$3I_2 >>$	50Q1	50Q2	50Q3	50Q4

The appropriate 50Q1–50Q4 element must be enabled and set to provide unbalanced fault detection for OOS blocking in phase distance trip logic.

Instantaneous				
<u>Directional Outputs</u>	<u>Level 1</u>	<u>Level 2</u>	<u>Level 3</u>	<u>Level 4</u>
I _R >>		67N2	67N3	67N4
3I ₂ >>		67Q2	67Q3	67Q4
Time Delayed				
<u>Directional Outputs</u>				
I _R >>	67N1	67N2T	67N3T	67N4T
3I ₂ >>	67Q1	67Q2T	67Q3T	67Q4T

The negative-sequence directional elements, 32QF and 32QR, provide the directional supervision for 67N1–67N4 and 67Q1–67Q4 elements. The 32QF element supervises the forward-looking overcurrent elements, while the 32QR element supervises those set in the reverse direction. The nondirectional outputs are always available.

Each level of residual and negative-sequence overcurrent protection has a designated settable timer.

Supporting Drawings: Figure 2.27 and Figure 2.28.

ADDITIONAL VOLTAGE ELEMENTS

The relay contains seven independent voltage elements. Use these elements by themselves or in combination with other relay elements using the programmable output contact logic to create custom control and supervision schemes. Possible applications might include undervoltage supervision of instantaneous overcurrent elements, local and remote overvoltage alarms, etc.

Phase Voltage Elements

Single-phase and three-phase elements compare individual voltage magnitudes against under- and overvoltage thresholds.

Zero-Sequence Overvoltage Element

The zero-sequence overvoltage element (59N) is used in the Weak-Infeed logic of the Permissive Overreaching Transfer Trip Scheme logic. The 59N element output is also available for use in the programmable logic.

Positive-Sequence Overvoltage Elements

There are two positive-sequence (V_1) overvoltage elements: local bus (59PB) and remote bus (59PR). The 59PB element measures V_1 at the local bus. The 59PR element operates on an estimate of the voltage at the remote bus. The estimate is $V_{1\text{remote}} = V_1 - a_1 \cdot Z_1 L \cdot I_1$, where $Z_1 L$ is the positive-sequence replica line impedance, I_1 is the positive-sequence current, and a_1 is a settable scale factor.

<u>Settings</u>	<u>Mag.</u>	<u>Delay</u>	<u>I_L Comp.</u>	
Zero-Seq. O/V	59N			
Bus Phase U/V	27L			
	27A			
	27B			
	27C			
Bus Phase O/V	59L			
V ₁ Local O/V	59PBD			
V ₁ Remote O/V	59PRD	a1		
<u>Outputs</u>	<u>1ϕ</u>	<u>3ϕ</u>	<u>Seq.</u>	<u>Use in Other Logic</u>
Zero-Seq. O/V			59N	Weak-Infeed Logic
Neg.-Seq. O/V			59QL	Loss-of-Potential Logic
Bus Phase U/V	27L	3P27		Weak-Infeed and Pole Open Logic (27L)
	27A			
	27B			
	27C			
Bus Phase O/V	59L	3P59		No
V ₁ Voltage			59PL	Loss-of-Potential Logic
V ₁ Local O/V			59PB (w/ 59PBD Delay)	No
V ₁ Remote O/V			59PR (w/ 59PRD Delay)	No

Supporting Drawings: Figure 2.29 and Figure 2.30.

TIME-STEP BACKUP LOGIC TIMERS

Independent timers are provided for Zones 2, 3, and 4 of phase and ground distance protection and for each level of residual and negative-sequence overcurrent protection.

<u>Timer Settings</u>	<u>Phase 21</u>		<u>Gnd 21</u>		<u>67N</u>		<u>67Q</u>	
Zone/Level 1					67NL1D		67QL1D	
Zone/Level 2	Z2PD		Z2GD		67NL2D		67QL2D	
Zone/Level 3	Z3PD		Z3GD		67NL3D		67QL3D	
Zone/Level 4	Z4PD		Z4GD		67NL4D		67QL4D	
<u>Timer Inputs and Outputs</u>	<u>Phase 21</u>		<u>Gnd 21</u>		<u>67N</u>		<u>67Q</u>	
	In	Out	In	Out	In	Out	In	Out
Zone/Level 1					67N1	67N1	67Q1	67Q1
Zone/Level 2	M2P	M2PT	Z2G	Z2GT	67N2	67N2T	67Q2	67Q2T
Zone/Level 3	M3P	M3PT	Z3G	Z3GT	67N3	67N3T	67Q3	67Q3T
Zone/Level 4	M4P	M4PT	Z4G	Z4GT	67N4	67N4T	67Q4	67Q4T

COMMUNICATIONS-ASSISTED TRIPPING SCHEMES

With the help of communications, the relay includes tripping schemes that provide unit protection for transmission lines. No external coordination devices are required. The three scheme selections from the relay setting procedure are:

- Permissive Overreaching Transfer Trip (POTT)
- Directional Comparison Unblocking (DCUB)
- Directional Comparison Blocking (DCB)

All three schemes require Zone 2 set forward and Zone 3 set reverse. Develop other communications-assisted tripping schemes using logic inputs and the programmable output logic. Examples are discussed later in this section.

To use a communications scheme, select and set the scheme, and program inputs and outputs, to monitor and control the communications receiver and transmitter.

Permissive Overreaching Transfer Trip (POTT) Logic

This logic performs the following tasks:

- Keys the communications equipment to send permissive trip when any element you include in the MTCS logic variable asserts and the current-reversal logic is not asserted.
- Prevents keying and tripping by the POTT logic following a current reversal.
- Echoes the received permissive signal to the remote terminal.
- Prevents channel lockup during echo and test.

External Input

Received Permissive Trip Signal	PT	Assign PT to a programmable input. Drive with receiver output.
---------------------------------	----	--

Timer Settings

Zone 3 Rev. Block Delay	Z3RBD	Current-reversal guard timer.
Echo Block Delay	EBLKD	Prevents echoing of received PT, for settable delay after dropout of local permissive elements. Set to OFF to ignore EBLKD and defeat echo input to ATB logic.
Echo Time Delay P/U	ETDPU	Sets minimum time requirement for received PT, before echo begins. Set to OFF for no echo.
Echo Duration	EDURD	Limits echo duration, to prevent channel lockup.

Logic Outputs

Zone 3 Reverse Block	Z3RB	Current-reversal guard asserted.
Echo Conversion to Trip	ECTT	PT received, converted to a tripping condition for weak-infeed.
Key Permissive Trip	KEY	Signals communications equipment to transmit permissive trip.

	KEY1	Signals communications equipment to transmit permissive trip for single- and three-pole trips. Can have a 5-cycle extended dropout.
	KEY3	Signals communications equipment to transmit three-pole permissive trip. Can have a 5-cycle extended dropout.
Echo Key Permissive Trip Assisted Trip Block	EKEY ATB	Permissive trip signal keyed by Echo logic. Aided Trip Block. Driven by ECHO and DCUB logic.

Supporting Drawings: Figure 2.31 and Figure 2.32.

Directional Comparison Unblocking (DCUB) Logic

The DCUB logic is an extension of the POTT logic. The extension monitors the loss-of-guard output from the communications receiver, through an input programmed to the LOG function.

The typical application is a POTT scheme using FSK carrier as the communications medium.

External Inputs

Received Permissive Trip Signal	PT	Assign PT to a programmable input. Drive with receiver output.
Loss-of-GuardLOG		Assign LOG to a programmable input. Drive with contact from communications equipment.

Timer Settings

Guard-Present Delay	GARD1D	Sets minimum time requirement for reinstating permissive tripping following a loss-of-channel condition.
DCUB Disable Delay	UBDURD	Prevents tripping by POTT logic after a settable time following a loss-of-channel condition.
DCUB Duration Delay	UBEND	Sets minimum time required to declare a loss-of-guard condition.

Logic Outputs

Same as POTT outputs Unblocking Block	UBB	Use to disable tripping by the DCUB logic via SELOGIC control equations.
Permissive Trip Receive	PTRX	Permissive trip signal receive input to Trip logic.

Supporting Drawings: Figure 2.31 and Figure 2.33.

Directional Comparison Blocking (DCB) Logic

This logic performs the following tasks:

- Provides the individual carrier coordination timers for the Zone 2 and Level 2 elements to allow time for the block trip signal to arrive from the remote terminal.
- Instantaneously keys the communications equipment to transmit block trip for reverse faults and extends this signal for a settable time following the dropout of all Zone 3 and Level 3 elements.

- Latches block trip send condition by the phase distance elements following a close-in zero-voltage three-phase fault where the polarizing memory expires. Latch is removed when the polarizing memory voltage returns or current is removed.
- Extends the received block trip signal by a settable time.

External Input

Received Block Trip Signal	BT	Assign BT to a programmable input. Drive with block trip receive output.
----------------------------	----	--

Timer Settings

Zone 3 Dropout Extension Delay	Z3XD	Current-reversal guard timer.
Block Receive Extension Delay	BTXD	Sets reset time of block trip received condition after the reset of block trip input.
Zone 2 Phase 21 (M2P) Carrier Coord. Delay	Z2PSD	Delays M2P element output.
Zone 2 Ground 21 (Z2G) Carrier Coord. Delay	Z2GSD	Delays Z2G element output.
67N2 Carrier Coordination Delay	67N2SD	Delays 67N2 element output.
67Q2 Carrier Coordination Delay	67Q2SD	Delays 67Q2 element output.

Logic Outputs

Stop carrier	STOP	Program to an output contact to stop carrier.
Start carrier	START	Program to an output contact to start carrier. Includes current-reversal guard logic.
Block Trip Extension	BTX	Block trip receive signal extended by BTXD timer.

Supporting Drawings: Figure 2.34 and Figure 2.35.

For further information, request the SEL-321 DCB Application Guide (96-03) from your representative or the factory.

Creating Other Tripping Schemes

Permissive Underreaching Transfer Trip Schemes

Use the POTT logic for the echo keying and Weak-Infeed logic. Program an output contact with Zone 1 distance elements to key permissive trip.

Direct Underreaching Transfer Trip Schemes

Three-Pole Trip Applications

Assign an input to DT (Direct Trip). Program this element in the unconditional trip variable (MTU) to trip the breaker upon assertion of the DT input. Program an output contact with Zone 1 distance elements to key the communication equipment to send the direct trip signal when any Zone 1 element asserts.

Single-Pole Trip Applications

Assign inputs to DTA, DTB, and DTC. Assertion of an input causes the corresponding trip variable to assert.

Direct Transfer Trip Schemes

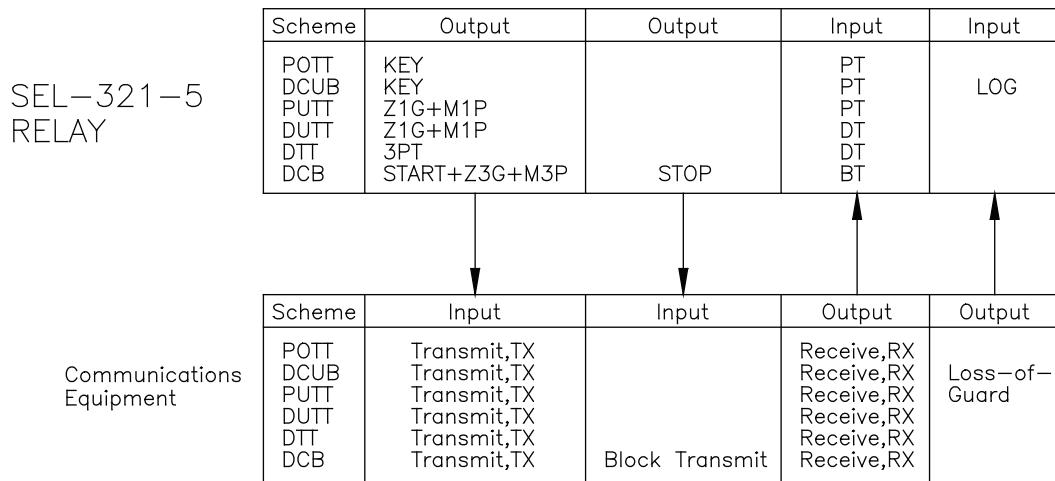
Three-Pole Trip Applications

Assign an input to DT (Direct Trip). Program this element in the unconditional trip variable to trip the breaker upon assertion of the DT input. Program an output contact with a tripping element to key the communication equipment to send the direct trip signal when the relay asserts a tripping signal.

Single-Pole Trip Applications

Assign inputs to DTA, DTB, and DTC. Assertion of an input causes the corresponding trip variable to assert.

Figure 2.1 shows the necessary connections between the SEL-321-5 Relay and the communication equipment.



DWG: 1015II05

Figure 2.1: Signal Connections Between Relay and Communication Equipment

OTHER LOGIC

Zone 1 Extension (Z1X) Scheme Logic

This logic modifies the reach of all Zone 1 distance elements by multiplier Z1EXTM once all three poles are closed for Z1EXTD time.

The Zone 1 reaches cannot be extended if any of the following elements are asserted: M1P through M4P, Z1G through Z4G, 51NP, or 51QP.

All Zone 1 reaches retreat to their set reach when the programmable input assigned to CLOSE asserts.

Settings

Zone 1 Extension Delay	Z1EXTD	Sets the minimum time all three breaker poles must be closed before extending the Zone 1 reach.
Zone 1 Extension Multiplier	Z1EXTM	Sets the scalar by which all Zone 1 reaches are multiplied—never less than one.

External Input

Close Signal	CLOSE	Assign CLOSE to a programmable input. Drive with the close signal to the breaker(s).
--------------	-------	--

Logic Output

Extend Zone 1 Reaches	Z1X	When asserted, Zone 1 reaches are extended.
-----------------------	-----	---

Supporting Drawing: Figure 2.36.

Remote-End-Just-Opened (REJO) Logic

The REJO logic accelerates tripping for one- or two-phase in-section faults without using a communications channel. This logic generates a tripping condition, if any elements in the MTCS variable assert and a REJO condition exists.

Settings

Coordinating Timer	REJOD	Delays REJO assertion to permit coordination for out-of-section faults.
Current Detectors	3P50R	Sets phase current threshold for detecting load.

Logic Outputs

Current above 3P50R threshold in all three phases	3P50R	Three-phase current is present to indicate remote breaker is closed. This must drop out to declare REJO.
Current above 3P50R threshold in one phase	50P	One-phase current is above the 3P50R threshold. This must remain asserted for REJO declaration.
Remote-End-Just-Opened	REJO	Enables tripping by elements in the MTCS variable.

Supporting Drawing: Figure 2.37.

Switch-Onto-Fault (SOTF) Logic

The SOTF logic permits specified elements to trip for a settable time after the breaker closes. Specify these elements in the programmable logic variable called MTO.

Tripping by elements in the MTO variable may be enabled two ways: asserting the CLOSE input or by timing the slowest 52a contact transition period. Select either or both means in the setting procedure.

External Input

Close Signal	CLOSE	Drive with the close signal to the breaker(s).
Breaker Aux. Contacts	52A1	Drive with breaker auxiliary contacts. The number of inputs depends on the application and whether single- or three-pole tripping is used.
	52A2	
	52AA1	
	52AA2	
	52AB1	
	52AB2	
	52AC1	
	52AC2	

Settings

Close Enable Delay	CLOEND	Sets minimum time duration after all currents drop out, before CLOSE input activates SOTF logic.
52A Enable Delay	52AEND	Sets minimum time after all breaker poles open before activating SOTF logic.
SOTF Time Duration	SOTFD	Sets how long tripping by elements in MTO is active following breaker closure.
High-set Phase O/C Pickup	50H	

Logic Output

Switch-onto-Fault Logic Enabled	SOTFE	Enables three-pole tripping by elements in MTO logic variable.
---------------------------------	-------	--

Supporting Drawing: Figure 2.38.

Loss-of-Potential (LOP) Logic

This logic detects one, two, or three blown potential fuses. The LOP condition blocks all distance elements and forces the negative-sequence and ground directional decisions forward.

Single-Pole Open conditions clear LOP declarations.

Settings

LOP Time Delay	LOPD	Sets time delay before LOP can assert following the loss of one or two potential fuses.
Medium-set Phase O/C Pickup	50M	Single-phase overcurrent threshold for blocking LOP during faults.
Zero-seq. (V_0) O/V Pickup	59NL	Sets V_0 threshold for detecting one or two blown fuses.
Pos.-seq. (V_1) O/V Pickup	59PL	Sets V_1 threshold for detecting three blown fuses.

Outputs

LOP indication	LOP	Always available even if ELOP = N. Does not block distance elements.
Internal LOP block	ILOP	Enabled by ELOP = Y. Blocks distance elements.

Supporting Drawing: Figure 2.39.

Pole-Discordance Logic

This logic can be used to alarm or trip the relay. It checks the 52A inputs from either one or two breakers, SPPDD cycles after any single-pole trip signal drops out. If all three 52A inputs from a breaker do not agree, the appropriate pole-discordance output variable (PD1 or PD2) immediately asserts.

Timer Setting

Single-Pole Trip

Phase-Discordance Delay	SPPDD	Sets time delay for checking the 52A input statuses following the dropout of a single-pole trip signal.
-------------------------	-------	---

Outputs

Pole Discordance 1	PD1	Breaker 1 pole discordance.
Pole Discordance 2	PD2	Breaker 2 pole discordance.

Supporting Drawing: Figure 2.40.

Pole Open Logic

This logic discriminates between a partially and fully-open line terminal. The Three-Pole Open (3PO) condition asserts when all three phases of the line are disconnected. The Single-Pole Open (SPO) condition asserts when one or two phases of the line remain energized.

The pole open logic uses either 52A status and undercurrent or single-phase undervoltage and undercurrent conditions to determine the pole open condition. You select which method the relay uses via the OPO setting.

If the setting OPO = 52, then a pole is open if the one (or two) 52A inputs associated with that phase are deasserted and if the current in that phase is below pickup of the four overcurrent elements 50L1–50L4.

If the setting OPO = 27, then a pole is open if a phase undervoltage condition exists and the current in that phase is below pickup of the four overcurrent elements 50L1–50L4.

The output of this logic influences both phase and ground distance element operations. SPO and 3PO conditions have independent Time Delayed Dropout (TDDO) timers.

Settings

Single-Pole Open Delay	SPOD	Stabilizing time delay after single-pole reclose.
Three-Pole Open Delay	3POD	Security time delay for dissimilar breaker pole closing.
Trip-Open Pole Delay	TOPD	Any trip that occurs while TOPD is timing results in a three-pole trip.
Open-Pole Option	OPO	Selects undervoltage or 52A pole open detection.

Outputs

Phase A Open	SPOA	Blocks 21AB and 21CA elements.
Phase B Open	SPOB	Blocks 21AB and 21BC elements.
Phase C Open	SPOC	Blocks 21BC and 21CA elements.
Single-Pole Open	SPO	Blocks all quadrilateral ground distance, clears LOP, and asserts 32QF. Includes SPOD delay.
Three-Pole Open	3PO	Blocks all ground distance. Includes 3POD delay.
Trip-Open-Pole	TOP	TOPD timer is timing.

Supporting Drawing: Figure 2.40 and Figure 2.41.

Stub Protection Logic

The LOP condition can enable a definite-time overcurrent element to detect faults on bus-sections not having PTs or to provide backup protection if potentials are lost. The same 50M overcurrent element used in the LOP logic serves as the fault detector for this logic. If ELOP = N, this logic is not enabled.

Timer Setting

Stub Protection Coord. Delay 50MFD Definite-time delay for 50MF.

Output

Stub Protection O/C Element 50MF Asserts for faults during LOP conditions if 50M asserted for 50MFD delay.

Supporting Drawing: Figure 2.42.

Trip Coil Monitor (TCM) Logic

Programmable inputs can be assigned to monitor the integrity of up to six trip-coil circuits. Each input must be connected in parallel with the appropriate tripping contacts.

If any monitoring input disagrees with the corresponding 52A input for 60 cycles, then the TCM element asserts. Table 2.3 shows the logic input assignments required to activate the TCM logic.

Table 2.3: Trip Coil Monitor Logic Input Assignment Options

Breaker 1		Breaker 2	
3PT	SPT	3PT	SPT
52A1,TCM1	52AA1, TCMA1 52AB1, TCMB1 52AC1, TCMC1	52A2,TCM2	52AA2, TCMA2 52AB2, TCMB2 52AC2, TCMC2

Logic Output

Trip Coil
Monitor condition TCM Trip coil path invalid condition.

Supporting Drawing: Figure 2.43.

Close Logic

This logic controls the CC element. Remotely close a circuit breaker with the **CLOSE** command. This command is available in the Breaker and Level 2 access levels. Both of these levels have separate passwords.

Issuing the **CLOSE** command asserts the CC element if the breaker is open. Use a SELOGIC control equation to program the CC element to any output contact connected to the closing circuit of the breaker.

The CC element asserts for 30 cycles or until the breaker closes or a tripping condition is detected.

Supporting Drawing: Figure 2.44.

Trip Suspicion Logic

Transferring polarizing potentials from one source to another during high loading conditions may result in a race condition between assertion of three-phase LOP and the phase distance elements. The Trip Suspicion logic ensures distance element security during this transfer.

Assign a relay input to monitor the device which initiates the potential transfer. The input assignment is PTXFR. For a five second period after asserting the PTXFR input, the Trip Suspicion logic delays tripping for 3 cycles.

Input

Potential Transfer	PTXFR	Drive with potential transfer switch initiation indication.
--------------------	-------	---

Output

Trip Suspicion	TS	Blocks all tripping conditions for 3 cycles.
----------------	----	--

Supporting Drawing: Figure 2.45.

Fault Identification Selection (FIDS) Logic

This logic identifies the faulted phase(s) for all faults involving ground by comparing the angle between I_0 and I_2 .

For those cases where there is no negative-sequence current except zero-sequence current, the FIDS logic uses single-phase undervoltage elements for faulted phase selection.

The FIDS logic is not active during an SPO condition.

Outputs

FIDS Selects A ϕ	FSA	Enables A ϕ ground distance and blocks AB and CA phase distance elements.
FIDS Selects B ϕ	FSB	Enables B ϕ ground distance and blocks AB and BC phase distance elements.
FIDS Selects C ϕ	FSC	Enables C ϕ ground distance and blocks BC and CA phase distance elements.

Open Phase Alarm Logic

This logic detects zero-sequence current in the presence of balanced voltages when all poles of the breaker are closed. This condition asserts an alarm element labeled OPA.

Use a SELLOGIC control equation to program OPA to an output contact for alarming.

Output

Open Pole Alarm Element OPA Indicates an open phase condition.

Supporting Drawing: Figure 2.46.

Contact Input Assignments

The one I/O board relay has eight assignable logic inputs IN1–IN8. The two I/O board relay has 16 inputs, IN1–IN16. You assign functions to each of the inputs from the assignments listed in Table 2.4 by using the **SET G** command. The assigned input statuses are available in Relay Word Rows 21–25 (see Table 2.4).

Table 2.4: Logic Input Assignment List

Function	Label	Application
Not Assigned	NA	Input Not Assigned
Setting Selection 1	SS1	Setting Group Selection Input 1
Setting Selection 2	SS2	Setting Group Selection Input 2
Setting Selection 3	SS3	Setting Group Selection Input 3
Permissive Trip	PT	Drive with PT receive output for POTT scheme
Block Trip	BT	Drive with BT receive output for DCB scheme
Direct Trip	DT	Asserts the DT element
Single-Pole Direct Trip A	DTA	Direct Trip A
Single-Pole Direct Trip B	DTB	Direct Trip B
Single-Pole Direct Trip C	DTC	Direct Trip C
Loss-of-Guard	LOG	Drive with loss-of-guard output from communications equipment
Potential Transfer	PTXFR	Drive with contact from the potential transfer switch
Single-Pole Trip Enable	SPTE	Assert to enable single-pole trip
Parallel A ϕ Block	PARA	Assert to block A ϕ ground distance protection
Parallel B ϕ Block	PARB	Assert to block B ϕ ground distance protection
Parallel C ϕ Block	PARC	Assert to block C ϕ ground distance protection
Bkr. 1 Position	52A1	Drive with Bkr. 1 auxiliary in 3PT applications ¹
Bkr. 2 Position	52A2	Drive with Bkr. 2 auxiliary in 3PT applications ²
Bkr. 1, A ϕ Pole Position	52AA1	Monitors Breaker 1 position, A ϕ
Bkr. 2, A ϕ Pole Position	52AA2	Monitors Breaker 2 position, A ϕ
Bkr. 1, B ϕ Pole Position	52AB1	Monitors Breaker 1 position, B ϕ
Bkr. 2, B ϕ Pole Position	52AB2	Monitors Breaker 2 position, B ϕ
Bkr. 1, C ϕ Pole Position	52AC1	Monitors Breaker 1 position, C ϕ
Bkr. 2, C ϕ Pole Position	52AC2	Monitors Breaker 2 position, C ϕ
Close	CLOSE	Drive with breaker close signal
Trip Coil Monitor 1	TCM1	Monitors Breaker 1 trip coil ³
Trip Coil Monitor 2	TCM2	Monitors Breaker 2 trip coil ⁴
Trip Coil Monitor, A ϕ 1	TCMA1	Monitors Breaker 1, A ϕ trip coil

Function	Label	Application
Trip Coil Monitor, B ϕ 1	TCMB1	Monitors Breaker 1, B ϕ trip coil
Trip Coil Monitor, C ϕ 1	TCMC1	Monitors Breaker 1, C ϕ trip coil
Trip Coil Monitor, A ϕ 2	TCMA2	Monitors Breaker 2, A ϕ trip coil
Trip Coil Monitor, B ϕ 2	TCMB2	Monitors Breaker 2, B ϕ trip coil
Trip Coil Monitor, C ϕ 2	TCMC2	Monitors Breaker 2, C ϕ trip coil
External Trigger	EXT	Assert to trigger event reports
Logic Point 1	LP1	Controls general purpose element LP1
Logic Point 2	LP2	Controls general purpose element LP2
Logic Point 3	LP3	Controls general purpose element LP3
Logic Point 4	LP4	Controls general purpose element LP4
Logic Point 5	LP5	Controls general purpose element LP5
Logic Point 6	LP6	Controls general purpose element LP6
Logic Point 7	LP7	Controls general purpose element LP7
Logic Point 8	LP8	Controls general purpose element LP8
Logic Point 9	LP9	Controls general purpose element LP9
Logic Point 10	LP10	Controls general purpose element LP10
Ext. Trip Unlatch	EXTUL	Assert to unlatch TPA, TPB, TPC, and 3PT

Invert the sense of any input assignment by including the SELOGIC control equation invert operator “!” immediately in front of the input assignment (e.g., !52A1 changes a 52a input to a 52b input).

¹ 52AA1, 52AB1, and 52AC1 follow 52A1 if they are not assigned to an input.

² 52AA2, 52AB2, and 52AC2 follow 52A2 if they are not assigned to an input.

³ TCMA1, TCMB1, and TCMC1 follow TCM1 if they are not assigned to an input.

⁴ TCMA2, TCMB2, and TCMC2 follow TCM2 if they are not assigned to an input.

SELOGIC CONTROL EQUATIONS

SELOGIC control equations perform the following tasks:

- Define what conditions assert the output contacts
- Define which elements and conditions trigger event reports
- Select the elements which trip for switch-onto-fault conditions
- Select the elements which trip unconditionally
- Select the elements which trip with communications assistance

Figure 2.2 gives an overview of SELOGIC control equations in the SEL-321-5 Relay.

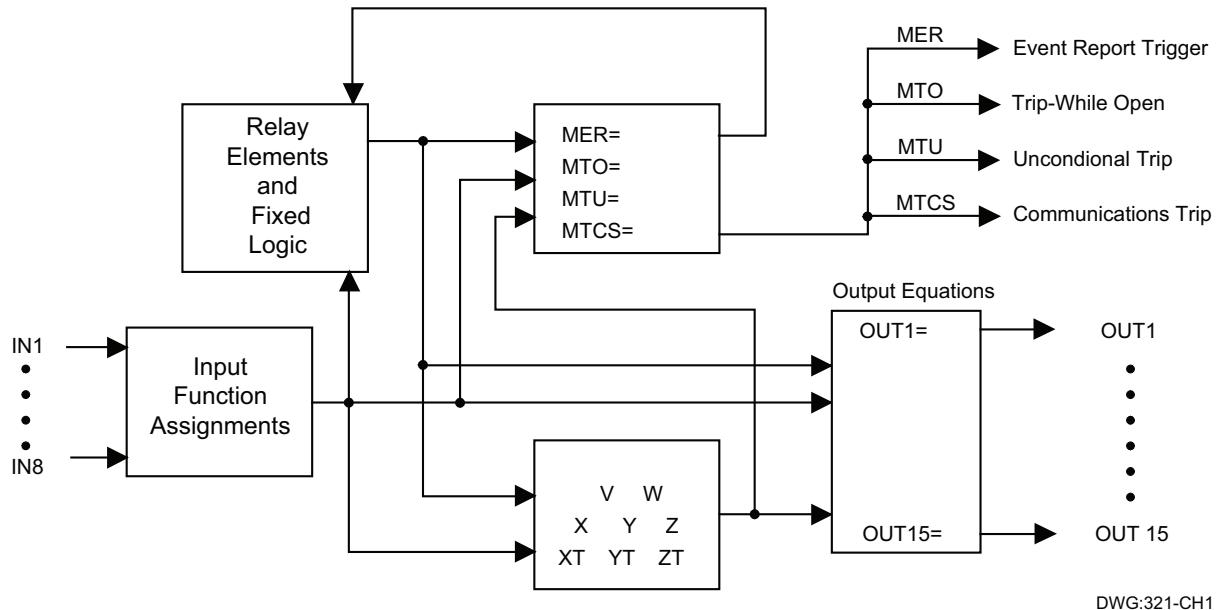


Figure 2.2: SEL-321-5 SELOGIC Control Equations Overview

Programming SELOGIC control equations is easy.

1. Use the **SET G** command to enter your input assignments into the Global settings of the relay. (“Global” means that only one set of input assignments is permitted. There are six sets of logic and element settings.) Table 2.4 lists all available input assignment choices.
2. Determine the relay element combinations you want for the following four purposes:

Communications-assisted trip	(set with MTCS logic variable)
Unconditional trip	(set with MTU logic variable)
Switch-onto-fault trip	(set with MTO logic variable)
Event report triggering	(set with MER logic variable)
3. Determine the output functions you require, including tripping, keying communications, etc. First, refer to the rear-panel wiring diagram, and choose the specific output contacts you wish to assign to various functions. For example, assume you want OUT1 and OUT2 to be three-pole trip outputs, OUT3 to follow the **CLOSE** command, and OUT4 to key communications. Any output contact may be assigned for tripping duty.

When you are designing your trip-condition, event-trigger, and output logic, you may use AND, OR, and NOT operators to develop virtually any combination of elements for each condition. There are also five intermediate variables (V, W, X, Y, and Z) which you can first program and subsequently use in Steps 2 and 3 above. Three of these (X, Y, and Z) also have independent general purpose time delay pickup/dropout timers. The outputs after these timers (XT, YT, and ZT) are also available.

4. Use the **SET L** command to enter your logic equations for V, W, X, Y, Z, MTCS, MTU, MTO, MER, and each of the outputs (except ALARM). Each setting group has its own associated logic equations.
5. If you want the same logic and relay element settings in more than one group, you do not need to retype the equations and settings. Instead copy them using the **COPY** command. To copy Group 1 settings to Group 2, use the command **COPY 1 2**.

Equation Programming

Program intermediate logic points (elements listed in Table 2.12) and the output contacts with SELOGIC control equations. This permits you to combine any element in Table 2.7, Table 2.9, or Table 2.12. Use non-dedicated timers for special applications, and assign these combinations to output contacts. Inputs can be assigned labels listed in Table 2.4.

Programming SELOGIC control equations consists of combining relay elements with logical AND (*), OR (+), and inversion (!) variables in a single string for each output contact. The following list defines the use of these variables. The simplest string consists of directly entering a single element.

- * AND Requires that elements on both sides of the * symbol be asserted before the logic condition is true. For example, to supervise the M1P element with the 27L element, program the SELOGIC control equation as: M1P * 27L.
- + OR Requires that one element on either side of the + symbol be asserted before the logical condition is true. The following setting closes the OUT9 output contact when either the M1P or 27L element asserts: OUT9 = M1P + 27L.
- ! Invert Inverts the value of the element immediately following the ! symbol. For example, to block the 50H element if all three phases voltages are below the 27L threshold, program the SELOGIC control equation as: 50H * !3P27.
- \ Insert a \ symbol at the end of the first line of a SELOGIC control equation (just before pressing [RETURN]), to continue the same equation to the second line. Otherwise, the equation may only be one line. There is a two-line (80 characters per line—160 characters max) limit for a single equation and a 100-term (element names and operators) limit per equation.

SELOGIC Control Equation Operator Order of Operations

When the SELOGIC control equations are computed, the ! is applied first, followed by AND (*) functions, and finally OR (+) functions are computed. The *, +, and ! functions may be used in any combination for any output contact. For example, to signal that the relay tripped by a switch-onto-fault operation, program one of the output contacts as follows (OUT 4 shown as an example):

OUT4 = TPA * SOTFE + TPB * SOTFE + TPC * SOTFE

This logic says that if TPA, TPB, or TPC asserts while SOTFE is asserted that OUT4 asserts to indicate a SOTF operation.

Exceptions

1. Variables (V, W, X, Y, or Z) cannot be programmed to themselves.
2. SELOGIC control equation variables can only be programmed with elements defined before them in the element list. Within Table 2.12, before means those elements to the right of the one being programmed.
3. Table 2.5 lists combinations of SELOGIC control equation operators that are not acceptable:

Table 2.5: Unacceptable SELOGIC Control Equation Operator Combinations

*+	**	!*	!+
+*	++	!!	

Program any single internal-use element from Table 2.14 to an output contact as long as nothing else is programmed to that output.

Programming an output equation to NA disables that output contact.

Relay Elements

Table 2.6 through Table 2.18 show the set of relay elements. Display any row of relay elements using the **TARGET** command and the TAR numbers in the left column of each table.

Table 2.6 shows front-panel status indicators. These are not logic elements. They correspond to the front-panel targets and bear the front-panel target names.

Table 2.6: Front-Panel Status Indicators

TAR	Status Indicators							
0	INST	TIME	COMM	SOTF	ZONE1	ZONE2	ZONE3	ZONE4
1	EN	A	B	C	G	Q	51	50

The primary elements of the relay are listed in Table 2.7. The status of these elements is updated by the relay logic, and these elements serve as a source for use in SELOGIC control equations. The most commonly used elements are shown as shaded items. All outputs, except ALARM, can be programmed by using the Primary Elements and SELOGIC control equations.

Table 2.7: Primary Elements

TAR	Elements							
2	Z4G	Z3G	Z2G	Z1G	M4P	M3P	M2P	M1P
3	Z4GT	Z3GT	Z2GT	LOP	M4PT	M3PT	M2PT	OPA
4	67Q4	67Q3	67Q2	67Q1	67N4	67N3	67N2	67N1
5	67Q4T	67Q3T	67Q2T	OST	67N4T	67N3T	67N2T	OSB
6	PD1	3P27	27L	50H	50MF	51NT	51QT	51PT
7	ZLOAD	SOTFE	TCM	CC	3PO	SPO	REJO	PD2
8	3P50R	51NP	51QP	51PP	50G	50PP	50M	50L
9	50Q4	50Q3	50Q2	50Q1	50N4	50N3	50N2	50N1
10	50ABC	X6ABC	X5ABC	3PT	TPC	TPB	TPA	32QF
11	3P59	59L	59N	59PR	59PB	59NL	59PL	50Q
12	BTX	GDS	STOP	START	FIDEN	FSC	FSB	FSA
13	32QR	KEY3	KEY1	EKEY	Z3RB	ATB	ECTT	KEY
14	XAG4	XAG3	XAG2	XAG1	MAG4	MAG3	MAG2	MAG1
15	XBG4	XBG3	XBG2	XBG1	MBG4	MBG3	MBG2	MBG1
16	XCG4	XCG3	XCG2	XCG1	MCG4	MCG3	MCG2	MCG1
17	MBC4	MBC3	MBC2	MBC1	MAB4	MAB3	MAB2	MAB1
18	SPOC	SPOB	SPOA	*	MCA4	MCA3	MCA2	MCA1
19	50HH	OSTI	50CA	50BC	50AB	*	*	*
20	Z1X	27C	27B	27A	UBOSB	ROK	3PSOTF	TOP

* Reserved for future use

Table 2.8: Primary Element Summary

Element	Comment
Z4G	Zone 4 Mho and/or Quad. Distance, Instantaneous
Z3G	Zone 3 Mho and/or Quad. Distance, Instantaneous
Z2G	Zone 2 Mho and/or Quad. Distance, Instantaneous
Z1G	Zone 1 Mho and/or Quad. Distance, Instantaneous
M4P	Zone 4 Phase Distance, Instantaneous
M3P	Zone 3 Phase Distance, Instantaneous
M2P	Zone 2 Phase Distance, Instantaneous
M1P	Zone 1 Phase Distance, Instantaneous
Z4GT	Zone 4 Ground Distance, Time Delayed
Z3GT	Zone 3 Ground Distance, Time Delayed
Z2GT	Zone 2 Ground Distance, Time Delayed
LOP	Loss-of-Potential Condition Indication
M4PT	Zone 4 Phase Distance, Time Delayed
M3PT	Zone 3 Phase Distance, Time Delayed
M2PT	Zone 2 Phase Distance, Time Delayed
OPA	Open Phase Alarm

Element	Comment
67Q4	Level 4 Directional Neg.-Seq. Overcurrent, Instantaneous
67Q3	Level 3 Directional Neg.-Seq. Overcurrent, Instantaneous
67Q2	Level 2 Directional Neg.-Seq. Overcurrent, Instantaneous
67Q1	Level 1 Directional Neg.-Seq. Overcurrent
67N4	Level 4 Directional Residual Overcurrent, Instantaneous
67N3	Level 3 Directional Residual Overcurrent, Instantaneous
67N2	Level 2 Directional Residual Overcurrent, Instantaneous
67N1	Level 1 Directional Residual Overcurrent
67Q4T	Level 4 Directional Neg.-Seq. Overcurrent, Time Delayed
67Q3T	Level 3 Directional Neg.-Seq. Overcurrent, Time Delayed
67Q2T	Level 2 Directional Neg.-Seq. Overcurrent, Time Delayed
OST	Out-of-Step Trip Condition Declaration
67N4T	Level 4 Directional Residual Overcurrent, Time Delayed
67N3T	Level 3 Directional Residual Overcurrent, Time Delayed
67N2T	Level 2 Directional Residual Overcurrent, Time Delayed
OSB	Out-of-Step Block Condition Declaration
PD1	Breaker 1 Phase Discordance Declaration
3P27	Three-Phase Undervoltage Condition
27L	Single-Phase Undervoltage Condition
50H	High-Set Phase Overcurrent, Instantaneous
50MF	Medium-Set Phase Overcurrent Time Delayed by 50MF Timer
51NT	Residual Time-Overcurrent Timed Out
51QT	Negative-Sequence Time-Overcurrent Timed Out
51PT	Phase Time-Overcurrent Timed Out
ZLOAD	Load Encroachment Element
SOTFE	Switch-On-to-Fault Logic Enabled
TCM	Trip Coil Monitor Alarm
CC	Close Command Control Element
3PO	Three Poles Open
SPO	Single-Pole Open
REJO	Remote End Just Opened Condition
PD2	Breaker 2 Phase Discordance Declaration
3P50R	REJO Logic Overcurrent Element Pickup
51NP	Residual Time-Overcurrent Element Pickup
51QP	Negative-Sequence Time-Overcurrent Element Pickup
51PP	Phase Time-Overcurrent Element Pickup
50G	50G1 + 50G2 + 50G3 + 50G4
50PP	50PP1 + 50PP2 + 50PP3 + 50PP4
50M	Medium-Set Phase Overcurrent
50L	50L1 + 50L2 + 50L3 + 50L4

Element	Comment
50Q4	Level 4 Nondirectional Neg.-Seq. Overcurrent, Instantaneous
50Q3	Level 3 Nondirectional Neg.-Seq. Overcurrent, Instantaneous
50Q2	Level 2 Nondirectional Neg.-Seq. Overcurrent, Instantaneous
50Q1	Level 1 Nondirectional Neg.-Seq. Overcurrent, Instantaneous
50N4	Level 4 Nondirectional Residual Overcurrent, Instantaneous
50N3	Level 3 Nondirectional Residual Overcurrent, Instantaneous
50N2	Level 2 Nondirectional Residual Overcurrent, Instantaneous
50N1	Level 1 Nondirectional Residual Overcurrent, Instantaneous
50ABC	OOS Supervising Overcurrent Element, Pos.-Seq., Instantaneous
X6ABC	Zone 6, Out-of-Step Distance Element, Instantaneous
X5ABC	Zone 5, Out-of-Step Distance Element, Instantaneous
3PT	Three-Pole Trip
TPC	Trip C
TPB	Trip B
TPA	Trip A
32QF	Sequence Directional Element: Forward
3P59	Three-Phase Overvoltage Element
59L	Single-Phase Overvoltage Element
59N	Residual Overvoltage Element Status
59PR	Current Compensated Positive-Sequence Overvoltage Element Status
59PB	Local Positive-Sequence Overvoltage Element Status
59NL	Loss-of-Potential Zero-Sequence Overvoltage Element Status
59PL	Loss-of-Potential Positive-Sequence Overvoltage Element Status
50Q	50QF + 50QR
BTX	Block Trip Input Extension (active if EDCB = Y)
GDS	Ground Directional Selection
STOP	Carrier Stop for DCB (active if EDCB = Y)
START	Carrier Start for DCB (active if EDCB = Y)
FIDEN	FIDS logic enable
FSC	FIDS logic selects C ϕ
FSB	FIDS logic selects B ϕ
FSA	FIDS logic selects A ϕ
32QR	Sequence Directional Element: Reverse
KEY3	Three-Pole Trip Keying (active if EPOTT = Y)
KEY1	Single-Pole and Three-Pole Trip Keying (active if EPOTT = Y)
EKEY	Echo Key (active if EPOTT = Y)
Z3RB	Zone 3 Reverse Block (active if EPOTT = Y)
ATB	Aided Trip Block (active if EPOTT = Y)
ECTT	Echo Conversion to Trip (active if EPOTT = Y)
KEY	Key Permissive Trip Signal Start (active if EPOTT = Y)

Element	Comment
XAG4	Quadrilateral Ground Distance A ϕ , Zone 4
XAG3	Quadrilateral Ground Distance A ϕ , Zone 3
XAG2	Quadrilateral Ground Distance A ϕ , Zone 2
XAG1	Quadrilateral Ground Distance A ϕ , Zone 1
MAG4	Mho Ground Distance A ϕ , Zone 4
MAG3	Mho Ground Distance A ϕ , Zone 3
MAG2	Mho Ground Distance A ϕ , Zone 2
MAG1	Mho Ground Distance A ϕ , Zone 1
XBG4	Quadrilateral Ground Distance B ϕ , Zone 4
XBG3	Quadrilateral Ground Distance B ϕ , Zone 3
XBG2	Quadrilateral Ground Distance B ϕ , Zone 2
XBG1	Quadrilateral Ground Distance B ϕ , Zone 1
MBG4	Mho Ground Distance B ϕ , Zone 4
MBG3	Mho Ground Distance B ϕ , Zone 3
MBG2	Mho Ground Distance B ϕ , Zone 2
MBG1	Mho Ground Distance B ϕ , Zone 1
XCG4	Quadrilateral Ground Distance C ϕ , Zone 4
XCG3	Quadrilateral Ground Distance C ϕ , Zone 3
XCG2	Quadrilateral Ground Distance C ϕ , Zone 2
XCG1	Quadrilateral Ground Distance C ϕ , Zone 1
MCG4	Mho Ground Distance C ϕ , Zone 4
MCG3	Mho Ground Distance C ϕ , Zone 3
MCG2	Mho Ground Distance C ϕ , Zone 2
MCG1	Mho Ground Distance C ϕ , Zone 1
MBC4	Mho BC Phase Distance Zone 4, Instantaneous
MBC3	Mho BC Phase Distance Zone 3, Instantaneous
MBC2	Mho BC Phase Distance Zone 2, Instantaneous
MBC1	Mho BC Phase Distance Zone 1, Instantaneous
MAB4	Mho AB Phase Distance Zone 4, Instantaneous
MAB3	Mho AB Phase Distance Zone 3, Instantaneous
MAB2	Mho AB Phase Distance Zone 2, Instantaneous
MAB1	Mho AB Phase Distance Zone 1, Instantaneous
SPOC	Single-Pole Open, Phase C, Instantaneous
SPOB	Single-Pole Open, Phase B, Instantaneous
SPOA	Single-Pole Open, Phase A, Instantaneous
*	Reserved for future use
MCA4	Mho CA Phase Distance Zone 4, Instantaneous
MCA3	Mho CA Phase Distance Zone 3, Instantaneous
MCA2	Mho CA Phase Distance Zone 2, Instantaneous
MCA1	Mho CA Phase Distance Zone 1, Instantaneous

Element	Comment
50HH	Two or Three Phases Over High-Set, Instantaneous
OSTI	Out-of-Step Trip Initiate
50CA	50CA1 + 50CA2 + 50CA3 + 50CA4
50BC	50BC1 + 50BC2 + 50BC3 + 50BC4
50AB	50AB1 + 50AB2 + 50AB3 + 50AB4
*	Reserved for future use
*	Reserved for future use
*	Reserved for future use
Z1X	Zone 1 Extension Enable (active if EZ1EXT = Y)
27C	Phase C Undervoltage Condition
27B	Phase B Undervoltage Condition
27A	Phase A Undervoltage Condition
UBOSB	Unblock the Out-of-Step Block Condition
ROK	Relay-to-Relay Communications Established and Validated
3PSOTF	Switch-On-Fault Trip Extension
TOP	Trip During Pole Open Timer is Timing

Table 2.9 lists the assignment choices for the programmable inputs using the SET G command. **Section 3: Communications** gives detailed instructions on the use of the **SET G** command. The 52A1, 52A2, TCM1, and TCM2 elements in Table 2.9 are unique; they allow a single input to control three functional elements for cases when single-phase information is unavailable. Use the LP1 through LP10 inputs for functions you define. They may be used in SELLOGIC control equations.

Table 2.9: Assigned Input Statuses

TAR	Assigned Input Status Indicators							
21	LP1	SS3	SS2	SS1	EXT	DT	BT	PT
22	EXTUL	PARC	PARB	PARA	SPTE	PTXFR	LP2	LOG
23	LP3	CLOSE	52AC2	52AC1	52AB2	52AB1	52AA2	52AA1
24	LP5	LP4	TCMC2	TCMC1	TCMB2	TCMB1	TCMA2	TCMA1
25	DTA	DTB	DTC	LP6	LP7	LP8	LP9	LP10

Refer to Contact Input Assignments in this section for the definitions of the inputs listed in Table 2.9.

The following tables show additional SELLOGIC control equation variables available in the SEL-321-5 Relay. Table 2.10 lists command-settable Remote bits, RB1 through RB16. You may set, clear, or pulse the Remote bits via the **CONTROL** command. These Remote bits can be used in SELLOGIC control equations to design logic which can be set, cleared, or pulsed locally or remotely by entering a command. Refer to the **Section 3: Communications** for an explanation of the **CONTROL** command.

Table 2.10: Remote Bits

TAR	Elements							
26	RB8	RB7	RB6	RB5	RB4	RB3	RB2	RB1
27	RB16	RB15	RB14	RB13	RB12	RB11	RB10	RB9

Table 2.11: Remote Bit Summary

Element	Comment
RB8	Remote Bit 8
RB7	Remote Bit 7
RB6	Remote Bit 6
RB5	Remote Bit 5
RB4	Remote Bit 4
RB3	Remote Bit 3
RB2	Remote Bit 2
RB1	Remote Bit 1
RB16	Remote Bit 16
RB15	Remote Bit 15
RB14	Remote Bit 14
RB13	Remote Bit 13
RB12	Remote Bit 12
RB11	Remote Bit 11
RB10	Remote Bit 10
RB9	Remote Bit 9

Table 2.12 lists intermediate elements V, W, X, Y, and Z, which can be defined with SELOGIC control equations. The XT, YT, and ZT elements are time-delayed pickup and dropout representations of X, Y, and Z, respectively. Use these variables in multiple masks or output equations, or when a general purpose timer is required.

Table 2.12: Intermediate Elements

TAR	Elements							
28	ZT	Z	YT	Y	XT	X	W	V

Table 2.13: Intermediate Element Summary

Element	Comment
ZT	SELOGIC control equations Z Equation Output, Time Delayed
Z	SELOGIC control equations Z Equation Output, Instantaneous
YT	SELOGIC control equations Y Equation Output, Time Delayed
Y	SELOGIC control equations Y Equation Output, Instantaneous
XT	SELOGIC control equations X Equation Output, Time Delayed
X	SELOGIC control equations X Equation Output, Instantaneous
W	SELOGIC control equations W Equation Output, Instantaneous
V	SELOGIC control equations V Equation Output, Instantaneous

Table 2.14 lists internal elements which may be used singly to control output contacts for testing purposes but are not available for SELOGIC control equations. Use SELOGIC control equations to define MER, MTO, MTU, and MTCS. MER controls triggering of event reports. MTO, MTU, and MTCS establish tripping conditions.

Table 2.14: Internal Elements

TAR	Elements							
29	RAG4	RAG3	RAG2	RAG1	MER	MTO	MTU	MTCS
30	RCG4	RCG3	RCG2	RCG1	RBG4	RBG3	RBG2	RBG1
31	50AL4	50AL3	50AL2	50AL1	VPOLV	N3PT	L3PT	PTRX
32	50CL4	50CL3	50CL2	50CL1	50BL4	50BL3	50BL2	50BL1
33	50G4	50G3	50G2	50G1	50CL	50BL	50AL	CBAD
34	OSB4	OSB3	OSB2	OSB1	50PP4	50PP3	50PP2	50PP1
35	TS	TC	TB	TA	ZLOUT	ZLIN	ILOP	50P
36	SPT_EN	OSBC	OSBB	OSBA	LBOK	52AC	52AB	52AA
37	50AB4	50AB3	50AB2	50AB1	ATPC	ATPB	ATPA	50PPL
38	50CA4	50CA3	50CA2	50CA1	50BC4	50BC3	50BC2	50BC1
39	RBAD	51NR	51QR	51PR	FTG	FTA	FTB	FTC

Table 2.15: Internal Element Summary

Element	Comment
RAG4	A-phase-Ground Resistance Blinder, Zone 4
RAG3	A-phase-Ground Resistance Blinder, Zone 3
RAG2	A-phase-Ground Resistance Blinder, Zone 2
RAG1	A-phase-Ground Resistance Blinder, Zone 1
MER	Mask to Trigger Event Report Variable
MTO	Mask for Trip Breaker Open Variable
MTU	Mask for Trip Unconditional Variable
MTCS	Mask for Trip Communications-Scheme Variable
RCG4	C-phase-Ground Resistance Blinder, Zone 4
RCG3	C-phase-Ground Resistance Blinder, Zone 3
RCG2	C-phase-Ground Resistance Blinder, Zone 2
RCG1	C-phase-Ground Resistance Blinder, Zone 1
RBG4	B-phase-Ground Resistance Blinder, Zone 4
RBG3	B-phase-Ground Resistance Blinder, Zone 3
RBG2	B-phase-Ground Resistance Blinder, Zone 2
RBG1	B-phase-Ground Resistance Blinder, Zone 1
50AL4	A-phase Supervisory Overcurrent, Zone 4
50AL3	A-phase Supervisory Overcurrent, Zone 3
50AL2	A-phase Supervisory Overcurrent, Zone 2
50AL1	A-phase Supervisory Overcurrent, Zone 1
VPOLV	Positive-Sequence Polarizing Voltage Valid
N3PT	Not Three-Pole Trip
L3PT	Line Three-Pole Trip
PTRX	Permissive Trip Received
50CL4	C-phase Supervisory Overcurrent, Zone 4
50CL3	C-phase Supervisory Overcurrent, Zone 3
50CL2	C-phase Supervisory Overcurrent, Zone 2
50CL1	C-phase Supervisory Overcurrent, Zone 1
50BL4	B-phase Supervisory Overcurrent, Zone 4
50BL3	B-phase Supervisory Overcurrent, Zone 3
50BL2	B-phase Supervisory Overcurrent, Zone 2
50BL1	B-phase Supervisory Overcurrent, Zone 1
50G4	Residual Overcurrent Supervision, Zone 4
50G3	Residual Overcurrent Supervision, Zone 3
50G2	Residual Overcurrent Supervision, Zone 2
50G1	Residual Overcurrent Supervision, Zone 1
50CL	Any C-phase Overcurrent Supervision Element Pickup Up
50BL	Any B-phase Overcurrent Supervision Element Pickup Up
50AL	Any A-phase Overcurrent Supervision Element Pickup Up
CBAD	MIRRORED BITS® channel unavailability over threshold

Element	Comment
OSB4	Out-of-Step Block, Zone 4
OSB3	Out-of-Step Block, Zone 3
OSB2	Out-of-Step Block, Zone 2
OSB1	Out-of-Step Block, Zone 1
50PP4	Phase-to-Phase Supervisory Overcurrent, Zone 4
50PP3	Phase-to-Phase Supervisory Overcurrent, Zone 3
50PP2	Phase-to-Phase Supervisory Overcurrent, Zone 2
50PP1	Phase-to-Phase Supervisory Overcurrent, Zone 1
TS	Trip Suspicion Condition
TC	C-phase Trip
TB	B-phase Trip
TA	A-phase Trip
*	Reserved for Future Use
*	Reserved for Future Use
ILOP	Internal Loss-of-Potential
50P	Single-Phase REJO Overcurrent Element
SPT_EN	SPTE asserted or ESPT = Y or Y1
OSBC	Out-of-Step Block C-Phase
OSBB	Out-of-Step Block B-Phase
OSBA	Out-of-Step Block A-Phase
LBOK	Looped-Back Relay-to-Relay Communications Established and Validated
52AC	Breaker(s) Auxiliary Contact Pole C
52AB	Breaker(s) Auxiliary Contact Pole B
52AA	Breaker(s) Auxiliary Contact Pole A
50AB4	AB Overcurrent Supervision, Zone 4
50AB3	AB Overcurrent Supervision, Zone 3
50AB2	AB Overcurrent Supervision, Zone 2
50AB1	AB Overcurrent Supervision, Zone 1
ATPC	Assert Trip C
ATPB	Assert Trip B
ATPA	Assert Trip A
50PPL	Current latch for DCB scheme after polarizing memory expires.
50CA4	CA Overcurrent Supervision, Zone 4
50CA3	CA Overcurrent Supervision, Zone 3
50CA2	CA Overcurrent Supervision, Zone 2
50CA1	CA Overcurrent Supervision, Zone 1
50BC4	BC Overcurrent Supervision, Zone 4
50BC3	BC Overcurrent Supervision, Zone 3
50BC2	BC Overcurrent Supervision, Zone 2
50BC1	BC Overcurrent Supervision, Zone 1

Element	Comment
RBAD	MIRRORED BITS outage duration over threshold
51NR	Residual Time-Overcurrent Element Reset
51QR	Negative-Sequence Time-Overcurrent Element Reset
51PR	Phase Time-Overcurrent Element Reset
FTG	Fault Type Indicator—Ground Involvement
FTA	Fault Type Indicator—A-Phase Involvement
FTB	Fault Type Indicator—B-Phase Involvement
FTC	Fault Type Indicator—C-Phase Involvement

Table 2.16 shows the status indicators for the input and output contacts for relays with one I/O board. Table 2.17 shows status indicators for the input and output contacts for relays with two I/O boards.

Table 2.16: I/O Contact Targets (One I/O Board Version)

TAR	Status Indicators							
40	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8
41	OUT9	OUT10	OUT11	OUT12	OUT13	OUT14	OUT15	!ALARM
42	TMB8	TMB7	TMB6	TMB5	TMB4	TMB3	TMB2	TMB1
43	MIRBRK	MIRFRA	MIRPAR	MIROVR	MIRIN	MIRSYC	MIRDAT	MIRDIS
44	IN8	IN7	IN6	IN5	IN4	IN3	IN2	IN1
45	RMB8	RMB7	RMB6	RMB5	RMB4	RMB3	RMB2	RMB1

Table 2.17: I/O Contact Targets (Two I/O Board Version)

TAR	Status Indicators							
40	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8
41	OUT9	OUT10	OUT11	OUT12	OUT13	OUT14	OUT15	!ALARM
42	OUT17	OUT18	OUT19	OUT20	OUT21	OUT22	OUT23	OUT24
43	OUT25	OUT26	OUT27	OUT28	OUT29	OUT30	OUT31	OUT32
44	TMB8	TMB7	TMB6	TMB5	TMB4	TMB3	TMB2	TMB1
45	MIRBRK	MIRFRA	MIRPAR	MIROVR	MIRIN	MIRSYC	MIRDAT	MIRDIS
46	IN8	IN7	IN6	IN5	IN4	IN3	IN2	IN1
47	IN16	IN15	IN14	IN13	IN12	IN11	IN10	IN9
48	RMB8	RMB7	RMB6	RMB5	RMB4	RMB3	RMB2	RMB1

Table 2.18: I/O Contact Targets Summary (One I/O Board and Two I/O Board Version)

Element	Comment
MIRBRK	Break detected on MIRRORED BITS communication channel
MIRFRA	Framing error detected on MIRRORED BITS communication channel
MIRPAR	Parity error detected on MIRRORED BITS communication channel
MIROVR	Data received too quickly on MIRRORED BITS communication channel
MIRIN	Too much idle time detected on MIRRORED BITS communication channel
MIRSYC	Synchronization request received on MIRRORED BITS communication channel
MIRDAT	Data error detected on MIRRORED BITS communication channel
MIRDIS	MIRRORED BITS not enabled or relay is disabled

TRIP LOGIC

The relay contains both three-pole and single-pole tripping logic.

The user programs the desired trip output signals to output contacts by using SELLOGIC control equations.

The user selects relay elements to trip:

- Unconditionally,
- For switch-onto-fault actions,
- And with communications assistance.

It also includes five choices for deasserting the trip outputs signals.

Selecting Single-Pole or Three-Pole Tripping Logic

The relay uses single-pole tripping logic if:

- Single-pole trip enable setting ESPT = Y, Y1, or
- Programmable input variable SPTE is asserted.

Otherwise, the relay uses three-pole tripping logic.

Tripping Output Signals

There are four tripping output variables, which can be programmed to drive output contacts for tripping breakers: TPA, TPB, TPC, and 3PT.

Variables TPA, TPB and TPC are phase-dependent tripping signals, designed to control the individual poles of a circuit breaker in single-pole tripping schemes.

Variable 3PT indicates three-pole trips.

Single-Pole Tripping Conditions

When the single-pole tripping logic is active, the SEL-321-5 Relay trips single-pole for the following trip conditions:

- Zone 1 SLG faults detected by the ground distance elements.
- Zone 2 SLG faults detected by the ground distance elements and permitted to trip through the communications-scheme logic.
- DTA, DTB, DTC assigned and asserted.
- See Appendix F for special single-pole tripping applications and other schemes.

All other tripping conditions (including switch-onto-fault, time-step trips, overcurrent trips, and trips during the SPO condition) cause three-pole trips.

Selecting Elements to Trip

The user selects the desired relay elements for unconditional trip, for switch-onto-fault, and for tripping with communications assistance.

The user programs three variables with the desired elements, using the **SET L** command: MTU, MTO, and MTCS.

MTU (Unconditional Trip Variable)

Include Zone 1 and time delayed protective elements in this equation, for example:

$$\text{MTU} = \text{M1P} + \text{Z1G} + \text{M2PT} + \text{Z2GT} + \text{M3PT} + \text{Z3GT} + 51\text{NT}$$

MTO (Switch-On-Fault Trip Variable)

Include more-sensitive elements for instantaneous and sensitive tripping when the breaker is first closed onto a fault. For example, to trip instantaneously on Zone 2 elements:

$$\text{MTO} = \text{M2P} + \text{Z2G}$$

MTCS (Communications-Scheme Trip Variable)

Set the combination of overreaching elements which can trip only if the communications logic permits (on the basis of POTT permission received, for example). If Zone 2 elements are the desired overreaching elements, then set:

$$\text{MTCS} = \text{M2P} + \text{Z2G}$$

Unlatch Logic Selections

This logic deasserts asserted tripping elements.

One of five unlatch options is chosen with the TULO (Trip Unlatch Option) setting:

<u>Option</u>	<u>Setting</u>	<u>Description</u>
N	TULO = N	Time-delayed dropout extension
1	TULO = 1	Undercurrent unlatch
2	TULO = 2	Breaker auxiliary unlatch
3	TULO = 3	Requires conditions of Options 1 and 2
4	TULO = 4	Unlatch when input assigned to EXTUL asserts

Supporting Drawings:

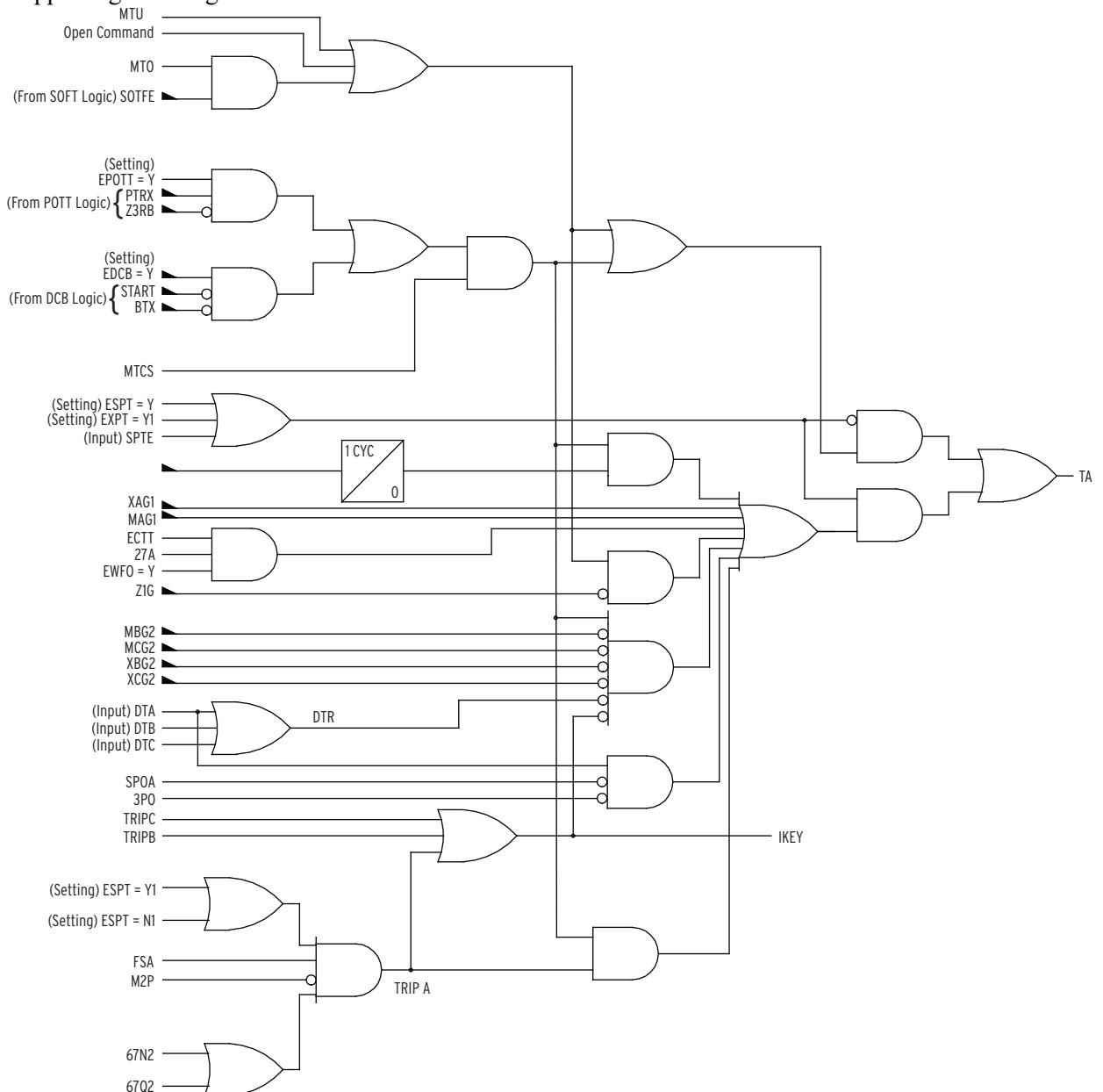


Figure 2.47 through Figure 2.49.

MULTIPLE SETTING GROUPS

The relay has six independent setting groups. Each group is a complete relay setting.

Select groups by two means: contact inputs or the **GROUP** command. Inputs assigned to SS1–SS3 control changing group settings by control switches. Input functions not assigned are treated as zero.

Table 2.19 shows what combinations of asserted logic inputs select which group.

Table 2.19: Setting Group Selections

SS1	SS2	SS3	Group Selected
0	0	0	Group designated by the GROUP Command
1	0	0	Group 1
0	1	0	Group 2
1	1	0	Group 3
0	0	1	Group 4
1	0	1	Group 5
0	1	1	Group 6
1	1	1	Group designated by the GROUP Command

Active Groups and Group Variables

The relay only uses one group setting at a time. The other setting groups are stored in nonvolatile memory.

The setting group used at any one time is called the Active Group. Contact inputs control the Active Group selection. The setting group selected by the **GROUP** command is labeled Group Variable. If the inputs select Group Variable, the **GROUP** command controls the setting group selection.

Global Settings

Inputs	SS1–SS3	Assign to any input. Assignment order is not important.
Timed Group Reset	TGR	Minimum delay that inputs (or input) selecting a new group must be asserted before group is switched.

METERING

Units:	Primary, computed from secondary inputs times instrument transformer ratio settings.
Accuracy:	$\pm 1.0\%$ of nominal input.

SYSTEM FREQUENCY TRACKING

The relay adjusts its sampling rate by monitoring the system frequency by using a zero-crossing detector on the A ϕ voltage input. The relay can be ordered with a nominal frequency of either 60 or 50 Hz.

The frequency tracking range is 55 to 65 Hz for 60 Hz relays and 45 to 55 Hz for 50 Hz relays. When the relay is first turned on, it assumes the nominal frequency.

Accuracy:	± 0.028 Hz at 60 Hz ± 0.020 Hz at 50 Hz
-----------	--

FAULT LOCATOR

Fault locations are computed from data stored in the event report.

Select the fault locating method in the relay settings: set LOCAT = Y when there are current sources in front of the relay location, and set LOCAT = R for radial applications. Set LOCAT = N to disable the fault location feature.

One of the elements in Table 2.20 must assert in the event report data for the relay to calculate a fault location.

Table 2.20: Fault Location Triggering Elements

Fault Type	Elements Which Must be Asserted
Phase-to-Phase Faults	M1P–M4P
Three-Phase Faults	M1P–M4P
Phase-to-Phase-Ground Faults	M1P–M4P
Line-Ground Faults	Z1G–Z4G, 67N1–67N4, 51NP

Fault locations are calculated from the data in the longest contiguous sequence of rows where at least one of the elements in Table 2.20 is asserted.

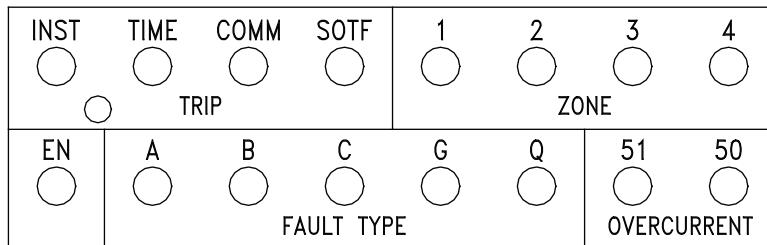
If the longest contiguous sequence duration is less than one-half cycle, or if none of the elements in Table 2.20 assert, the relay does not calculate a fault location. For these cases, \$\$\$\$\$ is reported for a fault location.

FRONT-PANEL TARGETS

The relay presents targets by two means:

- A two-row, 16-column, back-lighted LCD display
- Two rows of eight target/indicator LEDs

The LCD display shows the detailed information pertaining to a fault detected by the relay, displaying metering information, relay self-test status information, etc. The LED designations are shown in Figure 2.3.



MWG: M3215010

Figure 2.3: SEL-321-5 Front-Panel Targeting

General Target LED Description

Under normal operating conditions, only the enable (EN) LED is illuminated. Other LEDs illuminate when the relay trips. These LEDs are latching until reset by pressing the Target Reset Button, executing the **TARGET R** command, or removing power from the relay.

When a new trip occurs, the targets clear and display the latest tripping target.

Only elements masked for tripping illuminate the front-panel target LEDs for a tripping event; unused elements do not target. Refer to the following list of target illumination conditions for the rising edge of TPA, TPB, TPC, or 3PT.

<u>Targets</u>	<u>Definition and Conditions for Illumination</u>
INST	Definition: Instantaneous tripping event. Illuminates if any element of Table 2.21 is used in MTU and asserts for less time than the ITTD time delay setting (Instantaneous Target Time) when TPA, TPB, TPC, or 3PT assert, or if the relay trips and a TIME, SOTF, or COMM Target is not illuminated.
TIME	Definition: Time-delayed tripping event. Illuminates if any element of Table 2.21 is used in MTU and asserts for more time than ITTD when TPA, TPB, TPC, or 3PT assert.

Table 2.21: INST and TIME LED Qualifying Events

M1P–M4P	Z1G–Z4G
67N1–67N4	67Q1–67Q4
51PT	51NT
51QT	

COMM	Definition: Communications scheme-assisted tripping event. Tripping is a result of the communications-assisted trip logic.
SOTF	Definition: Switch-On-to-fault tripping event. SOTFE is asserted.
ZONE 1	Definition: Zone 1 or Level 1 element asserted. Illuminates if any of the following elements are asserted: M1P, Z1G, 67N1, or 67Q1
ZONE 2	Definition: Zone 2 or Level 2 element asserted. Illuminates if any of the following elements assert and like elements of shorter reach are not asserted: M2P, Z2G, 67N2, or 67Q2.
ZONE 3	Definition: Zone 3 or Level 3 element asserted. Illuminates if any of the following elements assert and like elements of shorter reach are not asserted: M3P, Z3G, 67N3, or 67Q3.
ZONE 4	Definition: Zone 4 or Level 4 element asserted. Illuminates if any of the following elements assert and like elements of shorter reach are not asserted: M4P, Z4G, 67N4, or 67Q4.
EN	Definition: Relay enabled (not latching).
A	Definition: A-phase is involved. Illuminates if any of the following distance elements are asserted: <ul style="list-style-type: none"> • MAG1 - MAG4 • XAG1 - XAG4 • MAB1 - MAB4 if $21AB < 21BC$ and $21CA$ and $I_2 > 0.3 \cdot I_1$ • M1P - M4P and $I_2 < 0.3 \cdot I_1$
B	Definition: B-phase is involved. Illuminates if any of the following distance elements are asserted: <ul style="list-style-type: none"> • MBG1 - MBG4 • XBG1 - XBG4 • MBC1 - MBC4 if $21BC < 21AB$ and $21CA$ and $I_2 > 0.3 \cdot I_1$ • M1P - M4P and $I_2 < 0.3 \cdot I_1$
C	Definition: C-phase is involved. Illuminates if any of the following distance elements are asserted: <ul style="list-style-type: none"> • MCG1 - MCG4 • XCG1 - XCG4 • MCA1 - MCA4 if $21CA < 21AB$ and $21BC$ and $I_2 > 0.3 \cdot I_1$ • M1P - M4P and $I_2 < 0.3 \cdot I_1$

G	Definition: Ground is involved. Illuminates if any of the following elements are asserted:
	<ul style="list-style-type: none"> • Z1G - Z4G • 67N1 - 67N4
Q	Definition: Negative-sequence current detected. Illuminates if 51QP or 50Q1–50Q4 are asserted.
51	Definition: Time-overcurrent element timed out. Illuminates if 51PT, 51QT, or 51NT are asserted.
50	Definition: Level 1–4, high-set, or Stub logic overcurrent elements are asserted. Illuminates if any of the following elements listed are asserted: <ul style="list-style-type: none"> • 67N1 * ZONE 1 LED conditions satisfied • 67N2 * ZONE 2 LED conditions satisfied • 67N3 * ZONE 3 LED conditions satisfied • 67N4 * ZONE 4 LED conditions satisfied • 67Q1 * ZONE 1 LED conditions satisfied • 67Q2 * ZONE 2 LED conditions satisfied • 67Q3 * ZONE 3 LED conditions satisfied • 67Q4 * ZONE 4 LED conditions satisfied • 50H • 50HH • 50MF

COMMUNICATIONS PORTS SPECIFICATIONS

Table 2.22 gives specifications for the three serial communications ports and the time-code input.

Table 2.22: Communications Ports Specifications

	Port 1	Port 2	Port 3	IRIG-B	Comment	
Description						
Type	EIA-232			Time Code		
Protocol	SEL LMD			N/A	SEL = Standard Communications LMD = Limited Multi drop (See Appendix G)	
	MB	N/A	MB = Relay-to-Relay communications – only one port			
Baud Rate	300 1200 2400 (Default) 4800 9600 19200 38400	300 1200 2400 (Default) 4800 9600 19200	N/A			
Data Bits	8 (Default) 7 6	8	N/A			
Parity	N (Default) E O	N	N/A	N = None E = Even O = Odd		
Stop Bits	1 (Default) 2	1	N/A			
Time Out	0–30 Minutes			N/A	0 = Port does not time out	
	0 (Default)	5 (Default)				
Auto	Y N			N/A	Y = Designated auto N = Not auto	
	N (Default)	Y (Default)				
RTS_CTS	Y N (Default) MBT	N/A	N/A	Y = Enable RTS/CTS hardware handshake N = Disable RTS/CTS hardware handshake MBT = MBT9600 modem used for Relay-to-Relay Digital Communications		
FAST_OP	Y N (Default)		N/A	Y = Enable Fast Operate command processing N = Disable Fast Operate command processing		

	Port 1	Port 2	Port 3	IRIG-B	Comment
Description					
Type	EIA-232			Time Code	
Connector Pin Assignments					
1	+5 Vdc	N/C	+5 Vdc	N/C = No connection	
2	RXD		+IRIG-B	RXD = Receive data input	
3	TXD		-IRIG-B	TXD = Transmit data output	
4	+12 Vdc	N/C	N/C	+12 Vdc @ 4 mA (max)	
5	GND		GND	Signal Ground	
6	N/C		N/C	No connection	
7	RTS	RTS always asserted	N/C	RTS = Data buffer full when asserted Port 3 always asserted	
8	CTS	N/C	N/C	N/C = No connection CTS = Transmit if asserted	
9	GND		GND	Signal ground	

Internal Time Clock Time-Code Synchronization Specifications

The relay internal time clock is the time reference for all relay functions. Connect the rear-panel port marked DEMODULATED IRIG-B to synchronize to an external time source.

Without an external IRIG-B time-code source, the internal time clock drift rate is ± 0.086 s/day. With IRIG-B, the internal clock is synchronized to within ± 1 ms of the time source.

Note that without an external IRIG-B time-code source, the date and time must be set whenever the relay power is cycled. See **Section 6: Installation** for further information.

SELF-TESTS

The relay runs a variety of self-tests. Table 2.23 summarizes the tests and their outputs and parameters. Some tests have warning and failure states, others only failure states. The relay generates a status report after any change in self-test status. This report may be retrieved using the STATUS command. Table 2.23 shows relay actions for any self-test condition: warning (W) or failure (F).

Table 2.23: Self-Test Summary

Self-Test	Limits		Message	Protection Disabled	ALARM Output
RAM	---		OK or U1–U8	Yes	Latched
ROM	---		OK or U28, U29, U30, U31	Yes	Latched
CR_RAM*	---		OK or GROUP 1–6 LOGIC 1–6 GLOBAL CAL CODE	Yes	Latched
SETTINGS	---		OK or GROUP LOGIC CAL GLOBAL	Yes	Latched
EEPROM	---		OK or GROUP 1–6 LOGIC 1–6 GLOBAL CAL CODE	Yes	Latched
A/D	---		OK/FAIL	Yes	Latched
+5 V PS	4.8	5.2	W	No	
	4.65	5.4	F	Yes	Latched
±5 V REG	±4.8	±5.25	W	No	
	±4.5	±5.5	F	Yes	Latched
±12 V REG	±11.5	±12.5	W	No	
	±11.2	±14.0	F	Yes	Latched
±15 V PS	±14.6	±15.60	W	No	
	±14.0	±16.0	F	Yes	Latched
TEMP	-40°C	+80°C	W	No	
	-50°C	+95°C	F	Yes	Latched
CHANNEL OFFSETS	30 mV		W	No	Pulsed
MASTER OFFSET	20 mV		W	No	Pulsed
	30 mV		F	Yes	Latched

- * SEL-321-5 Relays manufactured since June 1998 are equipped with a new Global setting, ERESTART. When ERESTART = Y, the relay restarts when a CR_RAM self-test failure is detected. This reset clears the relay date, time, and event history. On reset, if the failure condition is still present, the relay is disabled. In the event of a memory self-test failure, use the **RDGMEM** command to download the contents of relay memory before you turn off the relay.

TECHNICAL SPECIFICATIONS (1A NOMINAL RELAY)

General Element Ranges and Accuracy

Phase Mho Distance	Secondary Reach Setting Range:	0.25–320 Ω at the line angle
Ground Mho Distance	Secondary Reach Setting Range: $ k_{01} $ and $ k_0 $ setting range*: Angle k_{01} and k_0 setting range*:	0.25–320 Ω at the line angle 0–4 $\pm 45^\circ$ in 0.1° steps
* Note: Same setting applies to quadrilateral ground distance.		
Quadrilateral Distance	Secondary Reactive Reach: Secondary Resistive Reach: Non-homogeneous Factor (T, degrees):	0.25–320 Ω 0.25–250 Ω $\pm 20^\circ$ in 0.1° steps
Out-of-Step Distance	Secondary Reactance Setting Range: Secondary Resistance Setting Range:	± 480 Ω ± 350 Ω
Load Encroachment Detection	Secondary Impedance Setting Range: Forward Load Angle Setting (in degrees): Reverse Load Angle Setting (in degrees):	0.25–320 Ω -90° to $+90^\circ$ $+90^\circ$ to 270°
Distance Element Accuracy	Secondary Steady-State Error: $\pm 5\%$ of set reach ± 0.05 Ω at line angle (LA) for $V > 5$ V and $I > 0.4$ A $\pm 10\%$ of set reach ± 0.05 Ω at LA for $1 \text{ V} < V < 5$ V and $0.2 \text{ A} < I < 0.4$ A Transient Overreach Error: $\pm 5\%$ of set reach, plus steady-state error	$\pm 5\%$ of set reach ± 0.05 Ω at line angle (LA) for $V > 5$ V and $I > 0.4$ A $\pm 10\%$ of set reach ± 0.05 Ω at LA for $1 \text{ V} < V < 5$ V and $0.2 \text{ A} < I < 0.4$ A Transient Overreach Error: $\pm 5\%$ of set reach, plus steady-state error
Negative-Sequence Directional Element	Secondary Positive-Sequence Current Restraint Range: Secondary Forward Directional Current Supervision: Secondary Reverse Directional Current Supervision: Secondary Forward Directional Impedance Setting: Secondary Reverse Directional Impedance Setting:	0.02–0.5 0.05–1 A 0.05–1 A ± 320 Ω ± 320 Ω
Supervisory Overcurrent Phase	Secondary Pickup Setting Range: • Supervises ground distance	0.1–20 A, ± 0.01 A, $\pm 3\%$ of setting
Phase-to-Phase	Secondary Pickup Setting Range: • Supervises phase distance	0.2–34 A, ± 0.01 A, $\pm 3\%$ of setting
Positive-Sequence	Secondary Pickup Setting Range: • Supervises OOS logic	0.2–20 A, ± 0.01 A, $\pm 3\%$ of setting
Residual	Secondary Pickup Setting Range: Transient Overreach: • Supervises ground distance	0.1–20 A, ± 0.01 A, $\pm 3\%$ of setting $\pm 5\%$ of pickup

Directional Time-Overcurrent	Selectable Curve Shape:	Moderately inverse (US) or Longtime Standby (IEC) Inverse (US) or Standard Inverse (IEC) Very Inverse (US or IEC) Extremely Inverse (US or IEC)
	Neg.-Seq. pickup setting range:	0.1 A–3.2 A, ±0.05 A, ±3% of setting
	Residual Pickup setting range:	0.1 A–3.2 A, ±0.05 A, ±3% of setting
	Time Dial setting range:	0.5–15 in 0.01 steps (US) 0.05–1 in 0.01 steps (IEC)
	Timing:	±4% and ±1.5 cycles for current magnitudes between 2 and 20 multiples of pickup.
Nondirectional Residual/Neg.-Seq. Overcurrent	Secondary pickup setting range:	0.05–16 A, ±0.01 A, ±3% of setting
	Transient Overreach:	±5% of pickup
Ovvovoltage	Pickup:	0–150 V, ±5% of setting, ±1 V
	Transient Overreach:	±5% of pickup
Undervoltage	Pickup:	0–100 V, ±5% of setting, ±1 V
	Transient Overreach:	±5% of pickup
Miscellaneous Timers	Step Distance	Time Delay: 0–2000 cycles
	Communications Scheme	Time Delay: 0–2000 cycles
	DCB Carrier Coordination	Time Delay: 0–60 cycles
	Short Delay	Time Delay: 0–2000 cycles
	Long Delay	Time Delay: 0–8000 cycles
	Loss-of-Potential Set	Time Delay: 1–60 cycles

TECHNICAL SPECIFICATIONS (5A NOMINAL RELAY)

General Element Ranges and Accuracy

Phase Mho Distance	Secondary Reach Setting Range:	0.05–64 Ω at the line angle
Ground Mho Distance	Secondary Reach Setting Range: $ k_{01} $ and $ k_0 $ setting range*: 0–4 Angle k_{01} and k_0 setting range*: ±45° in 0.1° steps	0.05–64 Ω at the line angle
	* Note: Same setting applies to quadrilateral ground distance.	
Quadrilateral Distance	Secondary Reactive Reach: Secondary Resistive Reach: Non-homogeneous Factor (T, degrees):	0.05–64 Ω 0.05–50 Ω ±20° in 0.1° steps
Out-of-Step	Secondary Reactance Setting Range:	±96 Ω

Distance	Secondary Resistance Setting Range: $\pm 70 \Omega$
Load Encroachment Detection	Secondary Impedance Setting Range: $0.05\text{--}64 \Omega$ Forward Load Angle Setting (in degrees): -90° to $+90^\circ$ Reverse Load Angle Setting (in degrees): $+90^\circ$ to 270°
Distance Element Accuracy	Secondary Steady-State Error: $\pm 5\%$ of set reach $\pm 0.01 \Omega$ at line angle (LA) for $V > 5 \text{ V}$ and $I > 2 \text{ A}$ $\pm 10\%$ of set reach $\pm 0.01 \Omega$ at LA for $1 \text{ V} < V < 5 \text{ V}$ and $1 \text{ A} < I < 2 \text{ A}$
	Transient Overreach Error: $\pm 5\%$ of set reach, plus steady-state error
Negative-Sequence Directional Element	Secondary Positive-Sequence Current Restraint Range: $0.02\text{--}0.5$ Secondary Forward Directional Current Supervision: $0.25\text{--}5 \text{ A}$ Secondary Reverse Directional Current Supervision: $0.25\text{--}5 \text{ A}$ Secondary Forward Directional Impedance Setting: $\pm 64 \Omega$ Secondary Reverse Directional Impedance Setting: $\pm 64 \Omega$
Supervisory Overcurrent Phase	Secondary Pickup Setting Range: $0.5\text{--}100 \text{ A}, \pm 0.05 \text{ A}, \pm 3\% \text{ of setting}$ <ul style="list-style-type: none">• Supervises ground distance
Phase-to-Phase	Secondary Pickup Setting Range: $1.0\text{--}170 \text{ A}, \pm 0.05 \text{ A}, \pm 3\% \text{ of setting}$ <ul style="list-style-type: none">• Supervises phase distance
Positive-Sequence	Secondary Pickup Setting Range: $1.0\text{--}100 \text{ A}, \pm 0.05 \text{ A}, \pm 3\% \text{ of setting}$ <ul style="list-style-type: none">• Supervises OOS logic
Residual	Secondary Pickup Setting Range: $0.5\text{--}100 \text{ A}, \pm 0.05 \text{ A}, \pm 3\% \text{ of setting}$ Transient Overreach: $\pm 5\% \text{ of pickup}$ <ul style="list-style-type: none">• Supervises ground distance
Directional Time-Overcurrent	Selectable Curve Shape: Moderately inverse (US) or Longtime Standby (IEC) Inverse (US) or Standard Inverse (IEC) Very Inverse (US or IEC) Extremely Inverse (US or IEC)
	Neg.-Seq. pickup setting range: $0.5 \text{ A}\text{--}16 \text{ A}, \pm 0.05 \text{ A}, \pm 3\% \text{ of setting}$
	Residual Pickup setting range: $0.5 \text{ A}\text{--}16 \text{ A}, \pm 0.05 \text{ A}, \pm 3\% \text{ of setting}$
	Time Dial setting range: $0.5\text{--}15$ in 0.01 steps (US) $0.05\text{--}1$ in 0.01 steps (IEC)
	Timing: $\pm 4\%$ and ± 1.5 cycles for current magnitudes between 2 and 20 multiples of pickup.
Nondirectional Residual/Neg.-Seq. Overcurrent	Secondary pickup setting range: $0.25\text{--}80 \text{ A}, \pm 0.05 \text{ A}, \pm 3\% \text{ of setting}$ Transient Overreach: $\pm 5\% \text{ of pickup}$
Oversvoltage	Pickup: $0\text{--}150 \text{ V}, \pm 5\% \text{ of setting}, \pm 1 \text{ V}$ Transient Overreach: $\pm 5\% \text{ of pickup}$
Undervoltage	Pickup: $0\text{--}100 \text{ V}, \pm 5\% \text{ of setting}, \pm 1 \text{ V}$ Transient Overreach: $\pm 5\% \text{ of pickup}$

Miscellaneous	
Timers	
Step Distance	Time Delay: 0–2000 cycles
Communications Scheme	Time Delay: 0–2000 cycles
DCB Carrier Coordination	Time Delay: 0–60 cycles
Short Delay	Time Delay: 0–2000 cycles
Long Delay	Time Delay: 0–8000 cycles
Loss-of-Potential Set	Time Delay: 1–60 cycles

COMPLIANCE SPECIFICATIONS

Designed and manufactured under an ISO 9001 certified quality management system.

GENERAL SPECIFICATIONS

Voltage Inputs	120 V _{L-N} three-phase four-wire connection. 150 V _{L-N} continuous (connect any voltage from 0 to 150 Vac). 365 Vac for 10 seconds. Burden: 0.13 VA @ 67 V; 0.45 VA @ 120 V.
Current Inputs	5 A nominal: 15 A continuous, 500 A for 1 second, linear to 100 A symmetrical. 1250 A for 1 cycle. Burden: 0.27 VA @ 5 A, 2.51 VA @ 15 A.
	1 A nominal: 3 A continuous, 100 A for 1 second, linear to 20 A symmetrical. 250 A for 1 cycle. Burden: 0.13 VA @ 1 A, 1.31 VA @ 3 A.
Output Contacts	<p>Standard: Per IEC 255-0-20 : 1974, using the simplified method of assessment 6 A continuous carry 30 A make per IEEE C37.90 : 1989 100 A for 1 second 270 Vac/360 Vdc MOV for differential surge protection Pickup Time: <5 ms Dropout time: <8 ms (< 5 ms on the SEL-321-5) Breaking Capacity (L/R = 40 ms): 48 V 0.5 A 10,000 operations 125 V 0.3 A 10,000 operations 250 V 0.2 A 10,000 operations Cyclic Capacity (L/R = 40 ms): 48 V 0.5 A 2.5 cycles per second 125 V 0.3 A 2.5 cycles per second 250 V 0.2 A 2.5 cycles per second </p>

High-current interrupting option:

6 A continuous carry

30 A make per **IEEE C37.90 : 1989**

330 Vdc MOV for differential surge protection

Pickup Time: <5 ms

Dropout time: <8 ms

Breaking Capacity: 10 A 10,000 operations

48 and 125 V (L/R = 40 ms)

250 V (L/R = 20 ms)

Cyclic Capacity: 10 A 4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation

48 and 125 V (L/R = 40 ms)

250 V (L/R = 20 ms)

Note: Do not use high-current interrupting output contacts to switch ac control signals. These outputs are polarity-dependent.**Fast high-current interrupting option:**

6 A continuous carry

30 A make per **IEEE C37.90 : 1989**

330 Vdc MOV for differential surge protection

Pickup Time: <200 μ s

Dropout time: <8 ms (typical)

Breaking Capacity: 10 A 10,000 operations

48 and 125 V (L/R = 40 ms)

250 V (L/R = 20 ms)

Cyclic Capacity: 10 A 4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation

48 and 125 V (L/R = 40 ms)

250 V (L/R = 20 ms)

Note: Fast high-current interrupting output contacts are not polarity-dependent.See *Appendix J* for further details.**Optoisolated****Input Ratings****Standard fixed inputs:**

250 Vdc: Pickup 200–300 Vdc; dropout 150 Vdc

125 Vdc: Pickup 105–150 Vdc; dropout 75 Vdc

48 Vdc: Pickup 38.4–60 Vdc; dropout 28.8 Vdc

24 Vdc: Pickup 15.0–30 Vdc

Fixed level-sensitive inputs:

250 Vdc: On for 200–300 Vdc; off below 150 Vdc

125 Vdc: On for 105–150 Vdc; off below 75 Vdc

48 Vdc: On for 38.4–60 Vdc; off below 28.8 Vdc

Note: Nominal input current is 4 mA**Time-Code Input**

Relay accepts demodulated IRIG-B time-code input

Communications

Two rear-panel and one front-panel EIA-232 serial communications ports.

Terminal Connections	Rear Screw-Terminal Tightening Torque: Terminal Block Minimum: 8-in-lb (0.9 Nm) Maximum: 12-in-lb (1.4 Nm) Connectorized Minimum: 4.4-in-lb (0.5 Nm) Maximum: 8.8-in-lb (1 Nm)
	Note: Terminals or stranded copper wire. Ring terminals are recommended. Minimum temperature rating of 105°C.
Power Supply	Rated: 125/250 Vdc or Vac Range: 85–350 Vdc or 85–264 Vac Burden: < 25 W
	Rated: 48/125 Vdc or 125 Vac Range: 38–200 Vdc or 85–140 Vac Burden: < 25 W
	Rated: 24/48 Vdc Range: 18–60 Vdc polarity-dependent Burden: < 25 W
Dimensions	One I/O Board: 5.22" H x 19" W x 11.66" D (133 mm x 483 mm x 296 mm) Two I/O Boards: 6.97" H x 19" W x 11.66" D (177 mm x 483 mm x 296 mm)
Dielectric Strength	V, I inputs: 2500 Vac for 10 seconds Other: 3000 Vdc for 10 seconds (excludes EIA-232)
Operating Temp.	-40° to 185°F (-40° to +85°C)
Environment	IEC 68-2-30 Temperature/Humidity Cycle Test—six day (type tested)
Interference Tests	IEEE C37.90 SWC Test (type tested) IEC 255-22-1 1 MHz Burst Disturbance (type tested) IEC 801-4 Electrical Fast Transient/Burst (type tested)
Emissions	Canada ICES-001 (A) / NMB-001 (A)
Impulse Tests	IEC 255-5 0.5 joule 5000 volt test (type tested)
RFI Tests	IEEE C37.90.2 IEEE Trial-Use Standard, Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers. 10 V/M.
	<u>Exceptions:</u> 5.2.2 (2) Performed with 200 frequency steps per octave 5.5.3 <i>Digital Equipment Modulation Test</i> not performed 5.5.4 Test signal turned off between frequency steps to simulate keying
	IEC 255-22-3 Radiated EMI Test (type tested)
	<u>Exception:</u> 4.3.2.2 Frequency sweep approximated with 200 frequency steps per octave

Vibration and Shock Test ***IEC 255-21-1*** and ***-2***, Class 1 Test (type tested)

Exception:

4.1.4 Vibration Response Amplitude Tolerance increased to $\pm 25\%$
(Two I/O board version—rear-panel plug-in connectors option only)

ESD Test ***IEC 801-2*** Electrostatic Discharge Test (type tested)
Security Level: 3

Weight One I/O Board: 20 lb (9.1 kg); shipping weight 32 lb (14.5 kg)
Two I/O Boards: 26.5 lb (12 kg); shipping weight 40.6 lb (18.5 kg)

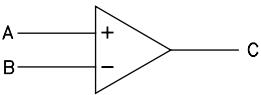
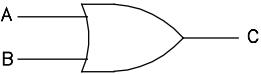
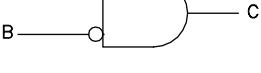
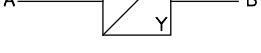
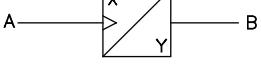
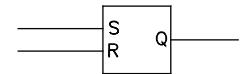
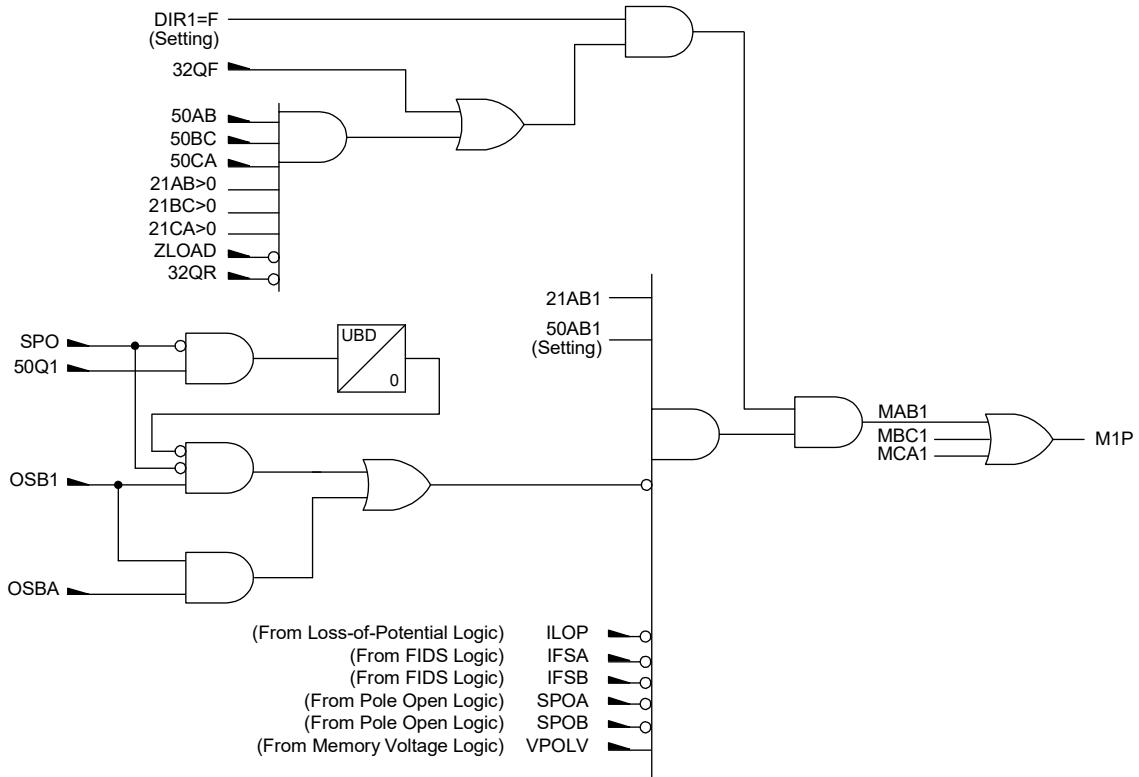
NAME	SYMBOL	FUNCTION
COMPARATOR		Input A is compared to input B. Output C asserts if A is greater than B.
INPUT FLAG		Input A comes from other logic.
OR		Either input A or input B asserted cause output C to assert.
EXCLUSIVE OR		If A or B are asserted, output C is asserted. If A and B are of the same state, C is deasserted.
NOR		If neither A nor B asserts, output C asserts.
AND		Input A and input B must assert to assert output C.
AND W/ INVERTED INPUT		If input A is asserted and input B is deasserted, output C asserts. Inverter "O" inverts any input or output on any gate.
NAND		If A and/or B are deasserted, output C is asserted.
TIME DELAYED PICK UP AND/OR TIME DELAYED DROP OUT		X is a time-delay-pickup value; Y is a time-delay-dropout value. B asserts time X after input A asserts; B will not assert if A does not remain asserted for time X. If X is zero, B will assert when A asserts. If Y is zero, B will deassert when A deasserts.
EDGE TRIGGER TIMER		Rising edge of A starts timers. Output B will assert time X after the rising edge of A. B will remain asserted for time Y. If Y is zero, B will assert for a single processing interval. Input A is ignored while the timers are running.
SET RESET FLIP FLOP		Input S asserts output Q until input R asserts. Output Q deasserts or resets when R asserts.
FALLING EDGE		B asserts at the falling edge of input A.

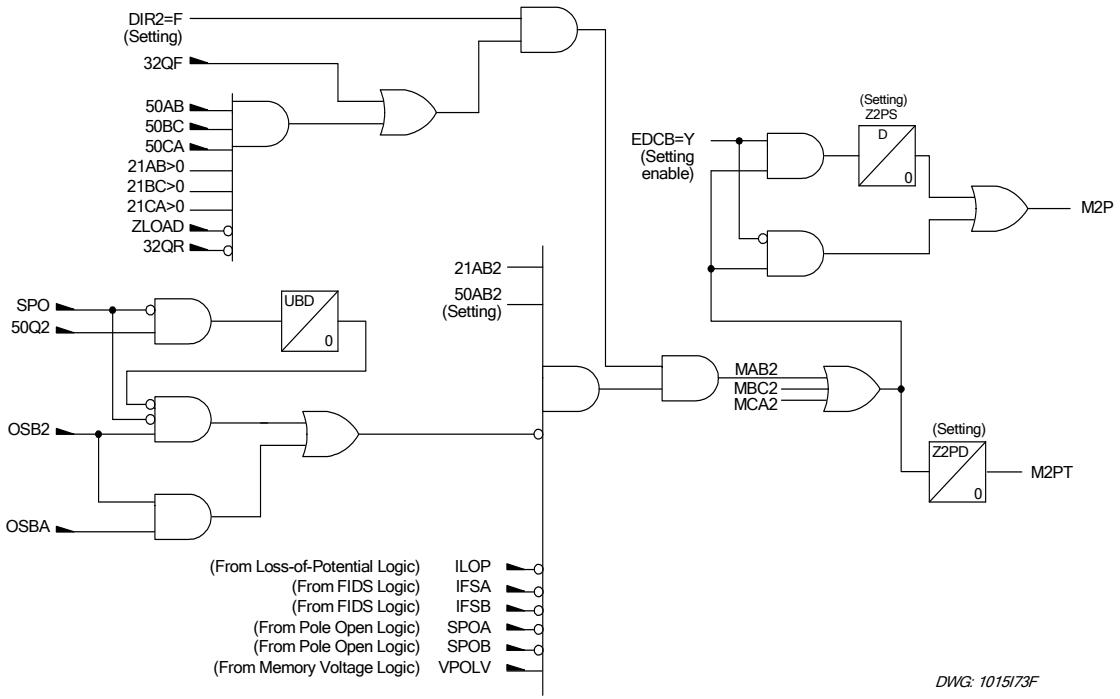
Figure 2.4: Logic Symbol Legend



Note: VPOLV deasserts if the positive-sequence memory voltage expires.

DWG: 1015I73E

Figure 2.5: Zone 1 Mho Phase Distance Element Logic



DWG: 1015I73F

Figure 2.6: Zone 2 Mho Phase Distance Element Logic

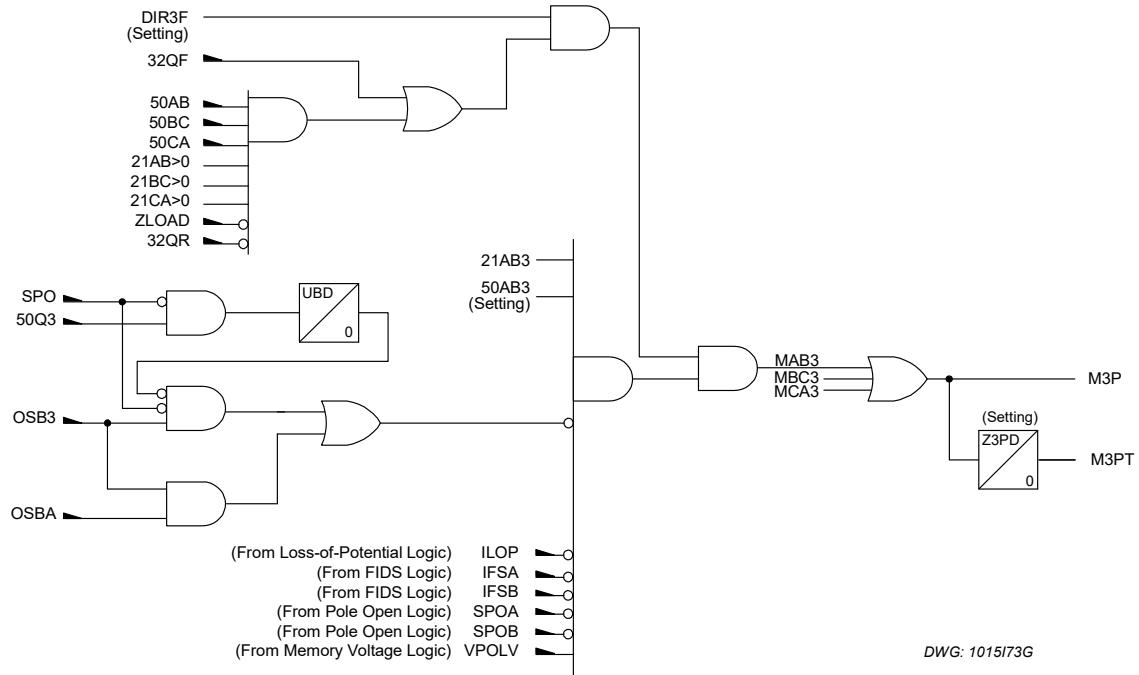


Figure 2.7: Zone 3 Mho Phase Distance Element Logic

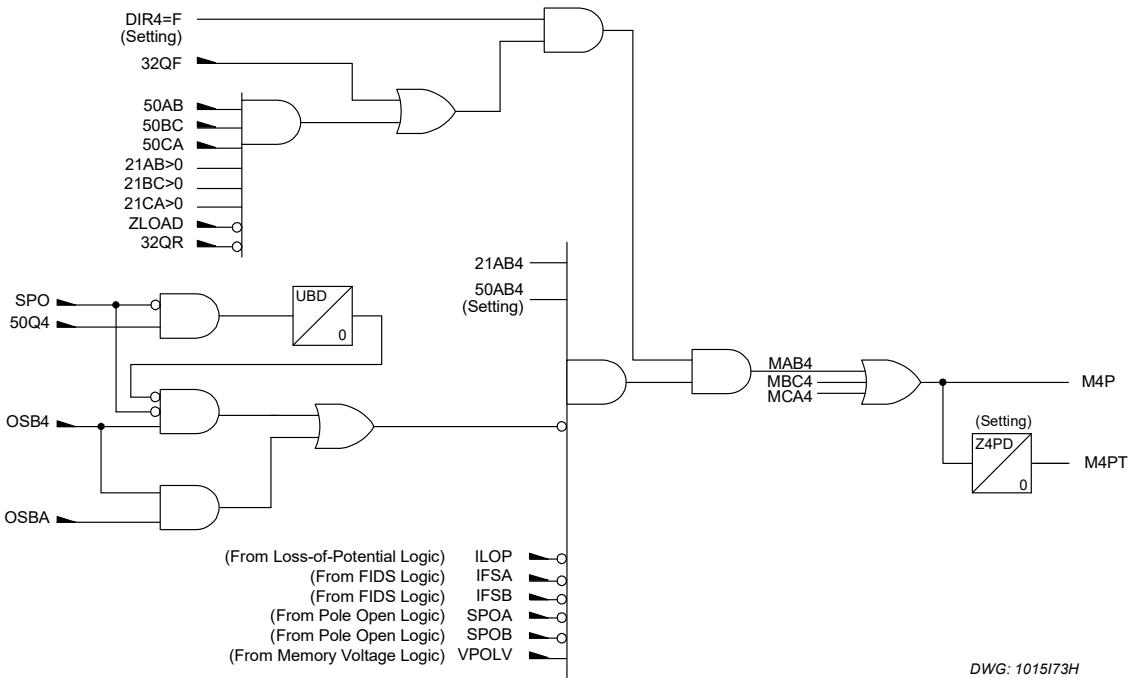
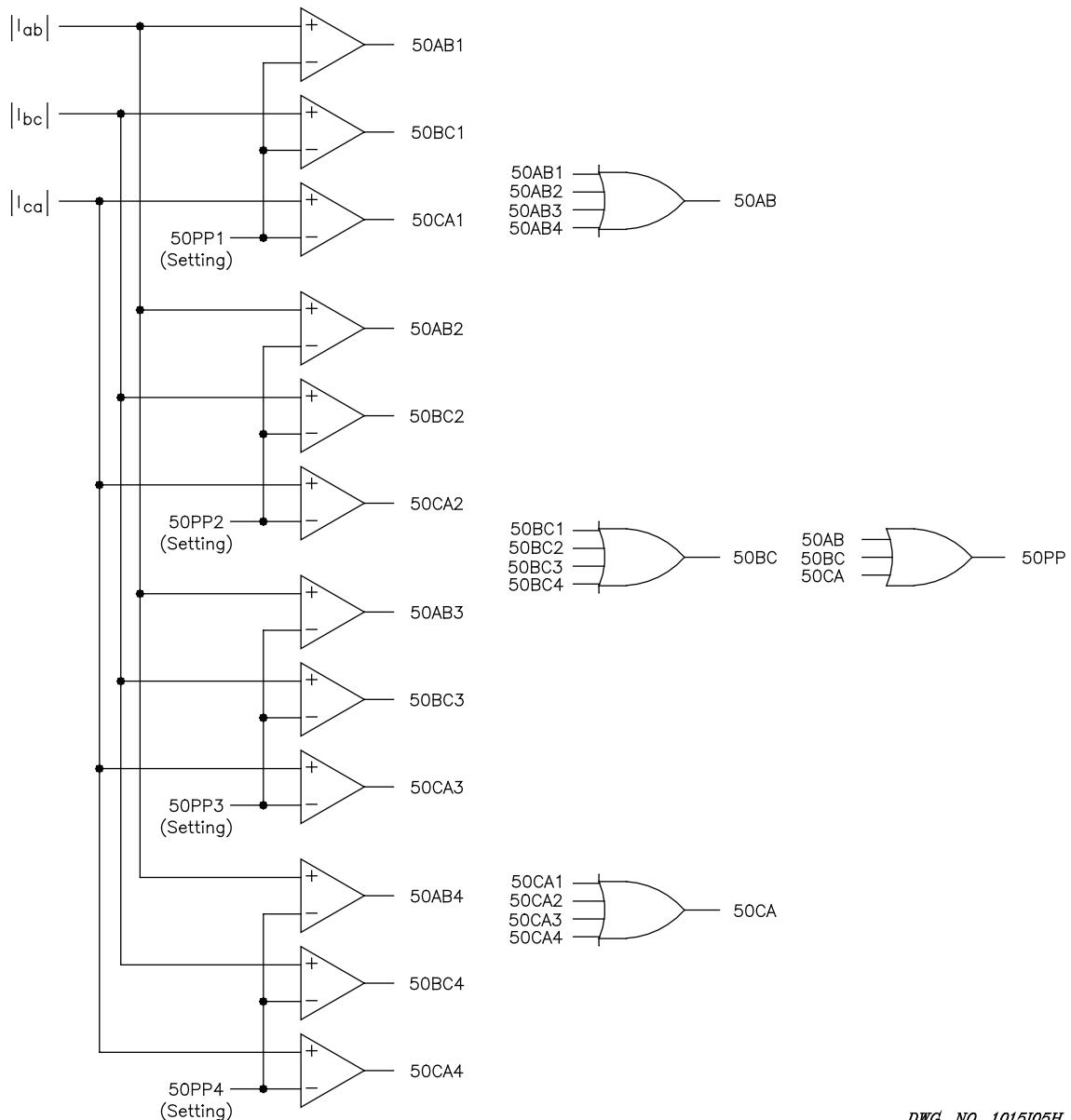


Figure 2.8: Zone 4 Mho Phase Distance Element Logic



DWG. NO. 1015105H

Figure 2.9: Supervisory Phase-to-Phase Overcurrent Elements

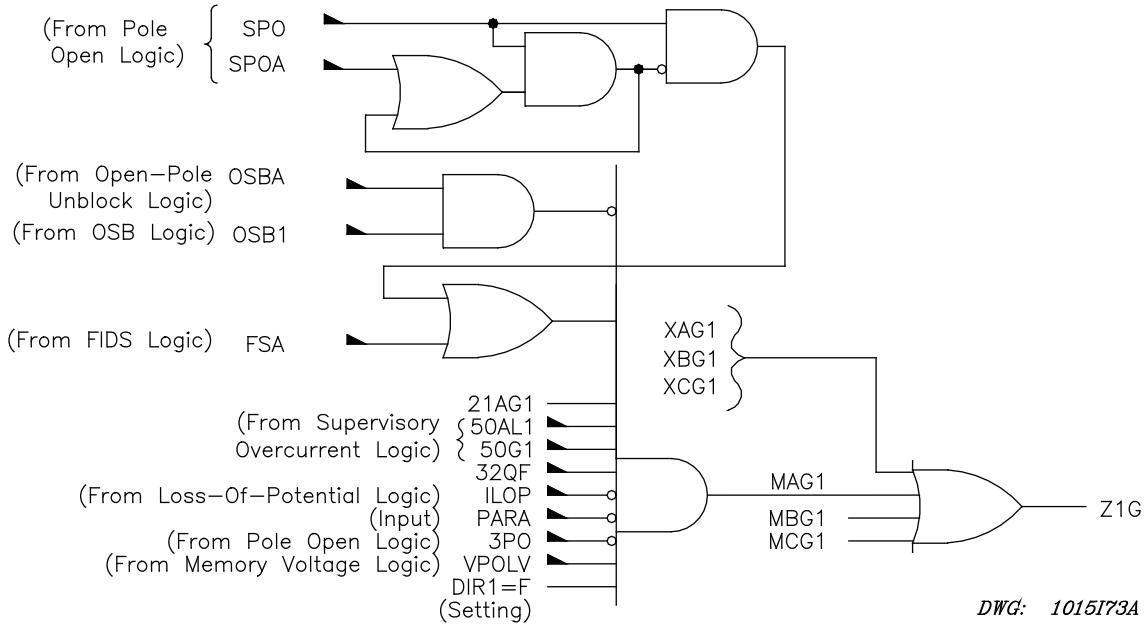


Figure 2.10: Zone 1 Mho Ground Distance Element Logic

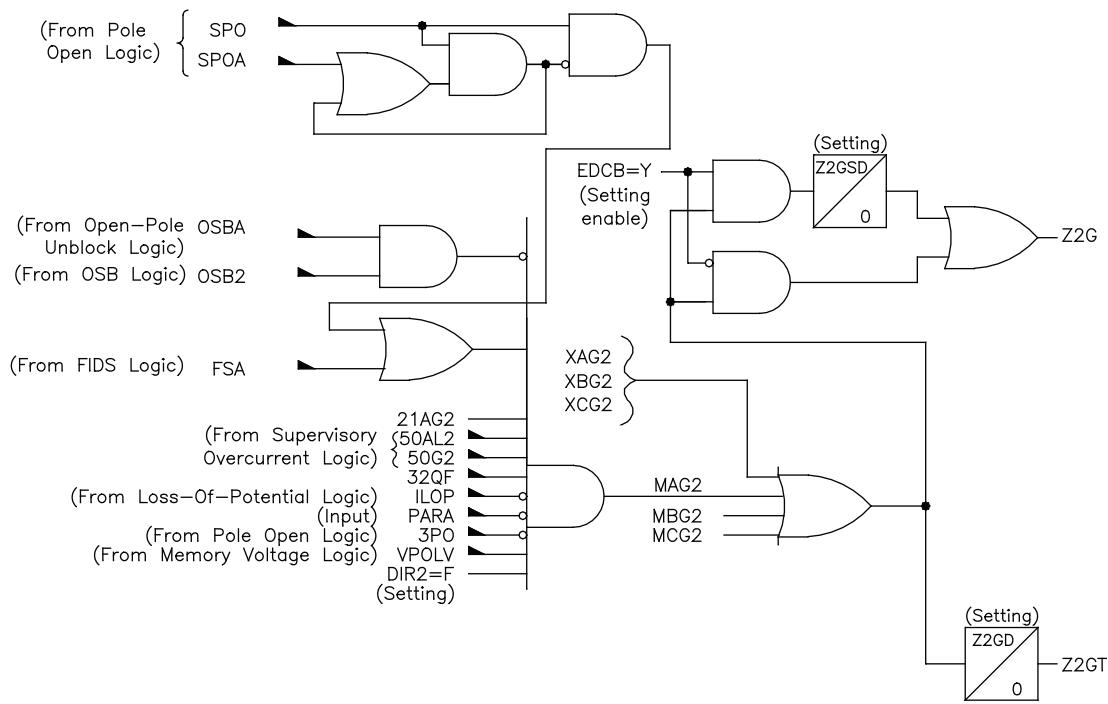
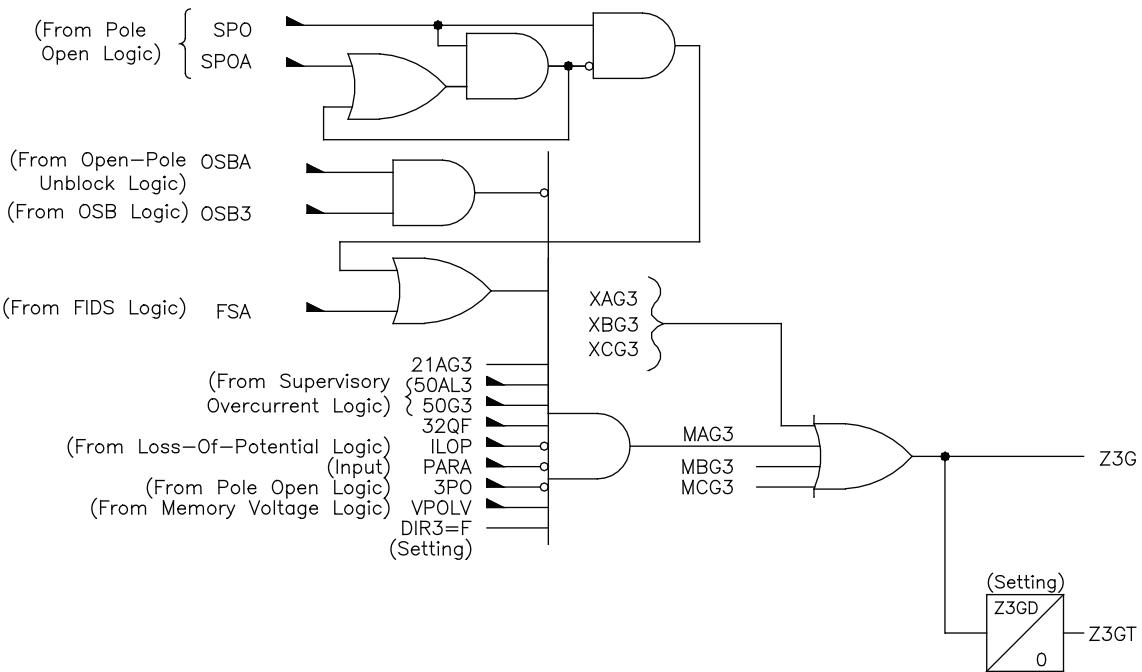
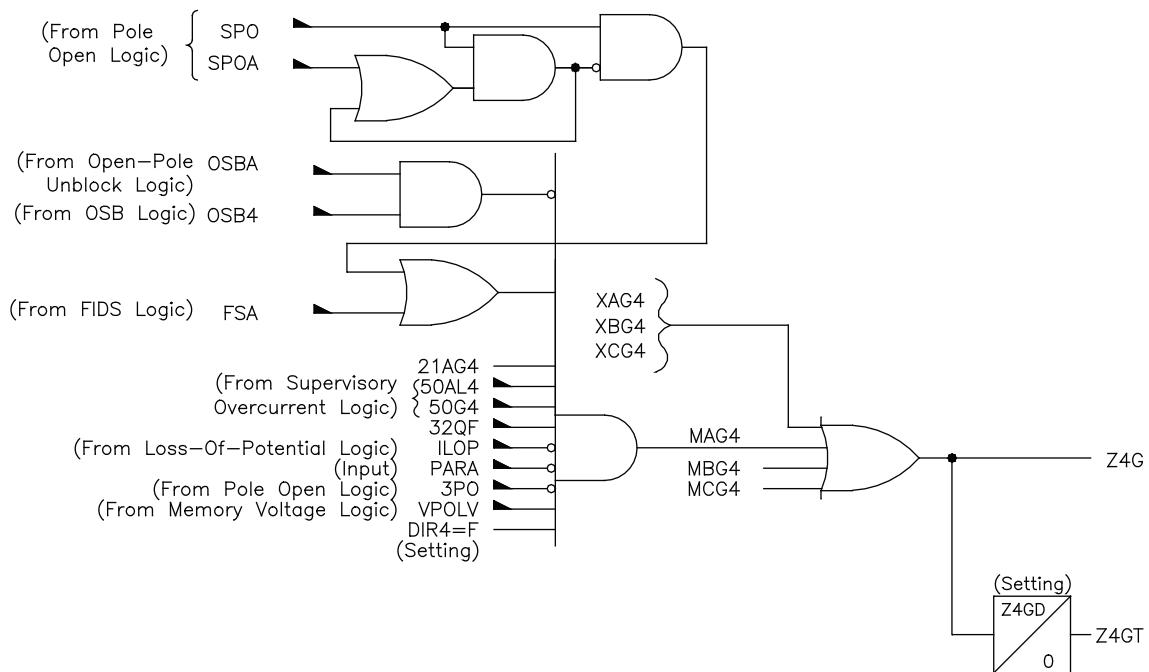


Figure 2.11: Zone 2 Mho Ground Distance Element Logic



DWG: 1015I73C

Figure 2.12: Zone 3 Mho Ground Distance Element Logic



DWG: 1015I73D

Figure 2.13: Zone 4 Mho Ground Distance Element Logic

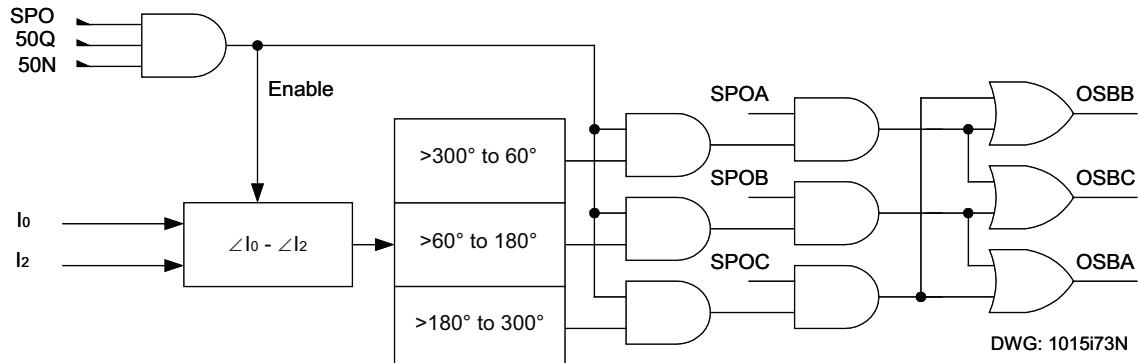


Figure 2.14: Open-Pole Ground Distance OSB Unblock Logic

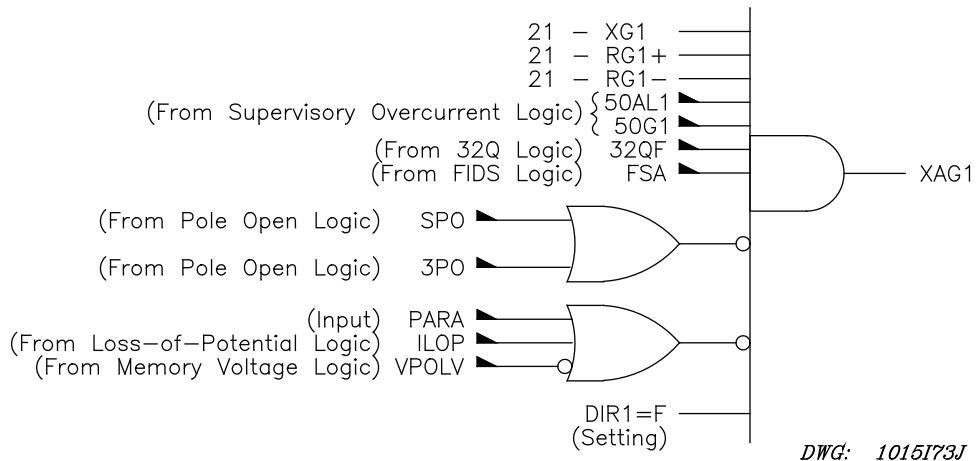


Figure 2.15: Zone 1 Quadrilateral Ground Distance Element Logic

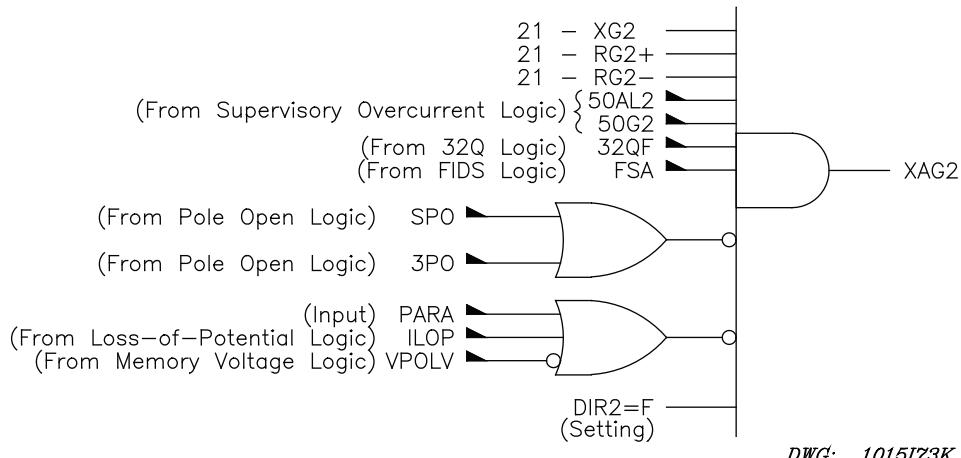


Figure 2.16: Zone 2 Quadrilateral Ground Distance Element Logic

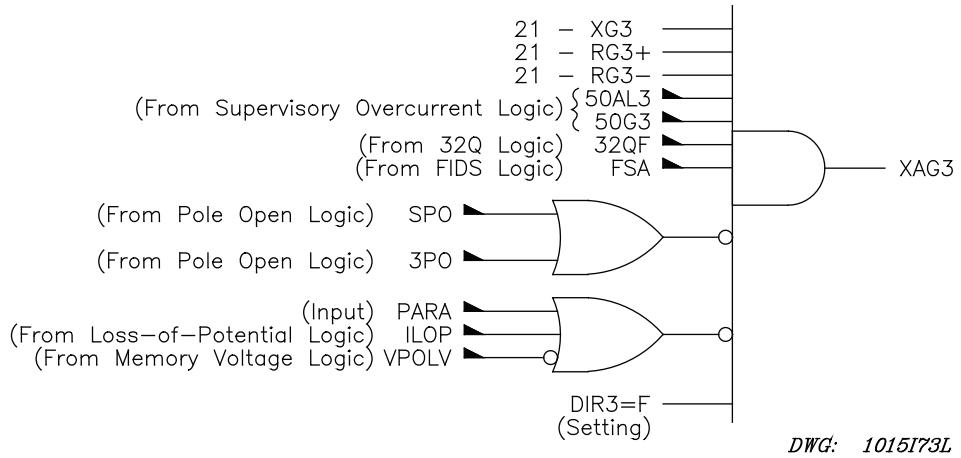


Figure 2.17: Zone 3 Quadrilateral Ground Distance Element Logic

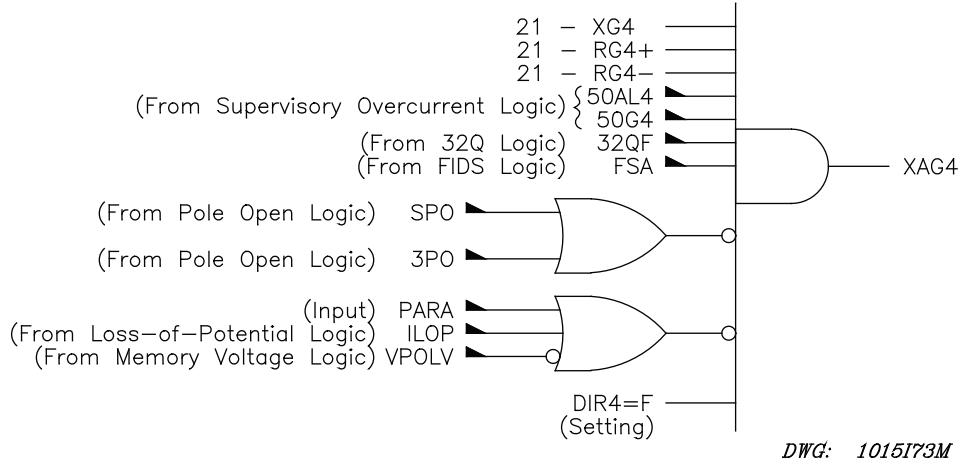


Figure 2.18: Zone 4 Quadrilateral Ground Distance Element Logic

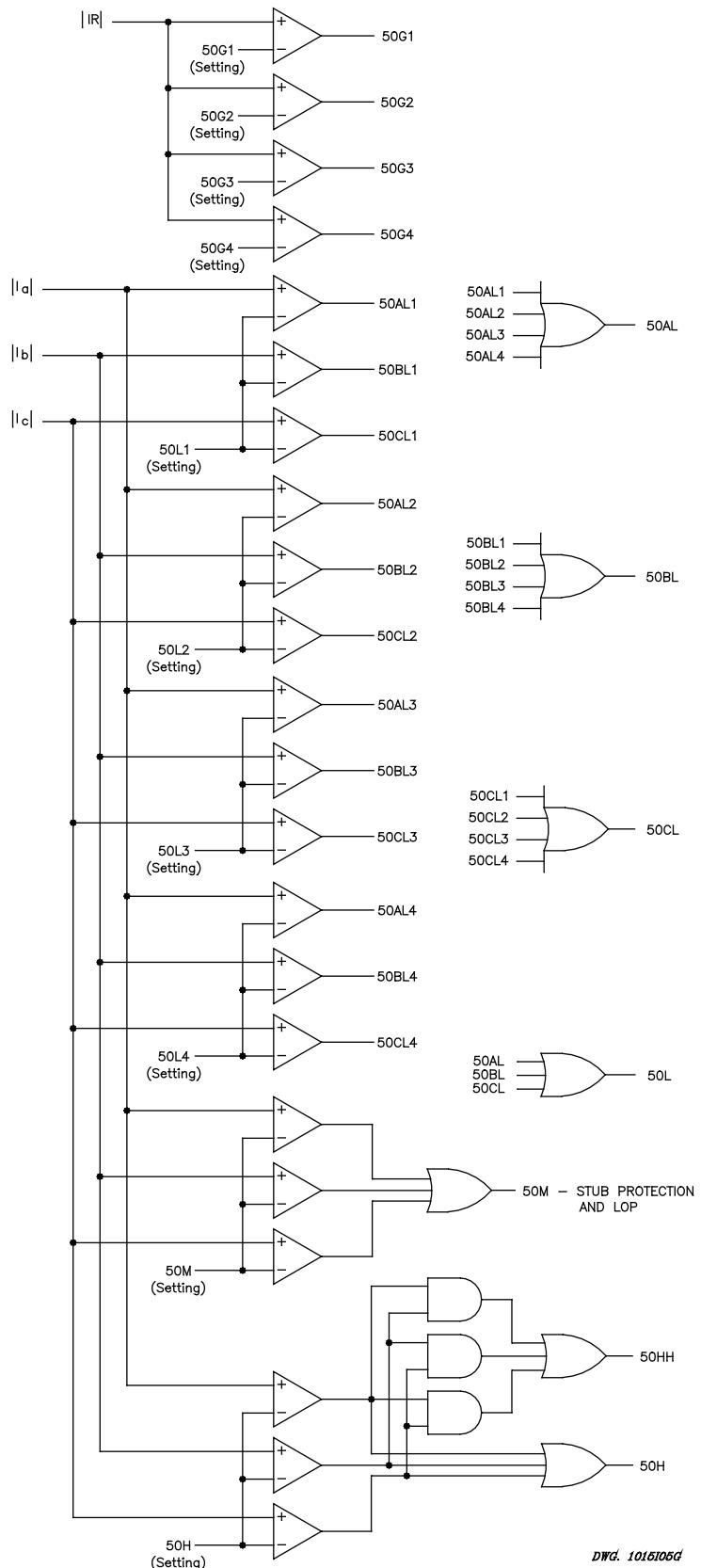


Figure 2.19: Supervisory Phase Overcurrent Elements

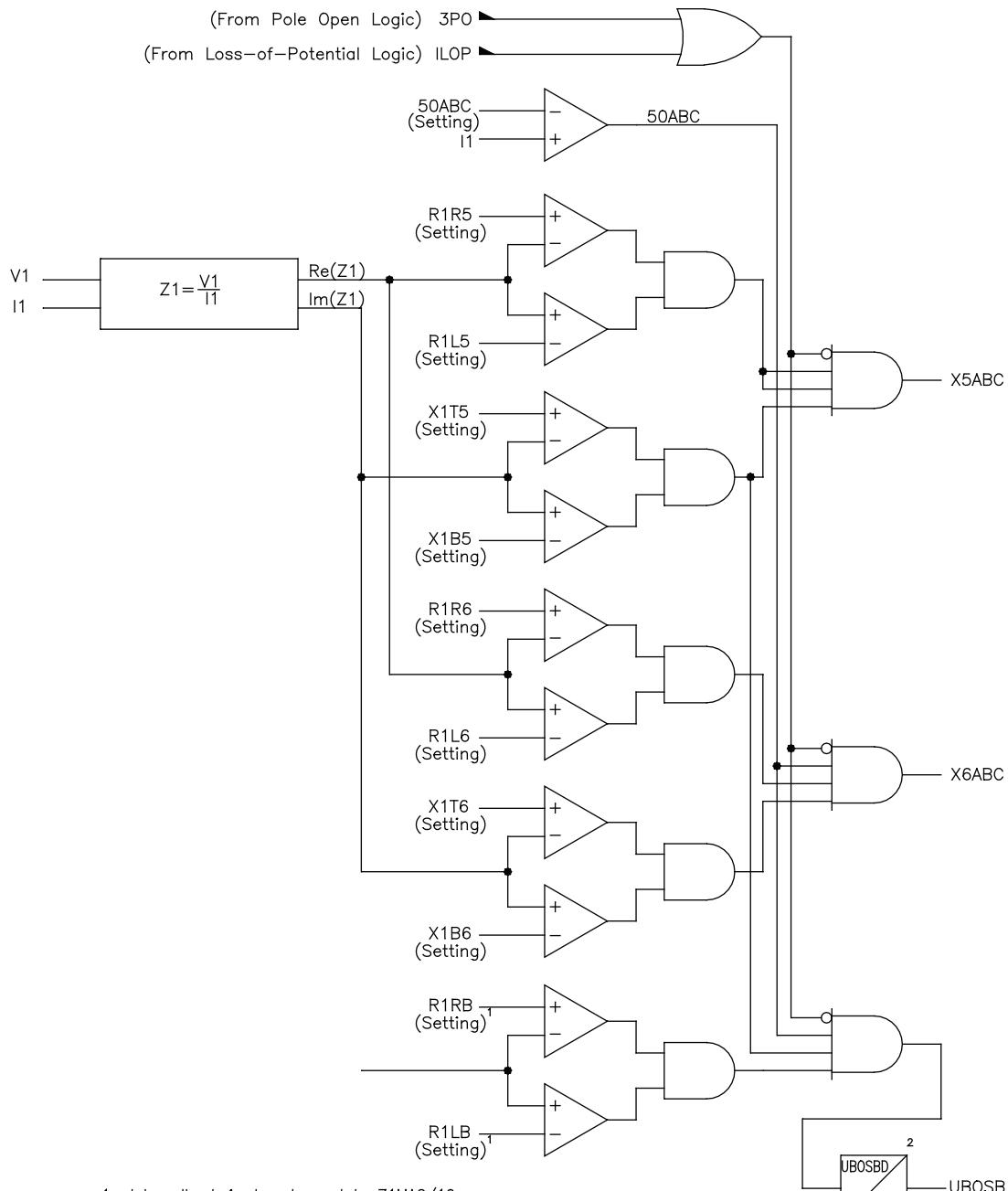


Figure 2.20: Out-of-Step Distance Element Logic

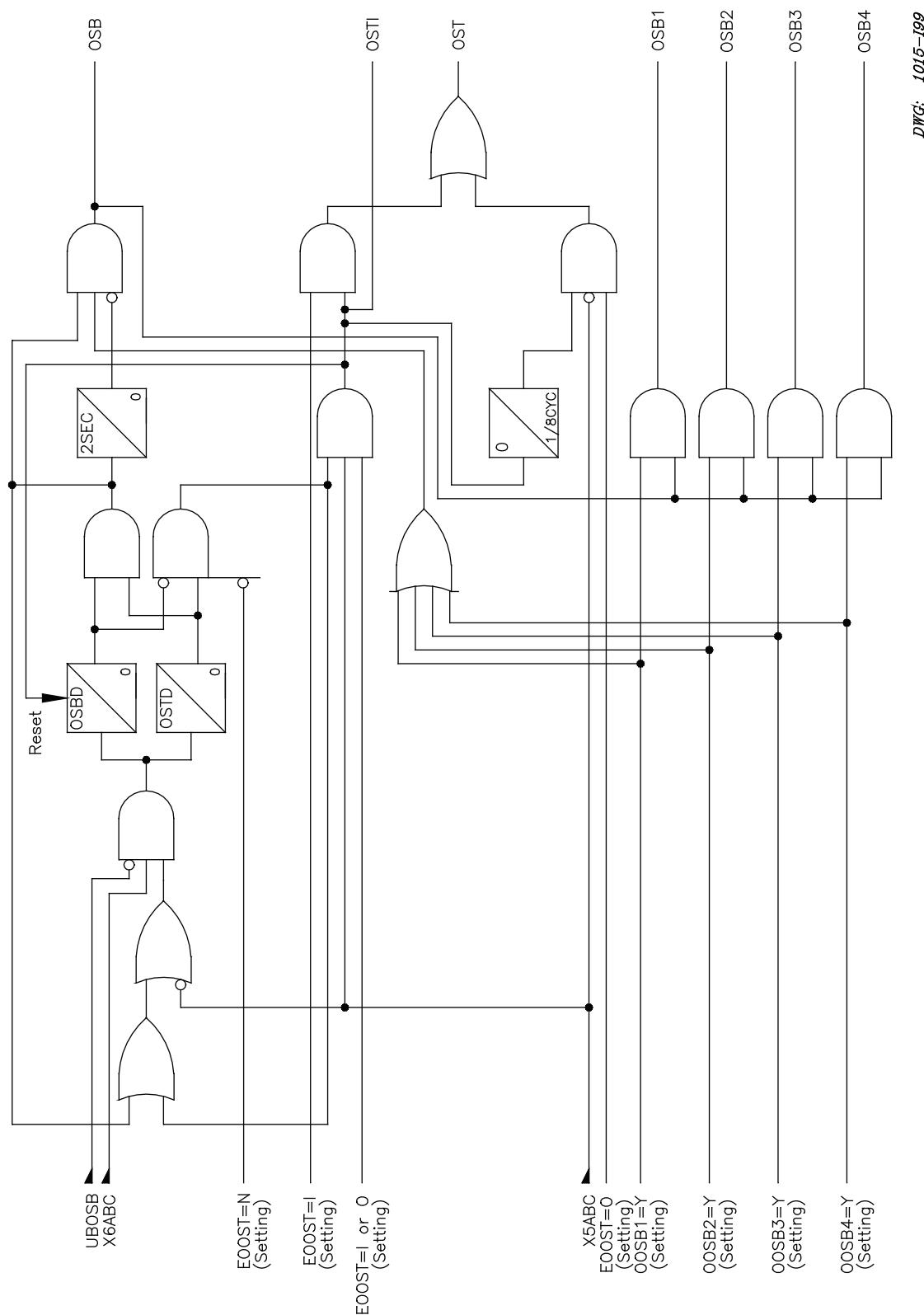


Figure 2.21: Out-of-Step Block and Trip Logic

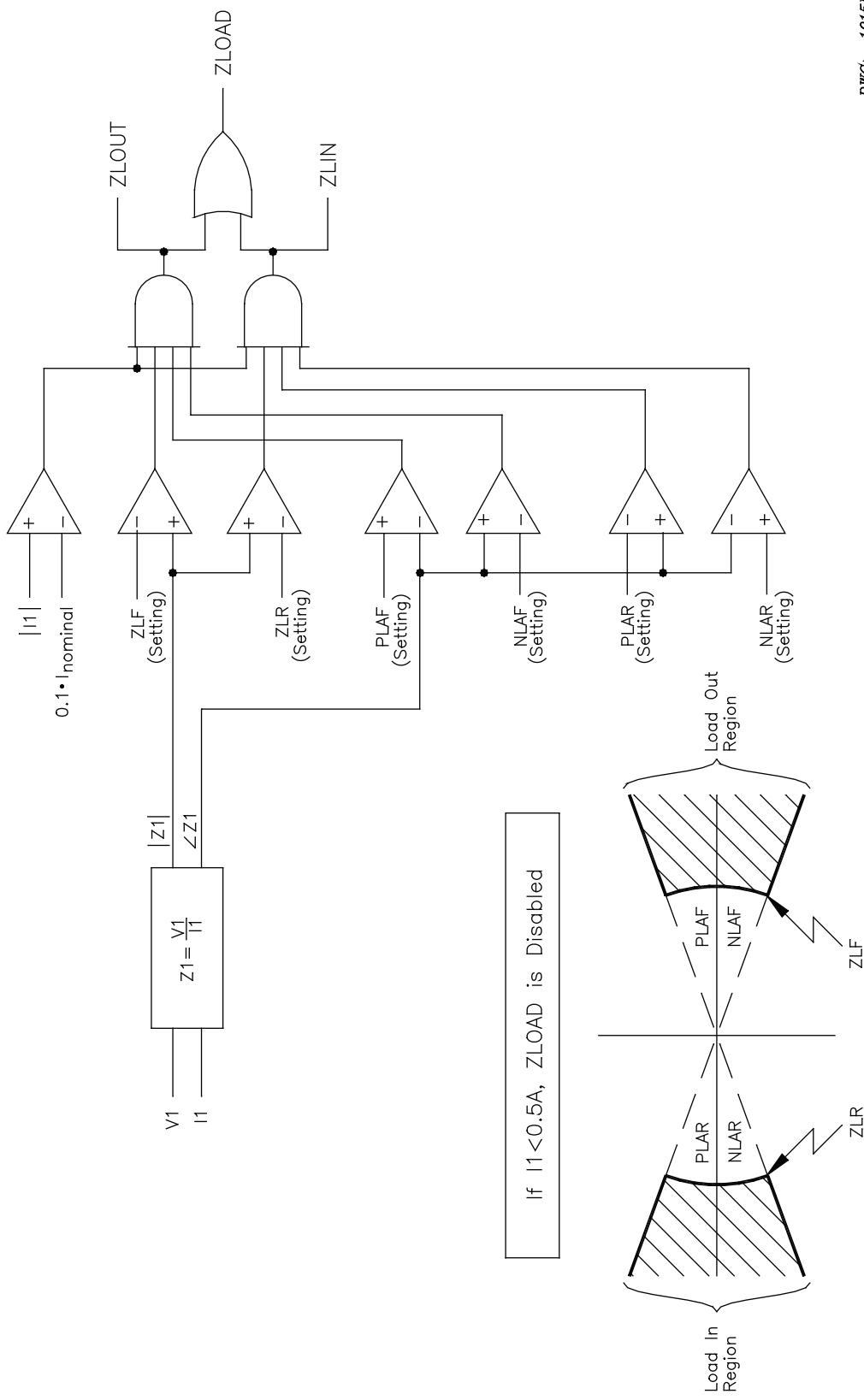


Figure 2.22: Load-Encroachment Logic

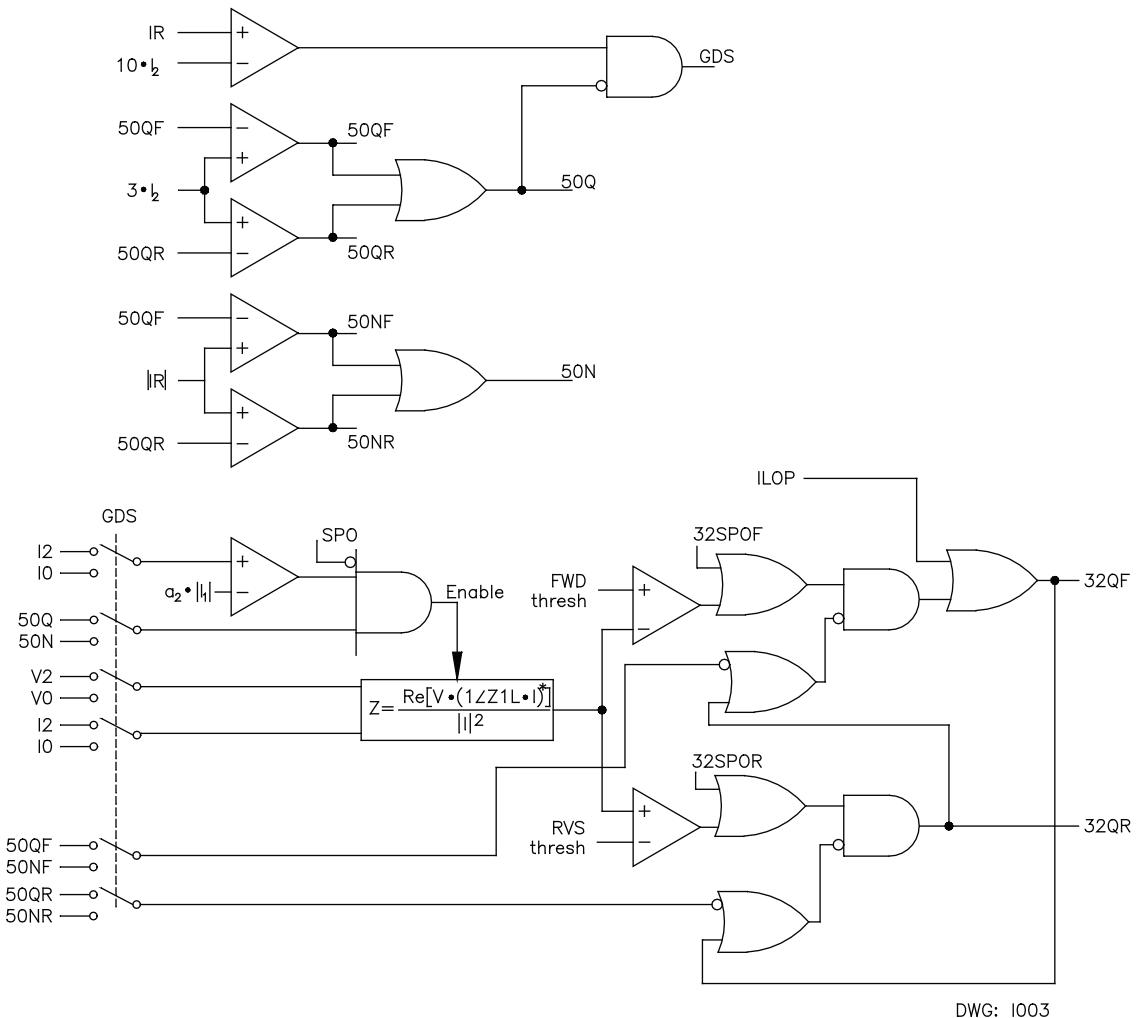


Figure 2.23: Directional Element Logic

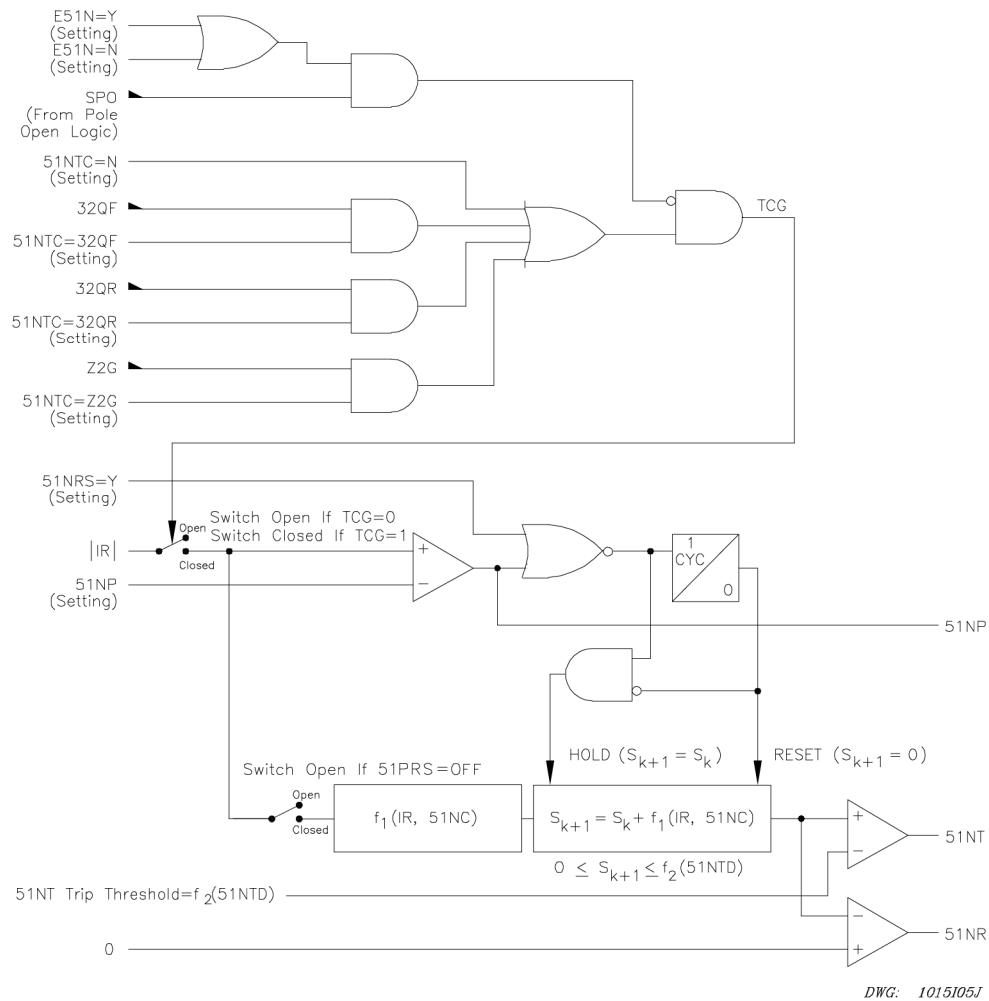


Figure 2.24: Phase Time-Overcurrent Element Logic

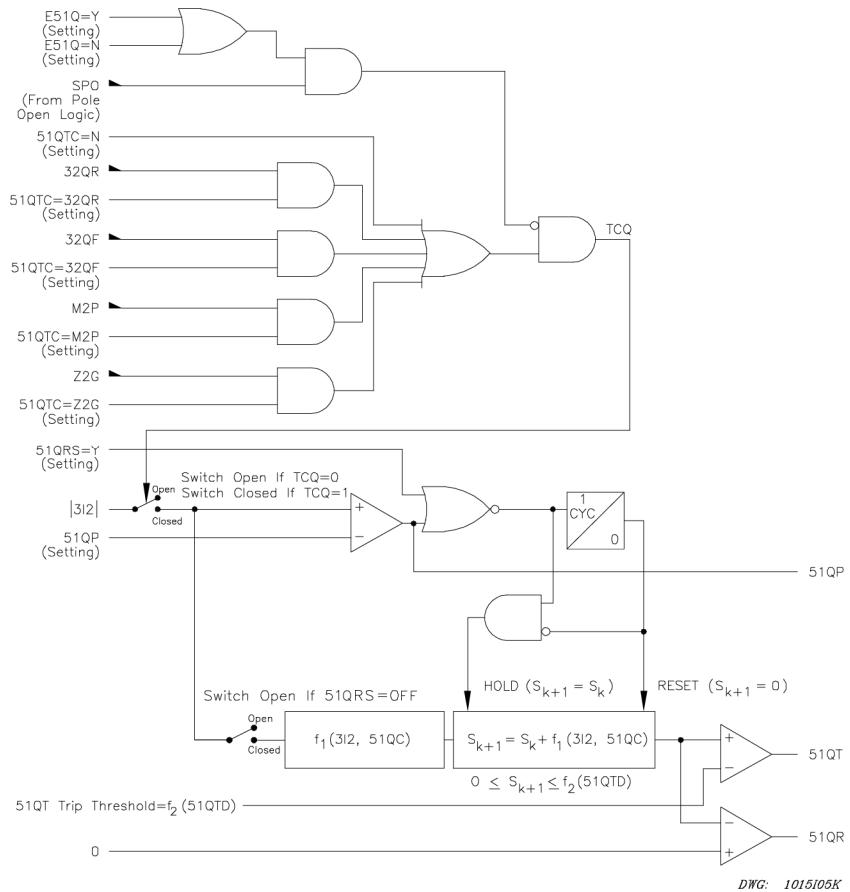


Figure 2.25: Negative-Sequence Time-Overcurrent Element Logic

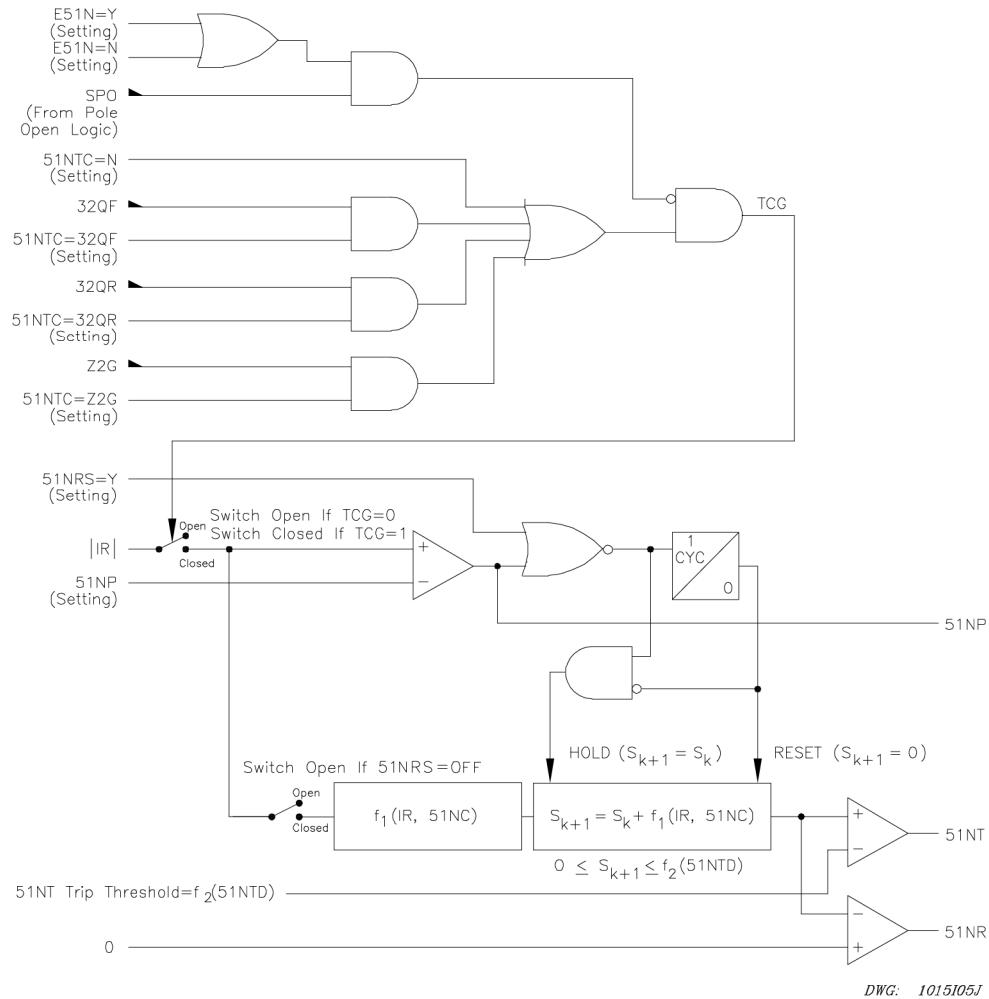
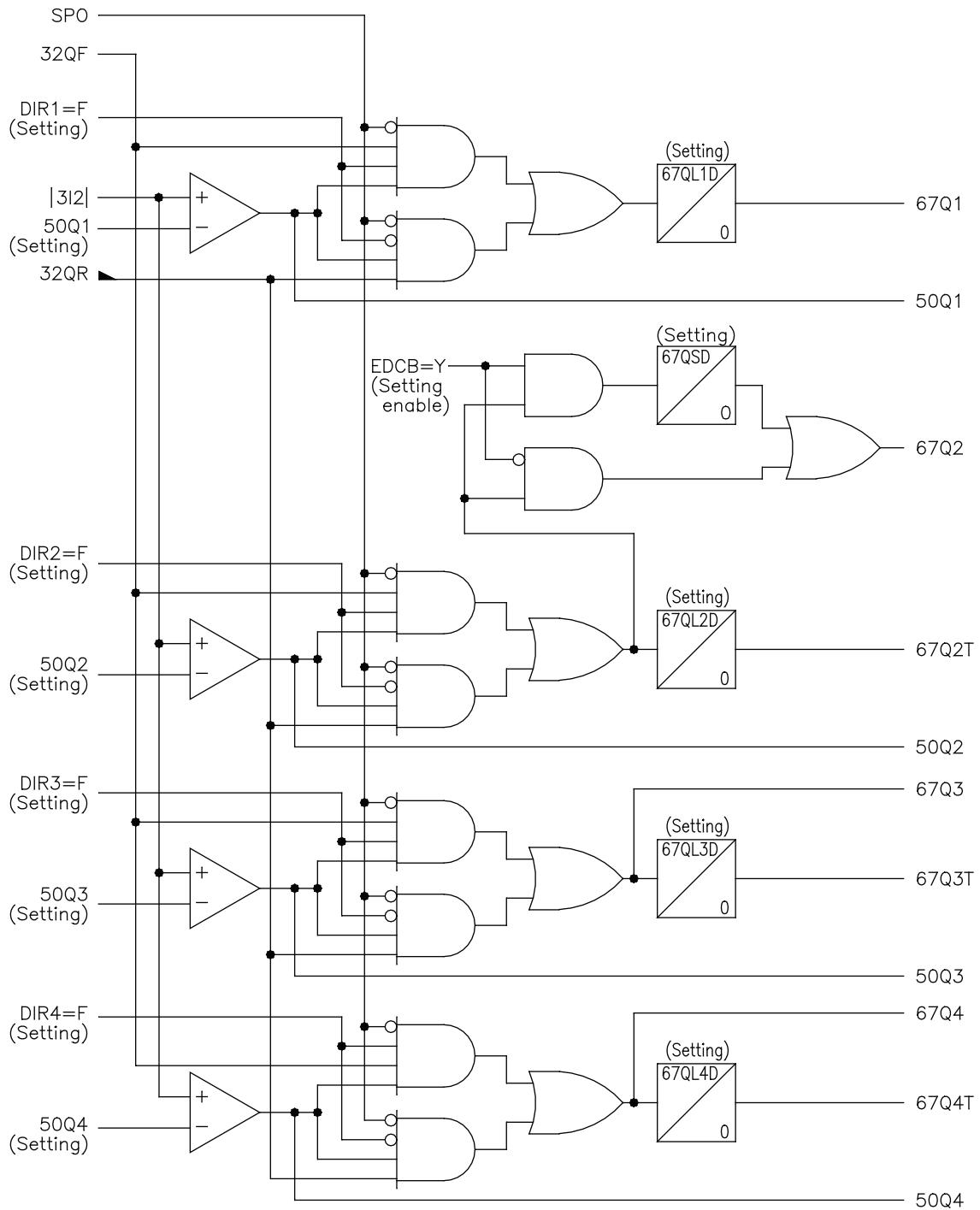
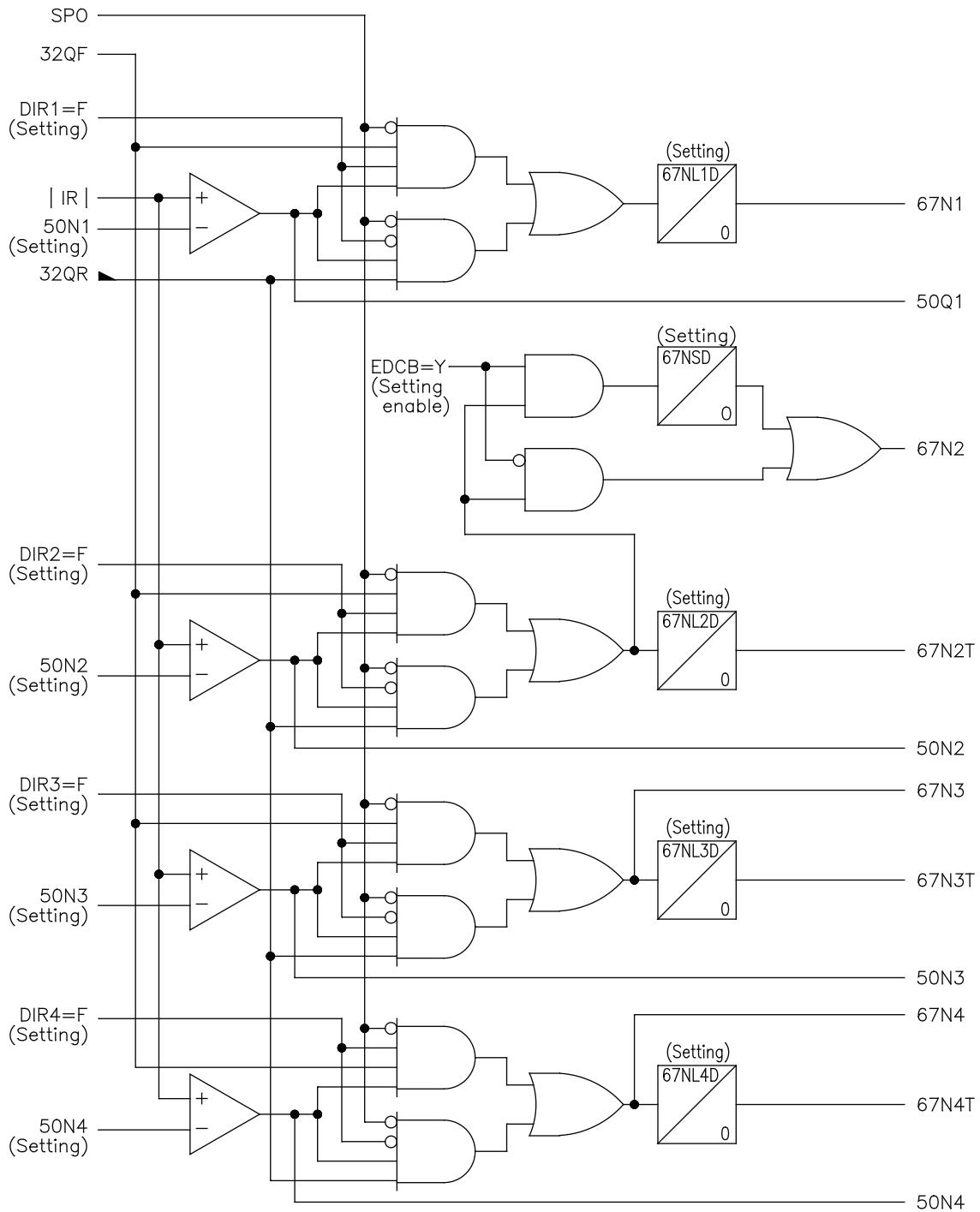


Figure 2.26: Residual Time-Overcurrent Element Logic



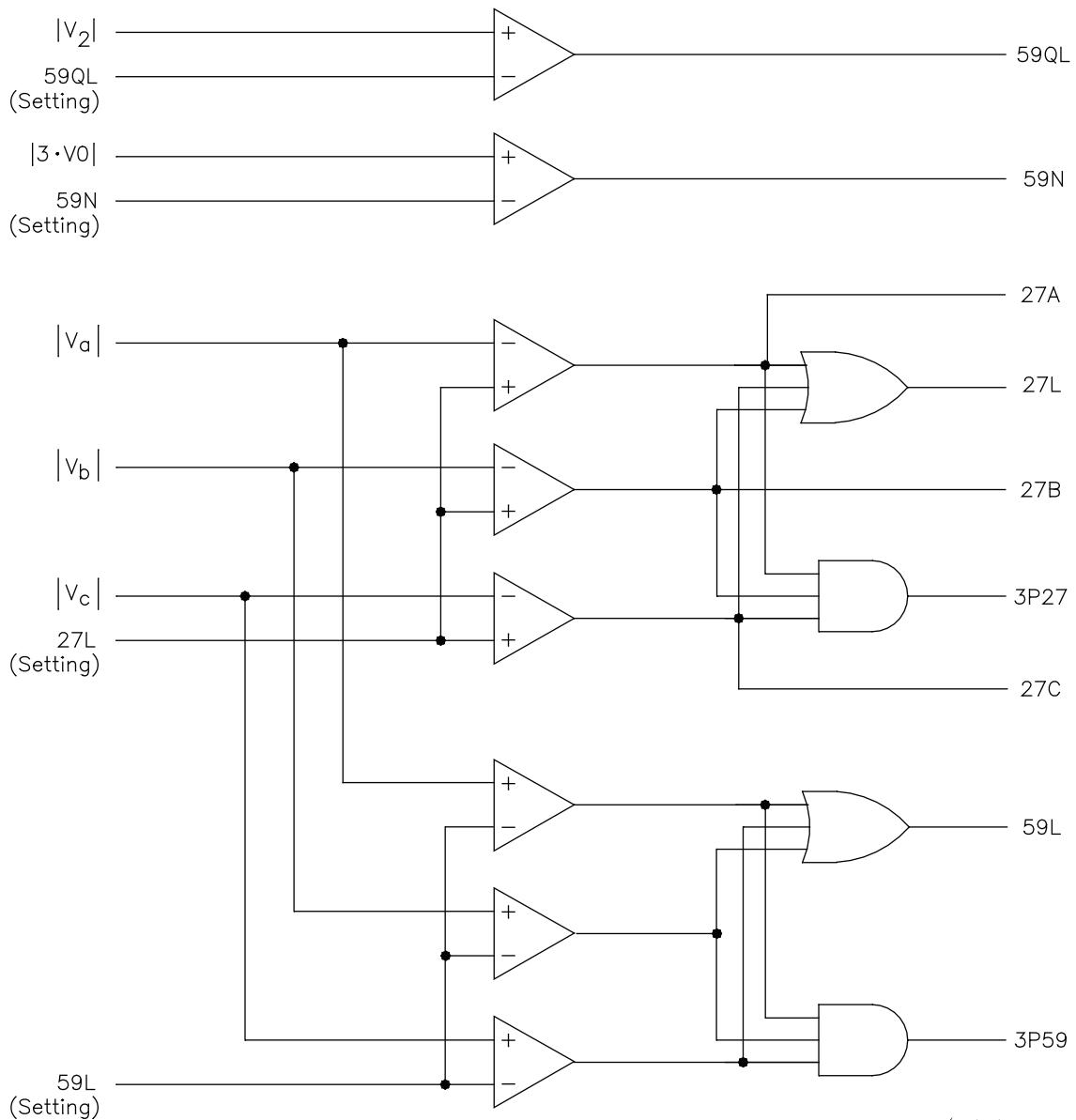
DWG: 1015-I74

Figure 2.27: Negative-Sequence Overcurrent Element Logic for Levels 1-4



DWG: 1015-I76

Figure 2.28: Residual Overcurrent Element Logic for Levels 1–4



DWG. 1015I05F

Figure 2.29: Voltage Element Logic

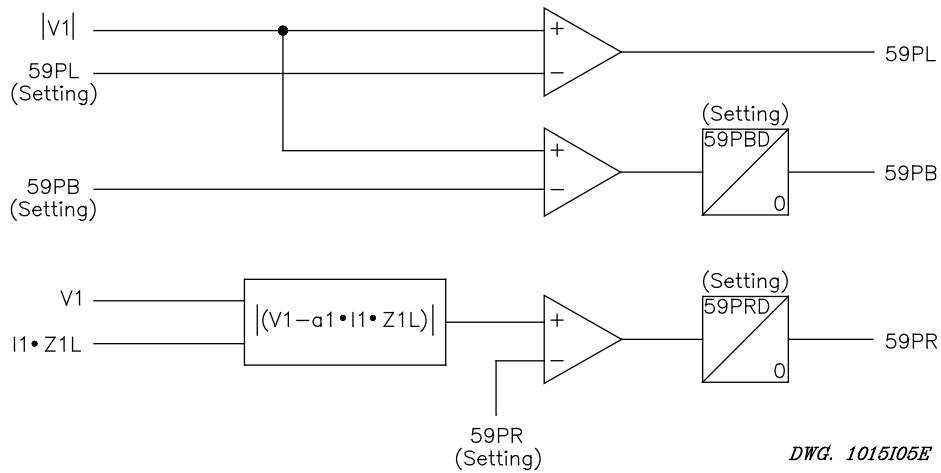


Figure 2.30: Positive-Sequence Overvoltage Element Logic

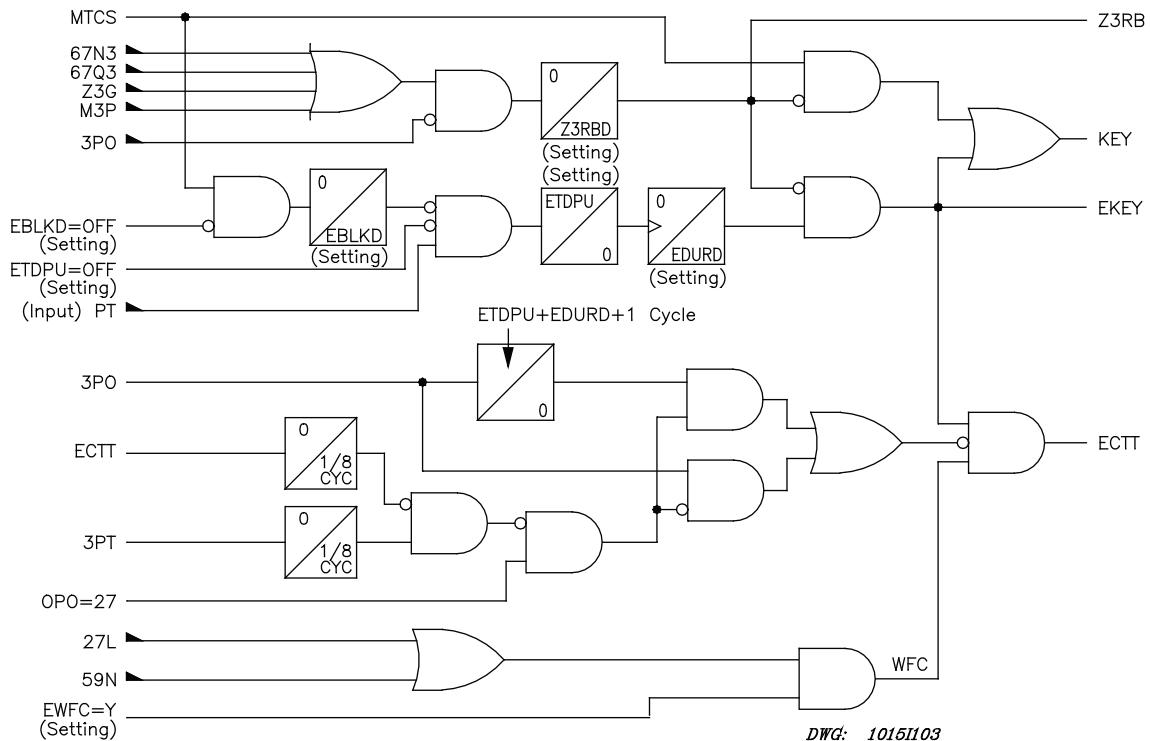


Figure 2.31: Permissive Overreaching Transfer Trip Scheme Logic

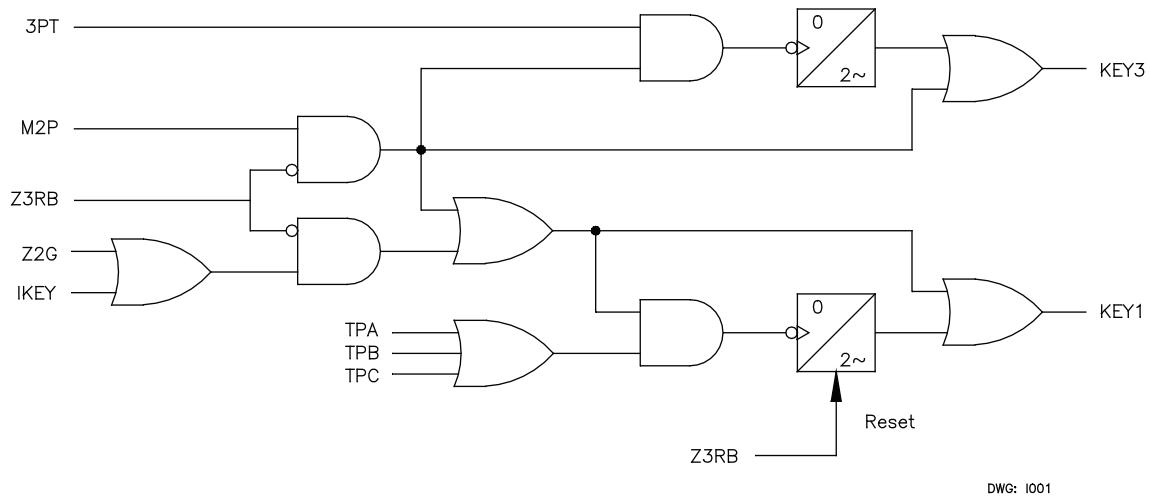


Figure 2.32: POTT Permissive Trip Keying Logic

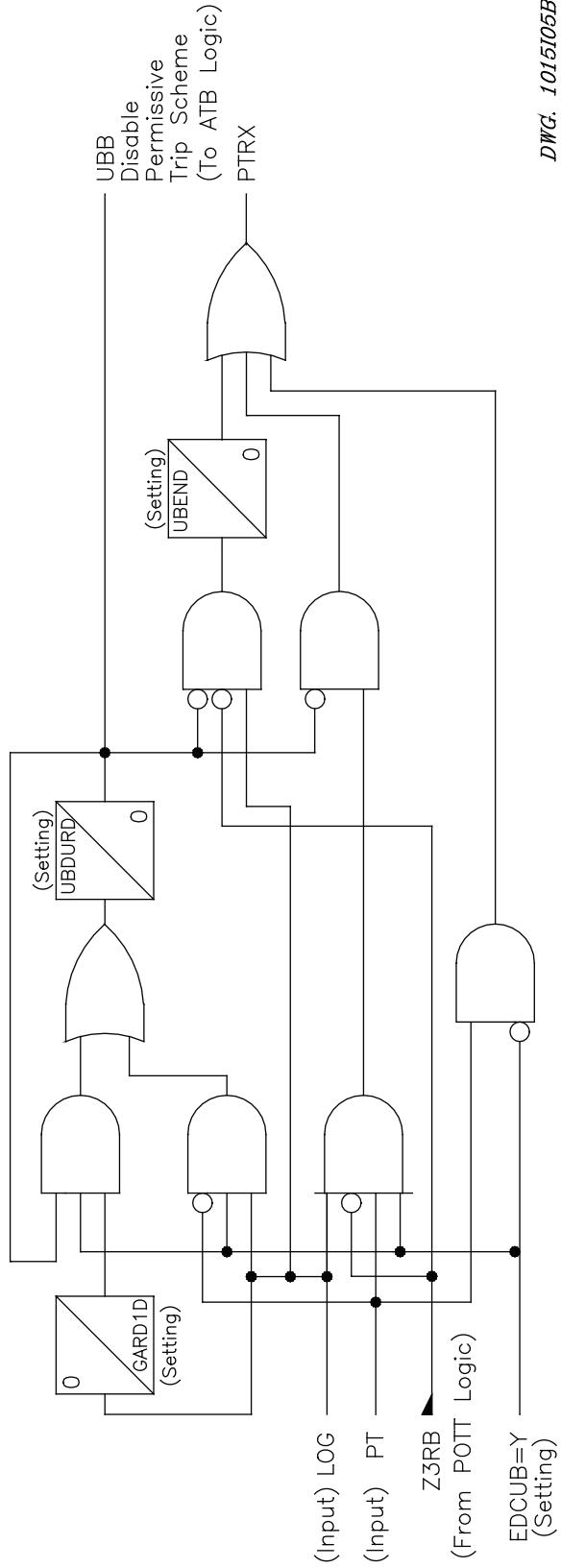
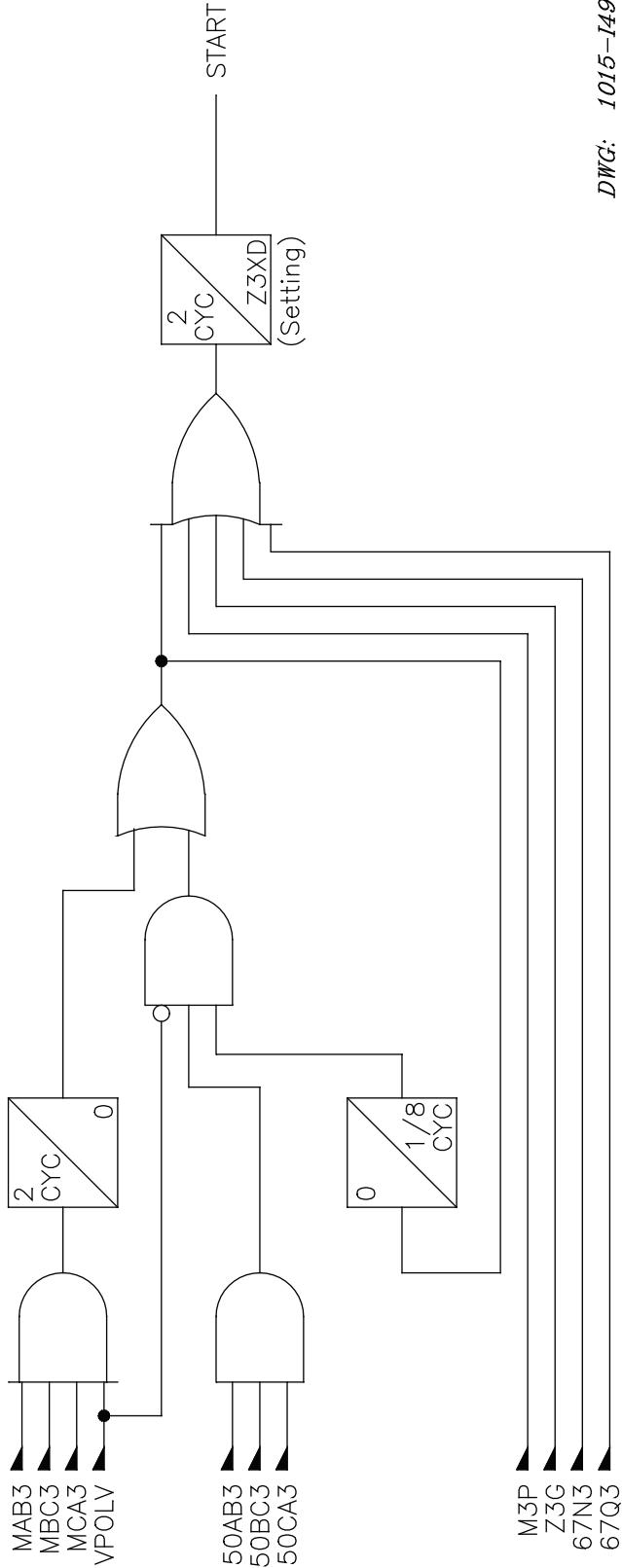


Figure 2.33: Directional Comparison Unblocking Scheme Logic



DWG: 1015-149

Figure 2.34: Directional Comparison Blocking Scheme Logic—1 of 2

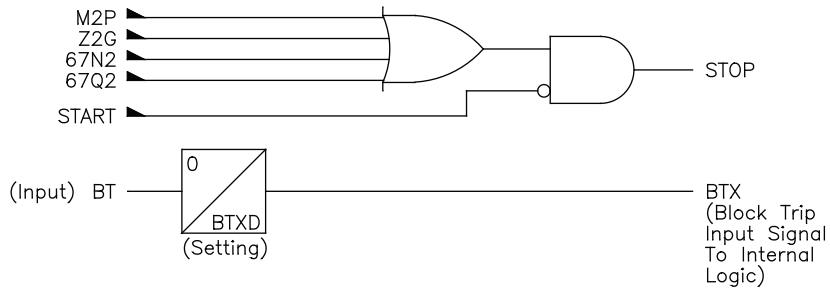


Figure 2.35: Directional Comparison Blocking Scheme Logic—2 of 2

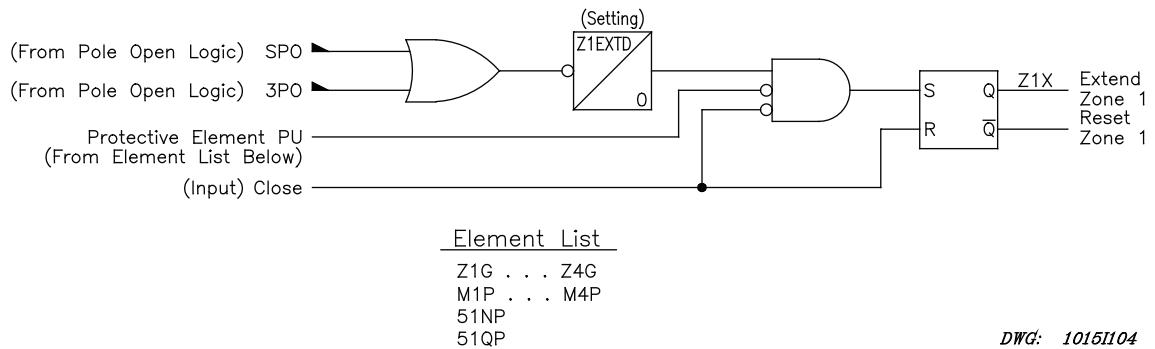


Figure 2.36: Zone 1 Extension Logic

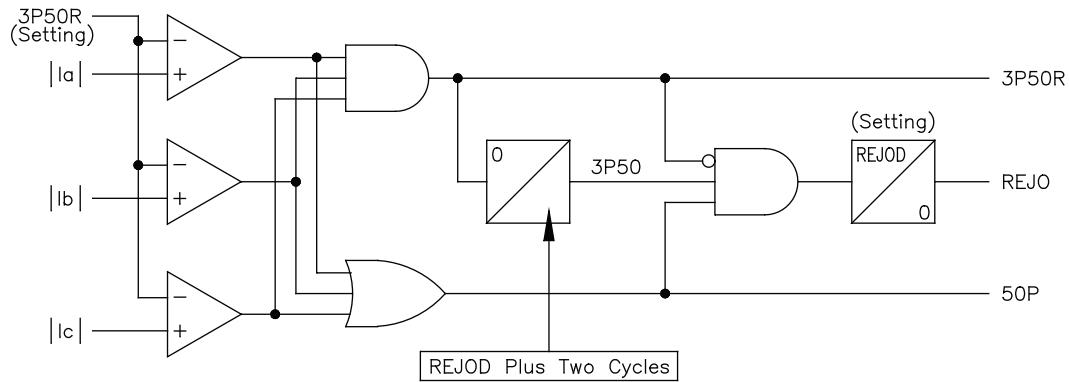


Figure 2.37: Remote-End-Just-Opened Logic

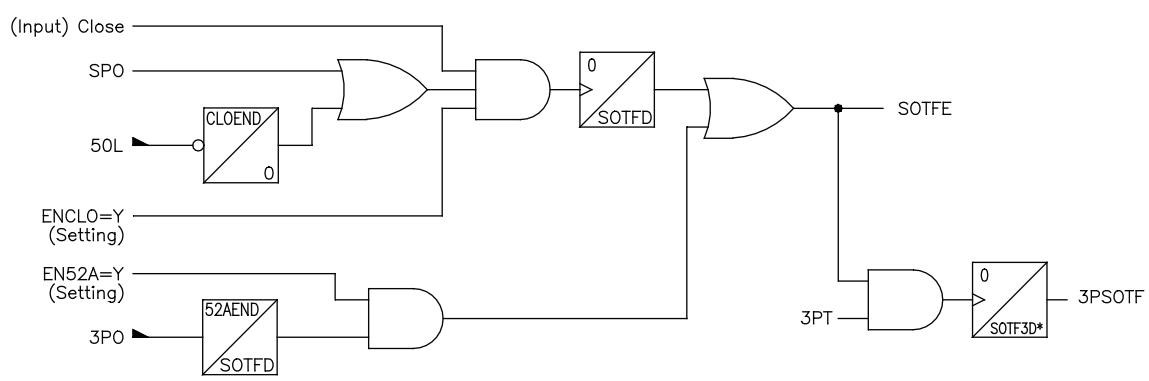


Figure 2.38: Switch-On-to-Fault Enable Logic

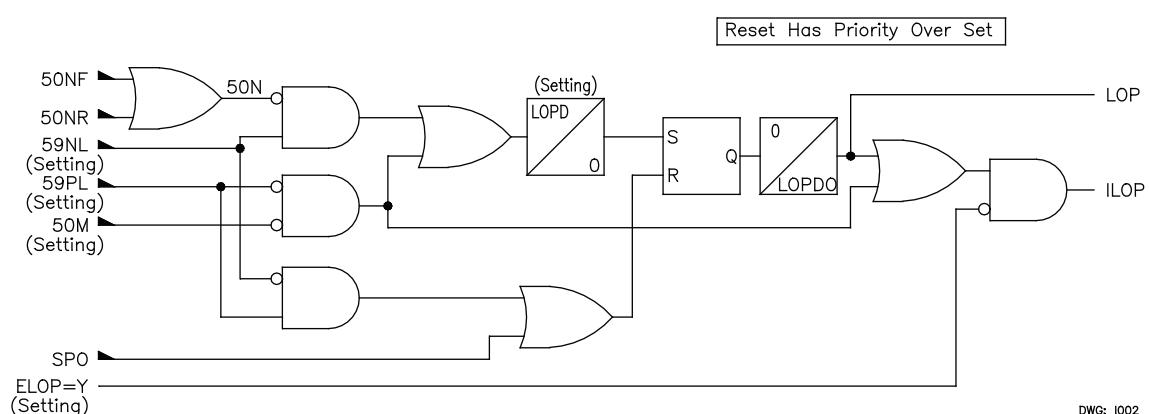


Figure 2.39: Loss-of-Potential Logic

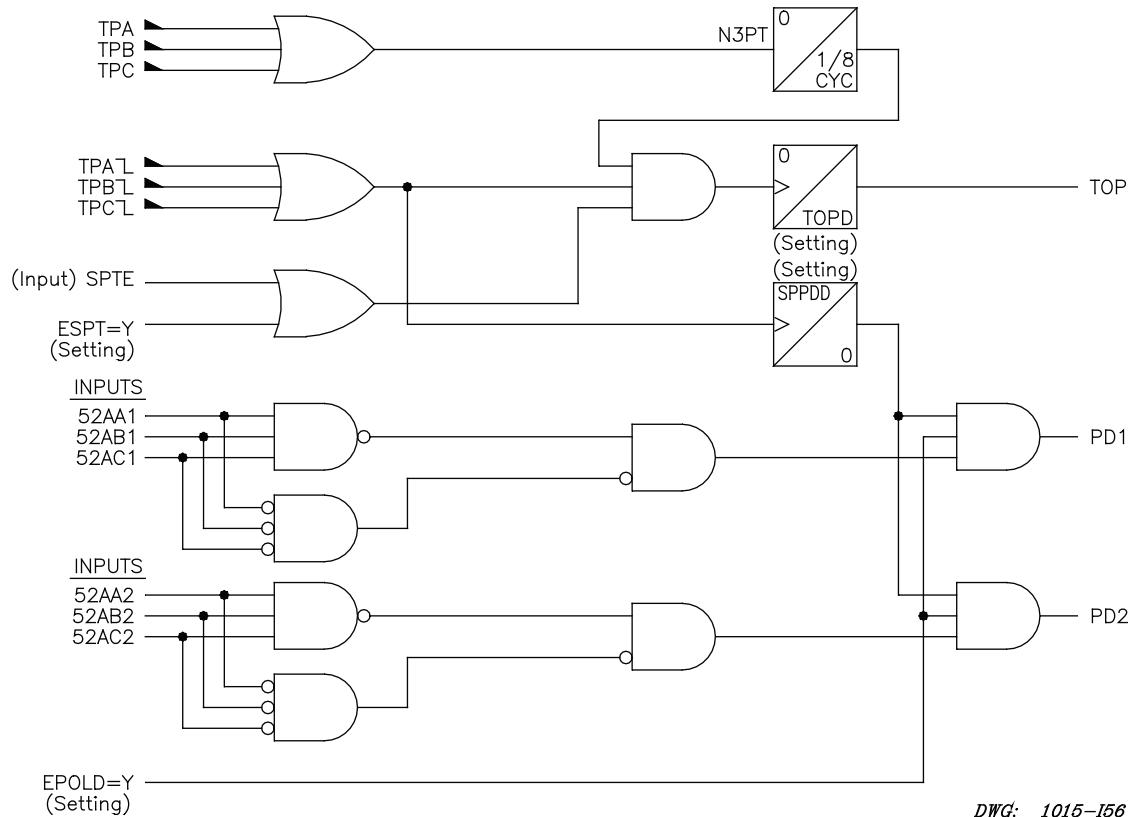


Figure 2.40: Pole-Discordance and Trip During Pole Open Logic

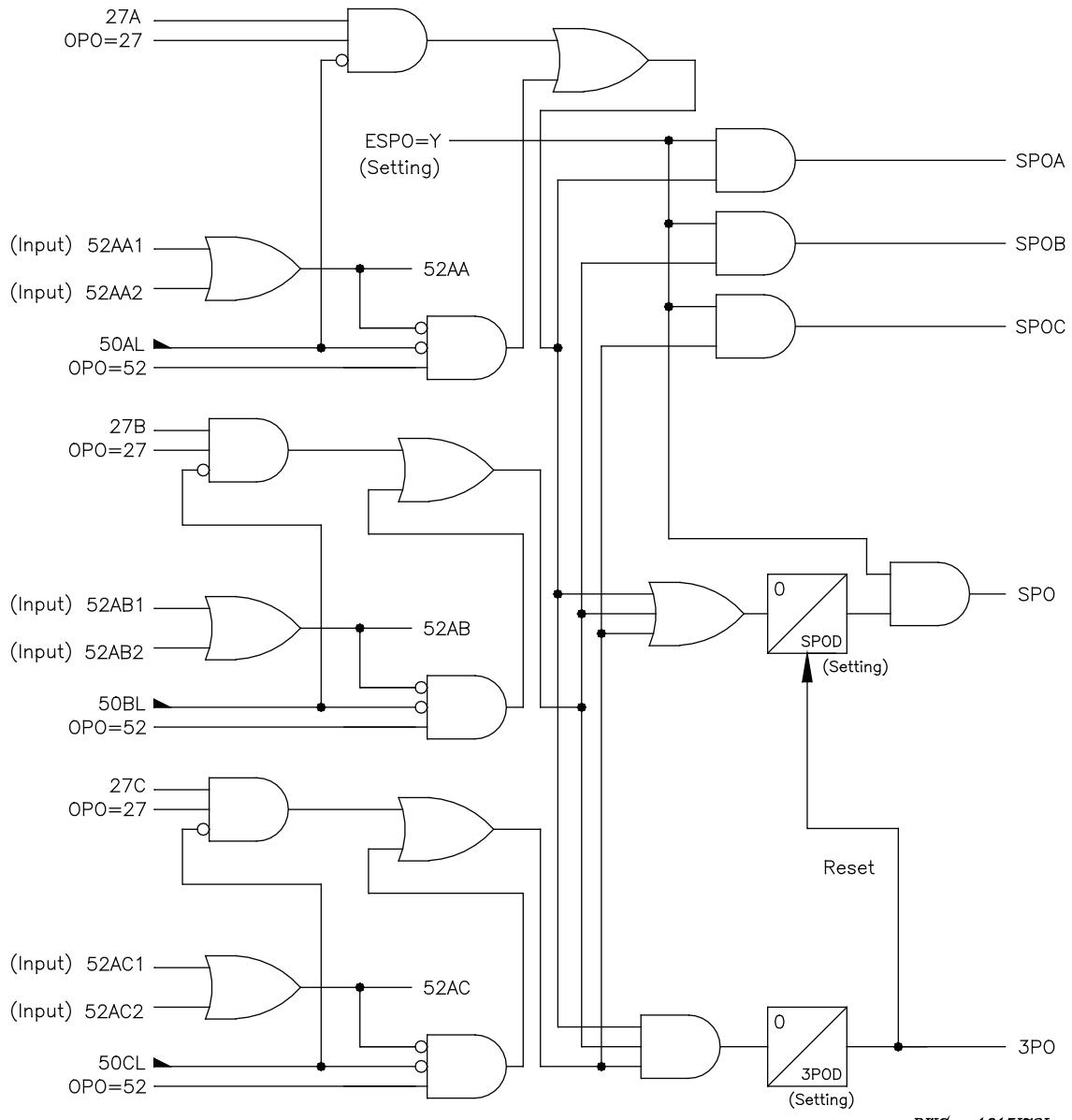
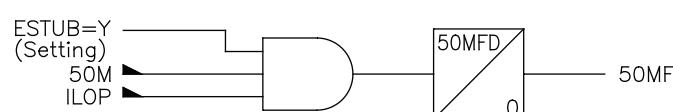


Figure 2.41: Pole Open Logic



DWG: 1015-I48

Figure 2.42: Stub Protection Logic

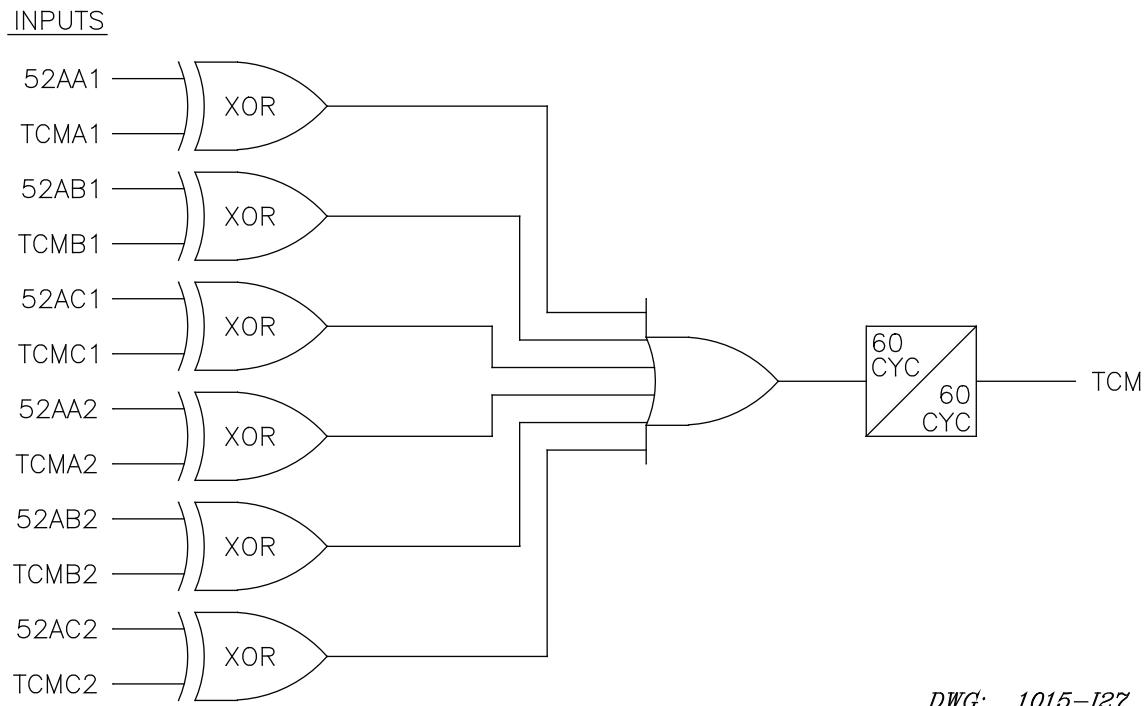


Figure 2.43: Trip Coil Monitor Logic

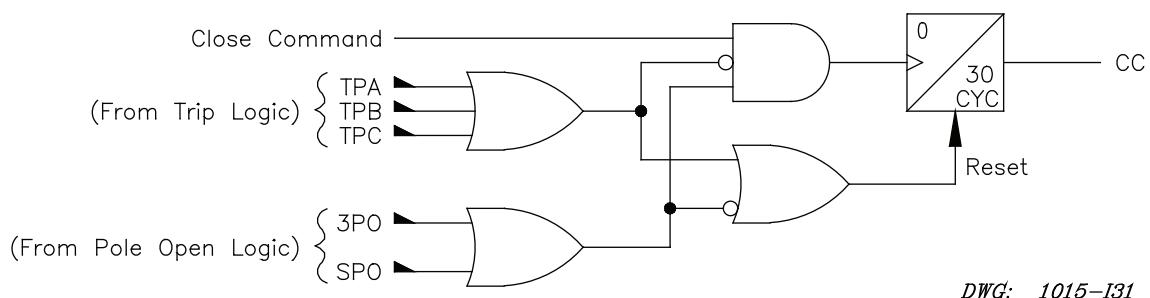


Figure 2.44: Close Logic

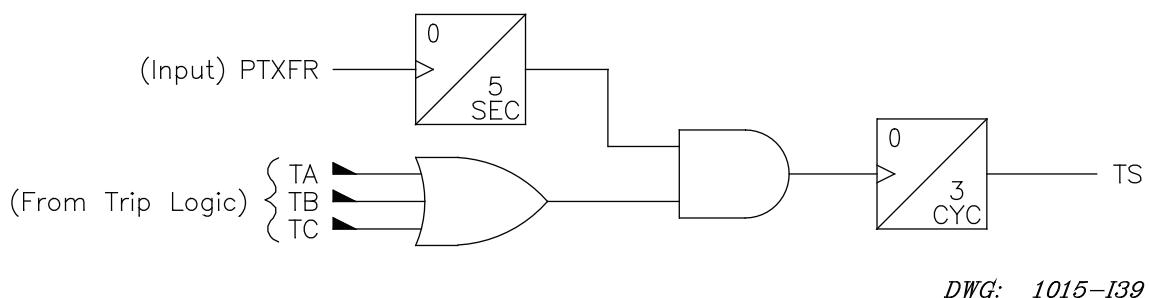
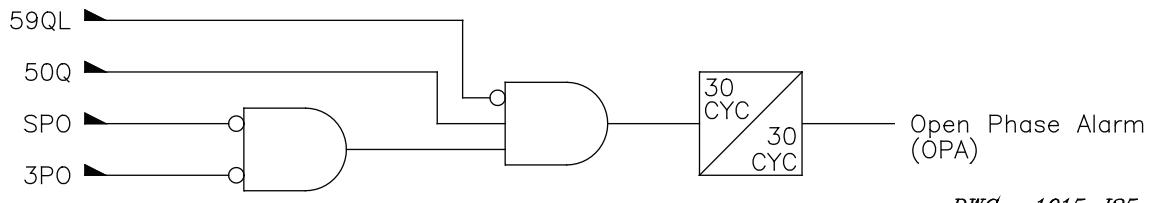


Figure 2.45: Trip Suspicion Logic



DWG: 1015-I25

Figure 2.46: Open Phase Alarm Logic

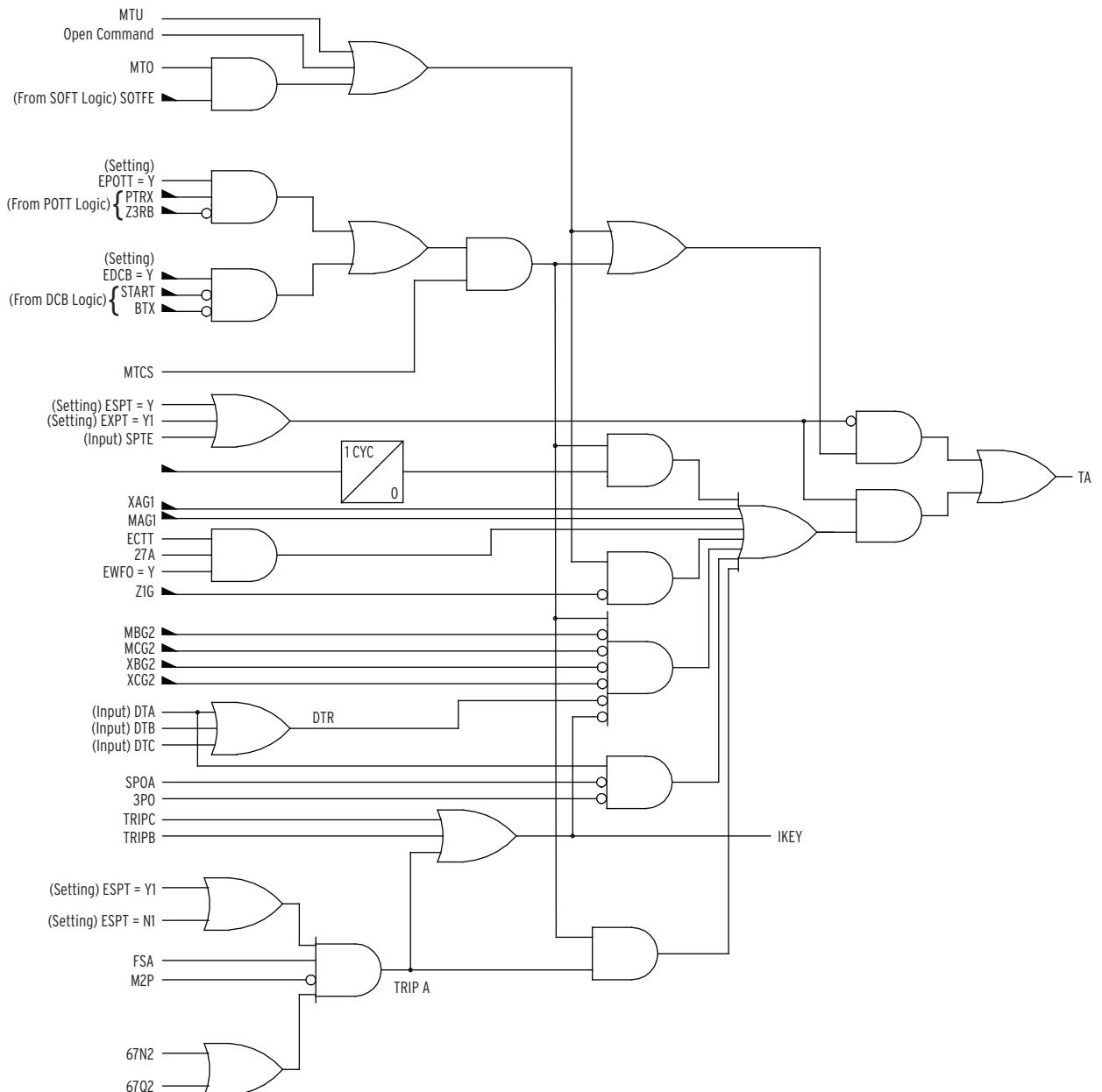


Figure 2.47: Trip Decision Logic for Phase A

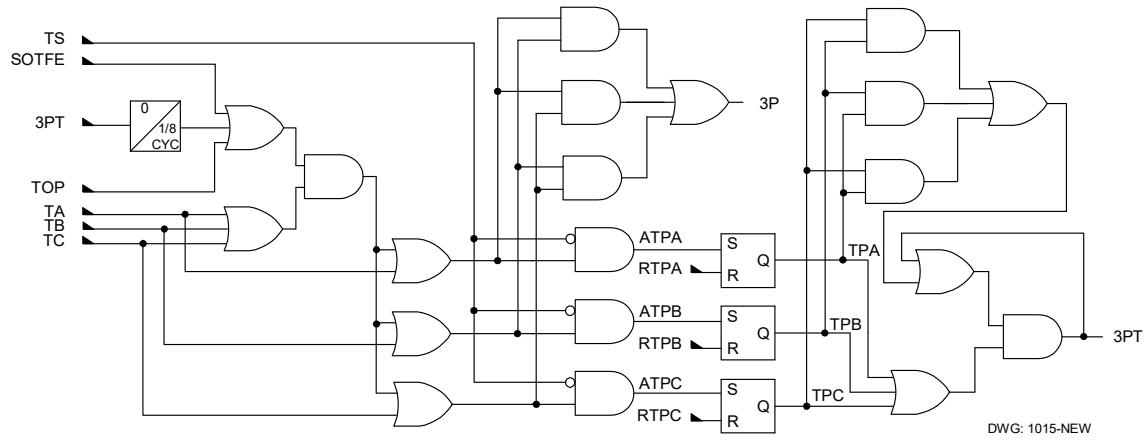


Figure 2.48: Trip Latch Logic

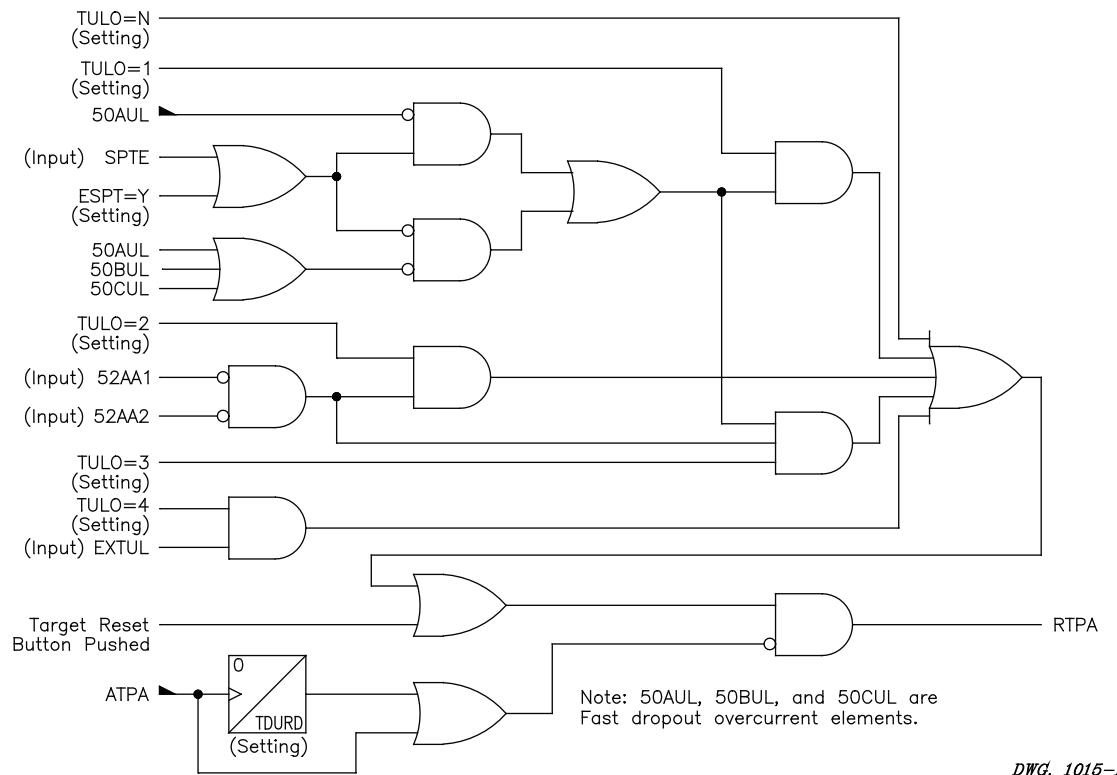


Figure 2.49: Trip Unlatch Logic for Phase A when EWFC = Y or N

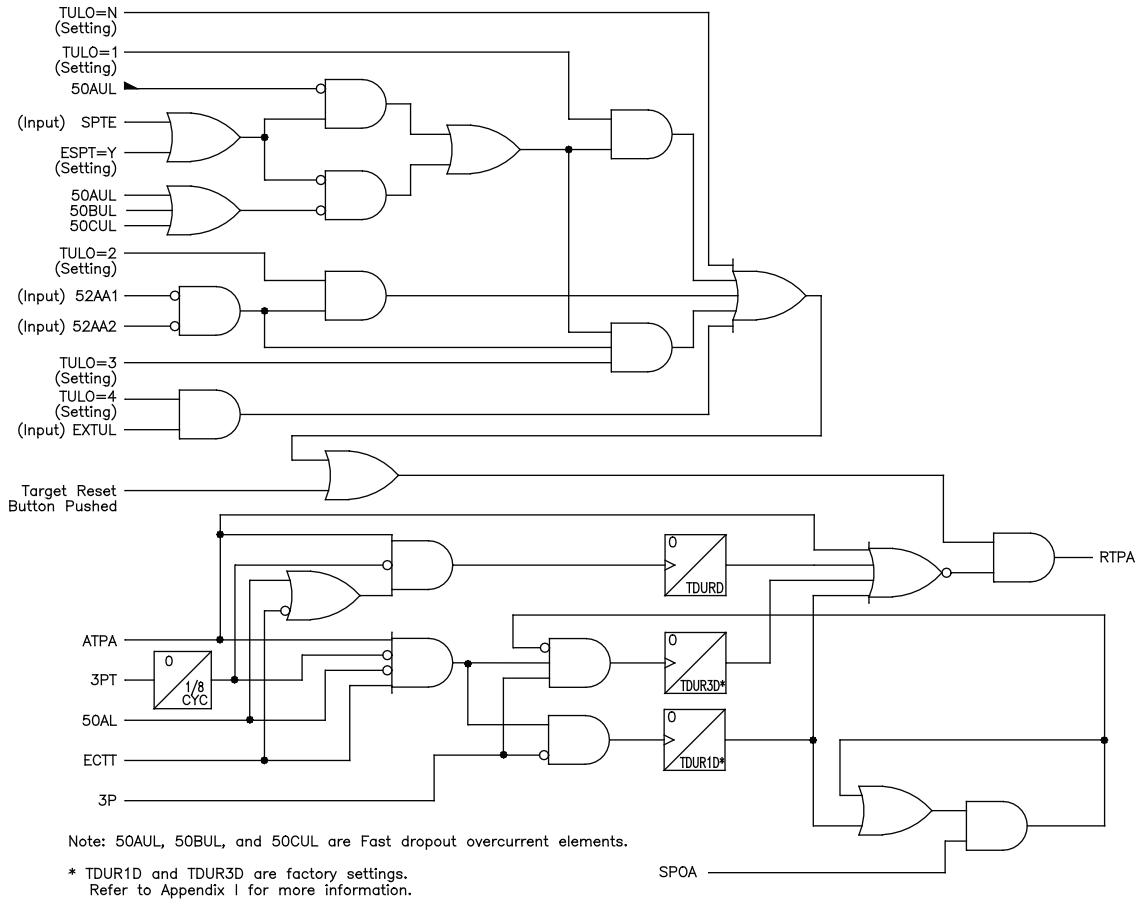


Figure 2.50: Trip Unlatch Logic for Phase A when $EWFC = Y$

DWG. 1015-NW2

DISTANCE ELEMENT OPERATING TIME CURVES AT NOMINAL FREQUENCY

Figure 2.51 shows operating times for the SEL-321-5 Relay distance elements. The diagrams show operating times at each test point. Operating times include output contact closure time (for standard and interrupting duty contact outputs).

For the distance element test, a fault was applied at a location representing a percentage of the Zone 1 relay reach setting. Tests were performed for source impedance ratios (SIR) of 0.1, 1.0, 10.0, and 30.0. No pre-fault load current or fault resistance was included.

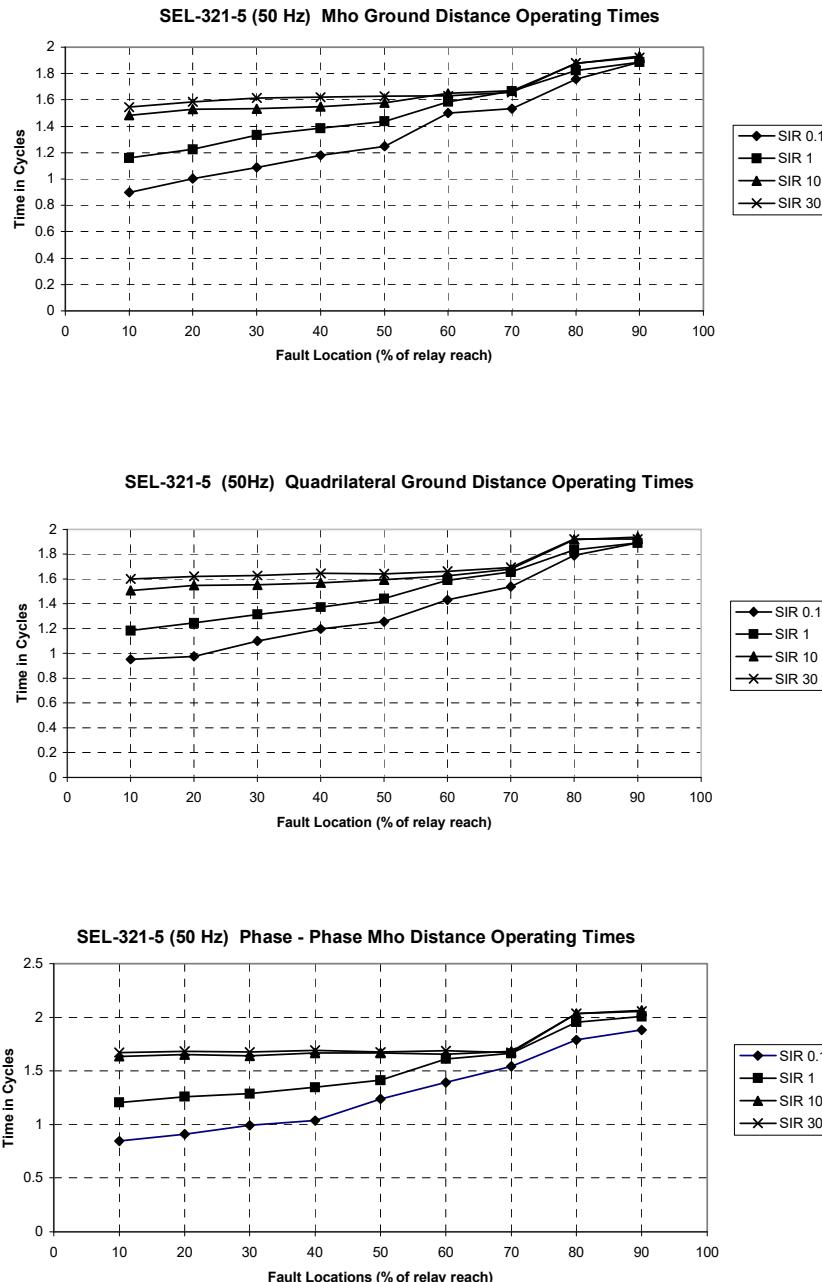


Figure 2.51: Ground and Phase Distance Speed Curves

TIME-OVERCURRENT CURVE EQUATIONS

Both US and IEC time-overcurrent curves are provided in the SEL-321-5 Relay. Use the **SET** command to select the curve characteristics you desire. Refer to **Section 3: Communications** for a complete description of the use of the **SET** command and selection of time-overcurrent characteristics.

These time curve equations are valid for all time-overcurrent elements. Plots showing operating time versus multiples of pickup current are shown on the following pages. The equations and curves apply while the product of the multiples of pickup and pickup setting is less than $32 \cdot I_{\text{nominal}}$ A, secondary.

Equations for U.S. Curves

t_M = curve operating time in seconds

t_r = reset time in seconds (for time delay reset)

TD = time dial setting

M = multiples of pickup. For curve operating time (t_M), $M > 1$.

For reset time (t_r), $M \leq 1$.

Curve U1: Moderately Inverse—See Figure 2.52

$$t_m = TD \left[0.0226 + \frac{0.0104}{M^{0.02} - 1} \right] \quad t_r = \frac{TD \cdot 1.08}{1 - M^2}$$

Curve U2: Inverse—See Figure 2.53

$$t_m = TD \left[0.180 + \frac{5.95}{M^2 - 1} \right] \quad t_r = \frac{TD \cdot 5.95}{1 - M^2}$$

Curve U3: Very Inverse—See Figure 2.54

$$t_m = TD \left[0.0963 + \frac{3.88}{M^2 - 1} \right] \quad t_r = \frac{TD \cdot 3.88}{1 - M^2}$$

Curve U4: Extremely Inverse—See Figure 2.55

$$t_m = TD \left[0.0352 + \frac{5.67}{M^2 - 1} \right] \quad t_r = \frac{TD \cdot 5.67}{1 - M^2}$$

Equations for IEC Curves

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

Curve C1: Standard Inverse—See Figure 2.56

$$t_m = TD \left[\frac{0.14}{M^{0.02} - 1} \right] \quad t_r = \frac{TD \cdot 13.5}{1 - M^2}$$

Beyond 20 multiples of pickup, all characteristics become definite-time equal to the time of $M = 20$.

Curve C2: Very Inverse—See Figure 2.57

$$t_m = TD \left[\frac{13.5}{M - 1} \right] \quad t_r = \frac{TD \cdot 47.3}{1 - M^2}$$

Curve C3: Extremely Inverse—See Figure 2.58

$$t_m = TD \left[\frac{80.0}{M^2 - 1} \right] \quad t_r = \frac{TD \cdot 80}{1 - M^2}$$

Curve C4: Long Time Backup—See Figure 2.59

$$t_m = TD \left[\frac{120.0}{M - 1} \right] \quad t_r = \frac{TD \cdot 120}{1 - M}$$

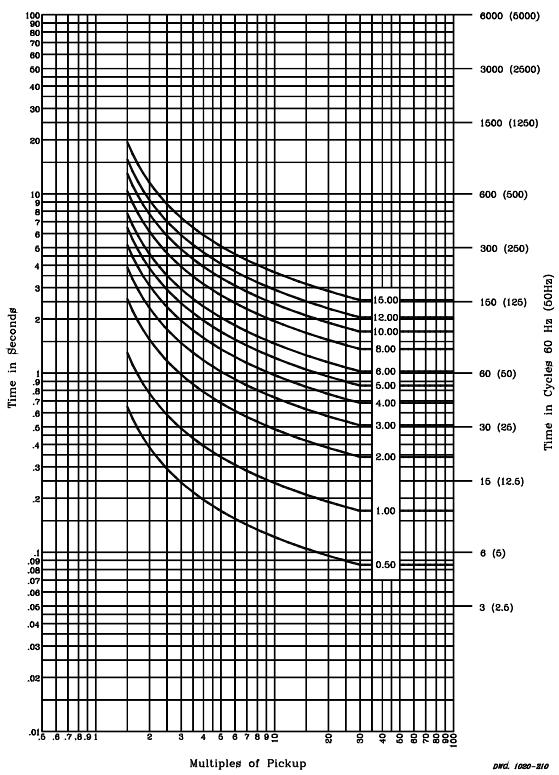


Figure 2.52: Time Curve U1

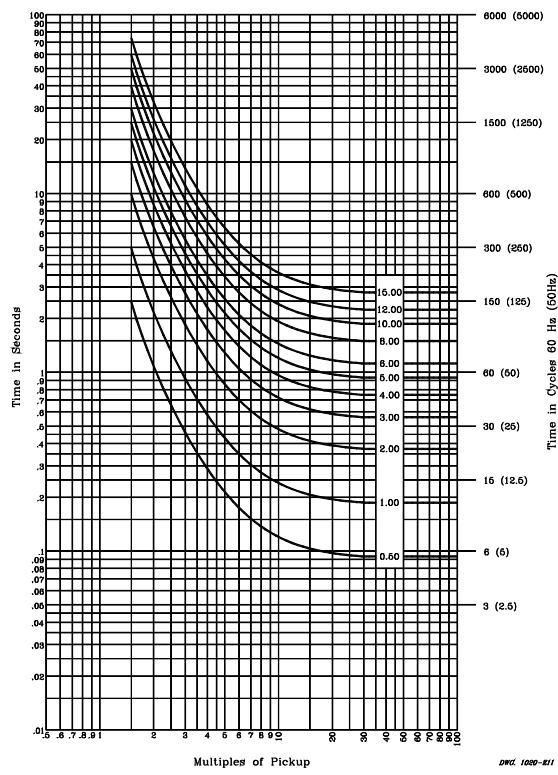


Figure 2.53: Time Curve U2

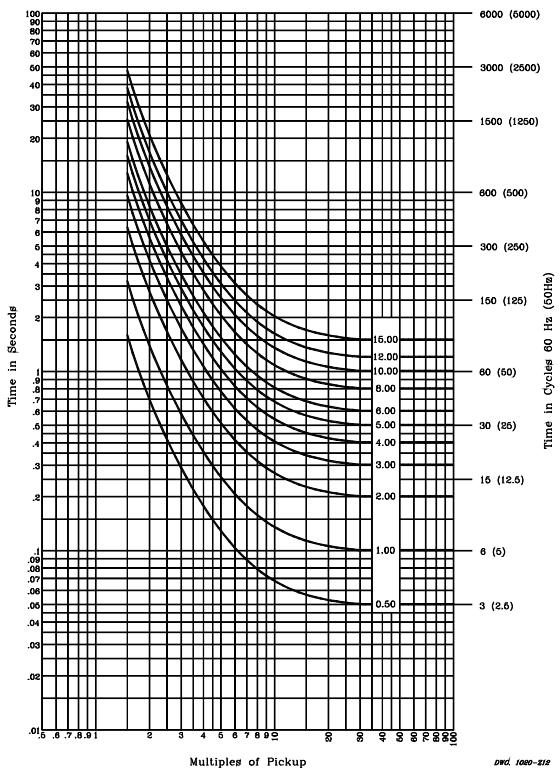


Figure 2.54: Time Curve U3

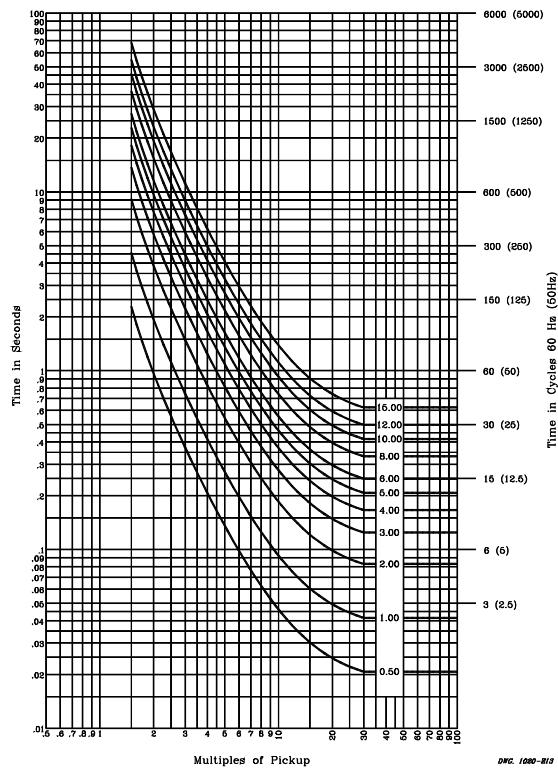


Figure 2.55: Time Curve U4

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SECTION 3: COMMUNICATIONS

INTRODUCTION

This section explains the communications protocol. It also gives examples of commands and front-panel operations for the SEL-321-5 Relay.

You set and operate the SEL-321-5 Relay via front-panel controls and serial communications interfaces. The serial interfaces may be connected to a computer terminal and/or modem. Relay communication serves these purposes:

- The relay responds to commands spanning all functions, (e.g., setting, metering, and control operations).
- The relay generates an event record for TRIP output assertions, for an event triggering command, or for the pickup of any relay element that triggers an event record.
- The relay transmits messages in response to changes in system status, e.g., self-test warning.
- No priority is set for communications ports. The last settings saved supersede all other settings. The relay avoids race conditions when two ports are addressed simultaneously.

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

Relay output appears boxed and in the following format:

EXAMPLE: BUS B, BREAKER 3 Date: 02/01/96 Time: 00:03:25.180

COMMUNICATIONS PROTOCOL

The communications protocol consists of hardware and software features.

Software Protocol

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><CR><LF>

A command transmitted to the relay should consist of the following:

- A command followed by either a carriage return or a carriage return and line feed.
- You may truncate commands to the first three characters. **EVENT 1 <ENTER>** would become **EVE 1 <ENTER>**.
- Upper- and lowercase characters may be used without distinction, except in passwords.

Note: The ENTER key on most keyboards 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 non-interactive messages in the following format:

<STX><CR><LF><MESSAGE LINE 1><CR><LF>

<MESSAGE LINE 2><CR><LF>

.

<LAST MESSAGE LINE><CR><LF><ETX><STX> <PROMPT><ETX>

Each message begins with the start-of-transmission character STX (ASCII character 02) and ends with the end-of-transmission character EXT (ASCII character 03). Each line of the message ends with a carriage return and line feed.

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

The relay transmits XON (ASCII hex 11) when the buffer drops below one-quarter full.

The relay transmits XOFF (ASCII hex 13) when the buffer is more than three-quarters 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 an XOFF command during transmission, it pauses until it receives an XON command. If there is no message in progress when the relay receives an XOFF command, it blocks transmission of any message presented to its buffer.

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)

Additional Software Protocol

The SEL-321-5 Relay includes additional software protocol that supports limited multidrop, Fast Meter, and Compressed ASCII. Refer to *Appendix G* for more information on the additional protocols.

Hardware Protocol

The following hardware protocol is designed for manual and automatic communications.

1. If RTS_CTS = N, RTS will always be asserted.
2. If RTS_CTS = Y, RTS deasserts when the relay is busy (momentarily unable to accept characters).
3. Port 3 does not support RTS_CTS hardware handshaking.
4. If RTS_CTS = Y, the relay does not send characters until the CTS input is asserted.

Alarm Conditions

The SEL-321-5 Relay asserts the ALARM output until self-tests pass when power is applied and at any diagnostic test failure. In addition to these, the ALARM output pulses with the commands and conditions shown in Table 3.1.

Table 3.1: Commands With Alarm Conditions

Command	Condition
2ACCESS	Entering Access Level 2 or Three wrong password attempts
ACCESS	Three wrong password attempts
BREAKER	Entering Breaker Access Level or Three wrong password attempts
COPY	Copying a group into the active setting group
GROUP	Changing the active setting group
PASSWORD	Any password is changed
SET commands	Changing the Global settings, an active logic setting group, or the active group setting

Main Board Jumpers

Installing and removing certain main board jumpers affects execution of some commands. Table 3.2 lists the jumpers you should be concerned with and their effects. See **Jumper Settings** in **Section 6: Installation** for details.

Table 3.2: Hardware Jumpers That Affect Commands

Jumper	Comment
P7: J105	Disables password protection when installed
P7: J106	Enables OPEN and CLOSE commands when installed

Automatic Messages

The relay may send the following messages to the port(s) designated automatic:

Startup Message:

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

```
EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 00:00:00.186
SEL-321
=
```

The ALARM relay should pull in.

Group Switch Message:

```
EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 23:31:17.489
Active Group = 2
Group Variable = 2
=>>
```

Status Report:

```
SEE THE STATUS COMMAND FOR THE FORMAT OF THE STATUS REPORT
```

Summary Event Report:

```
SEE THE EVENT REPORTING SECTION FOR THE FORMAT OF THE SUMMARY EVENT REPORT
```

COMMAND CHARACTERISTICS

The relay responds to commands sent from a terminal to each serial communications interface. The relay may also be accessed from the front-panel controls. For relay access via the front-panel controls, see *Front-Panel Operation* later in this section.

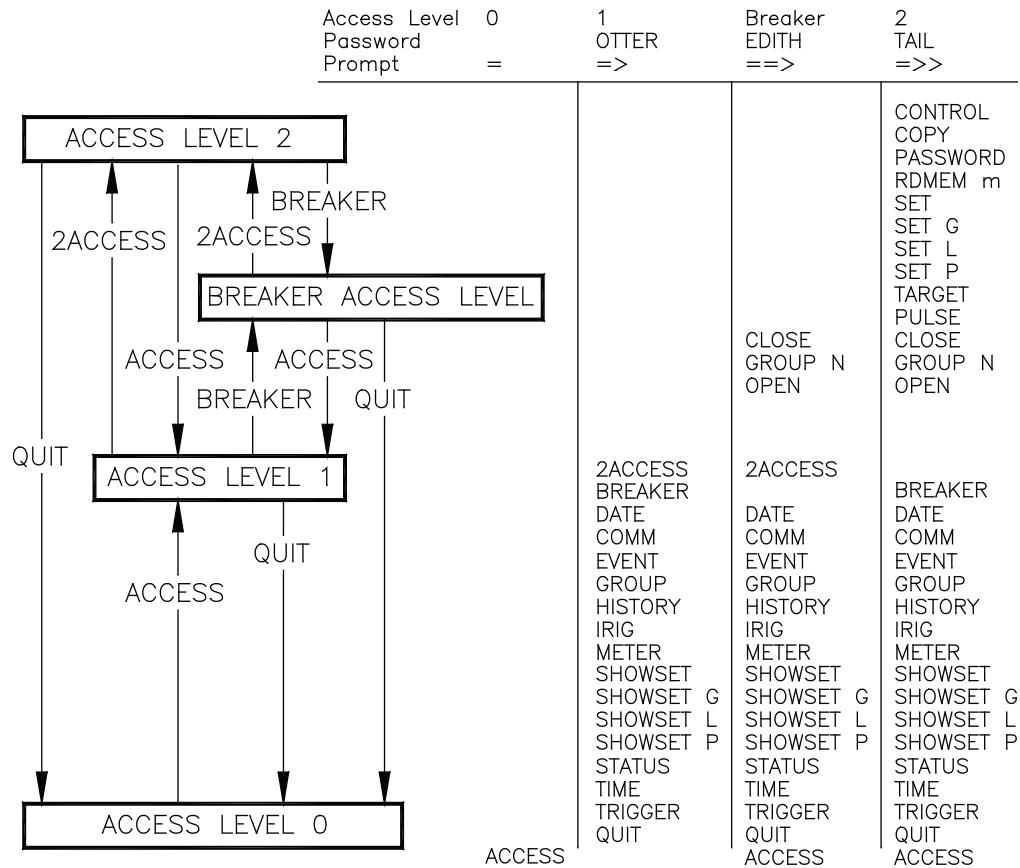
A multi-level password system provides security against unauthorized access. There are four access levels:

- | | |
|----------------------|--|
| Access Level 0 | – When the relay turns on, the relay is in Access Level 0 and honors only the ACCESS command, which moves to Access Level 1. Relay responds “Invalid Command” or “Invalid Access Level” to any other entry. |
| Access Level 1 | – Allows access to only those commands listed under Access Level 1 in Figure 3.1. |
| Breaker Access Level | – Allows access to CLOSE , OPEN and GROUP commands in addition to Access Level 1 commands. |

Access Level 2 – Allows access to **COPY**, **PASSWORD**, **TARGET**, and **SET** commands plus all commands at lower levels.

This access scheme allows you to give personnel access to only those functions they require.

Each level has an associated screen prompt and password. Figure 3.1 shows the access levels, passwords, prompts, commands available from each access level, and commands that move you between access levels.



DWG: 1015-193

Figure 3.1: Access Level Relationships

Changing Access Levels

To enter Access Level 1, type the following on a terminal connected to the relay via a serial port:

=ACCESS <ENTER>

The response is:

Password: ? @@@@@

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

```
EXAMPLE: BUS B, BREAKER 3      Date: 02/01/93      Time: 15:10:49.966
Level 1
=>
```

At the “=>” prompt you can execute any Access Level 1 command. Commands at this level involve display of information and generation of reports. No relay settings can be changed from Access Level 1. Change to other access levels in a similar manner by using the commands and passwords shown in Figure 3.1.

Command Format

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

You must separate arguments from the command by spaces, commas, semicolons, colons, or slashes. Enter commands after the terminal displays the access level prompt.

DESCRIPTION OF COMMANDS

2ACCESS

Use the **2ACCESS** command to enter Access Level 2. A password is required. The default password at this level is set to TAIL at the factory. Use the **PASSWORD** command at Access Level 2 to change passwords.

The following display indicates successful access:

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

EXAMPLE: BUS B, BREAKER 3      Date: 02/01/93      Time: 15:10:58.903
Level 2
=>>
```

You may use any command from the “=>>” prompt. The relay pulses the ALARM contact closed for one second after any Level 2 access attempt (unless an alarm condition exists).

ACCESS

ACCESS allows you to enter Access Level 1. A password is required. The default password at this level is set to OTTER at the factory; from Access Level 2, use the **PASSWORD** command to change this password, if you wish.

The following display indicates successful access:

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

EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 15:10:58.903
Level 1
=>
```

If you enter wrong passwords during three consecutive attempts, the relay pulses the ALARM contact closed for one second. This feature can alert personnel to an unauthorized access attempt if the ALARM contact is connected to a monitoring system.

BREAKER

Use the **BREAKER** command to enter breaker control access, Access Level B. A password is required to access this level. The default password for this level is set to EDITH at the factory; use the **PASSWORD** command to change this password.

The following display indicates successful access:

```
=>BREAKER <ENTER>
Password: ? EDITH <ENTER>

EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 15:11:14.607
Breaker Level
==>
```

You may use any Access Level 1 or Access Level B command from the “==>” prompt. The relay pulses the ALARM contact closed for one second after any Level B access attempt (unless an alarm condition exists).

CALIBRATION

Use the **CALIBRATION** command to enter the calibration access level. A password is required to access this level. The default password for this level is CLARKE at the factory; use the **PASSWORD** command to change this password. Use the calibration access level only under direction of the factory.

CLOSE

The **CLOSE** command asserts the CC element if no trip is asserted and the breaker is open. The CC element then remains asserted for 30 cycles, or until the breaker closes.

To use the CC element for breaker closing, program the CC element to an output contact by using the SET L command. For example, if you want to use Output 15 to close the breaker, set OUT15 = CC.

To close the circuit breaker with this command, type **CLOSE <ENTER>**. The prompting message “Close BREAKER (Y/N) ?” is displayed. Then “Are you sure (Y/N)?” Typing N

<ENTER> after either of the above prompts aborts the closing operation with the message “Command Aborted.”

If the Breaker Jumper (P7: J106) is not in place, the relay responds: “Aborted: Breaker Jumper Not in Place.”

```
==>CLOSE <ENTER>
Close BREAKER (Y/N) ? Y <ENTER>
Are you sure (Y/N) ? Y <ENTER>
Breaker CLOSED
==>
```

COMM

The **COMM** command displays integral relay-to-relay communications data. To get a summary report, enter the command without any parameters.

```
==>COMM <ENTER>
EXAMPLE: BUS B, BREAKER 3      Date: 03/21/98    Time: 10:45:08.993
SEL-321 POTT

FID=SEL-321-5-R450-V556112pb-D980605

Summary for Mirrored Bits Channel

For 03/05/98 17:18:12.993 to 03/21/98 10:45:08.993

    Total failures      3      Last error  Re-sync
    Relay disabled      1
    Data error          0      Longest failure 0 00:00:00.499
    Re-sync              0
    Underrun             1      Unavailability  0.000688%
    Overrun              0
    Parity error         1
    Framing error        0
=>
```

Use the L parameter to get a summary report, followed by a listing of the COMM records.

```
==>COMM L <ENTER>
EXAMPLE: BUS B, BREAKER 3      Date: 03/21/98    Time: 10:45:19.750
SEL-321 POTT

FID=SEL-321-5-R450-V556112pb-D980605

Summary for Mirrored Bits Channel

For 03/05/98 17:18:12.993 to 03/21/98 10:45:19.750

    Total failures      3      Last error  Re-sync
    Relay disabled      1
    Data error          0      Longest failure 0 00:00:00.499
    Re-sync              0
    Underrun             1      Unavailability  0.000688%
    Overrun              0
    Parity error         1
    Framing error        0

#   START      START      END      END      DURATION     EVENT
#   DATE       TIME      DATE      TIME
1  03/14/98  13:18:09.236 03/14/98  13:18:09.736  00:00:00.499  Parity Error
2  03/08/98  11:43:35.547 03/08/98  11:43:35.637  00:00:00.089  Underrun
3  03/05/98  17:18:12.993 03/05/98  17:18:13.115  00:00:00.121  Relay disabled
=>
```

There may be up to 255 records in the extended report. To limit the number of COMM records displayed in the report to the ten most recent records, type **COMM 10 L <ENTER>**. To select lines 10 through 20 of the COMM records for display in the report, type **COMM 10 20 L <ENTER>**. To reverse the order of the COMM records in the report, supply a range of row numbers, with the larger number first, i.e., **COMM 40 10 L <ENTER>**. To display all the COMM records that started on a particular day, supply that date as a parameter, i.e., **COMM 2/8/98 L <ENTER>**. To display all the COMM records that started between a range of dates, supply both dates as parameters, i.e., **COMM 2/21/98 2/7/98 L <ENTER>**. Reversing the order of the dates will reverse the order of the records in the report. To receive a summary report for a subset of the records, use one of the above records while omitting the L parameter.

Events occurring while loopback mode is enabled will have an L appended to the record in the report.

To clear the COMM records, type **COMM C <ENTER>**. The prompting message “Are you sure (Y/N) ?” is displayed. Typing **N <ENTER>** aborts the clearing operation with the message “Canceled.”

CONTROL *n*

The **CONTROL** command is a two-step, Access Level 2 command that allows you to control Relay Word bits RB1 through RB16. At the Access Level 2 prompt, type **CONTROL**, a space, and the number of the bit you wish to control (1–16). The relay responds by repeating your command followed by a colon. At the colon, type the **CONTROL** subcommand you wish to perform (see Table 3.3).

The following example shows the steps necessary to pulse Remote Bit 5 (RB5) for three seconds.

```
=>>CONTROL 5 <ENTER>
CONTROL RB5: PRB 5 3 <ENTER>
=>>
```

Table 3.3: SEL-321-5 Relay CONTROL Subcommands

Subcommand	Description
SRB <i>n</i>	Set Remote Bit <i>n</i>
CRB <i>n</i>	Clear Remote Bit <i>n</i>
PRB <i>n t</i>	Pulse Remote Bit <i>n</i> for <i>t</i> seconds <i>t</i> = 1 if not otherwise specified Note: <i>n</i> must match the CONTROL command bit number.

COPY *m n*

The **COPY** command copies settings and logic from setting Group *m* to Group *n* (*m* and *n* equal any combination of 1, 2, 3, 4, 5, or 6).

Usually, there are few setting or logic differences between groups. If you enter one setting group with the **SET** command, you can copy it to other groups with the **COPY** command. Use **SET** to modify copied setting groups.

If you copy settings to a group for which event reports exist, those event reports will show “SETTINGS CHANGED SINCE EVENT” when recalled with the **EVENT** command. The ALARM output contact closes momentarily when you change settings in an active setting group.

```
=>>COPY 4 6 <ENTER>
COPY 4 to 6

Are you sure (Y/N) ? Y <ENTER>

Please wait...
Settings copied
=>>
```

DATE

The **DATE** command displays the date stored by the internal calendar/clock. Set the date by typing **DATE mm/dd/yy <ENTER>**.

Set the date to February 1, 1996, by entering:

```
=>DATE 02/01/96 <ENTER>
02/01/96
=>
```

The relay sets and displays the new date.

EVENT

The **EVENT** command displays an event report. To select one of the 12 events stored in relay memory, enter the **EVENT** command with a number from 1 for the newest event, through 12 for the oldest event. If no event report is selected, the relay displays the newest event report. Type **EVENT 9 <ENTER>** to display an event report for the 9th event. To view an alternate format event report, append a format selector to the command. For example, type **EVENT 2 L <ENTER>** (parameters following **EVENT** can be entered in any order) to see the long event report for event number 2. The following list shows all possible format selectors.

<u>Format Selector</u>	<u>Event Report Type</u>
Omitted	1/4-Cycle Standard (Default) Event Report
L	1/16-Cycle Long Event Report
R	1/16-Cycle Unfiltered Long Event Report
C	1/16-Cycle SEL-5601-2 SYNCHROWAVE® Event Software Report
U	1/16-Cycle Unfiltered SYNCHROWAVE Event Software Report

Interruption of control power clears the event buffers. All event data are lost when event buffers are cleared. However, the relay retains a short history of each of the 40 newest events in nonvolatile memory (see the **HISTORY** Command).

Note: Adding a space M following the format selector replaces OUT1 through OUT8 with TMB1 through TMB8 and IN1 through IN8 with RMB1 through RMB8.

If an event buffer is empty when you request an event, the relay returns an error message:

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

Refer to **Section 4: Event Reporting** for a detailed explanation of the generation and analysis of event reports.

GROUP

The **GROUP** command designates the Group Variable. This variable (1–6) specifies which setting group is the active group when no Setting Group Selection inputs (SS1, SS2, SS3) are assigned or all assigned SS inputs are deasserted. See **Section 2: Specifications** for additional details on group switches.

```
=>>GROUP 2 <ENTER>
Change Group Variable:
Are you sure (Y/N) ? Y <ENTER>
=>>
```

The **GROUP** command does not clear the event report buffer. If the active group is changed, the relay pulses the ALARM output contacts and transmits the following message to ports designated automatic:

```
EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 23:31:17.489
Active Group = 2
Group Variable = 2
=>>
```

If you do not designate a setting group, the relay displays present group information:

```
=>>GROUP <ENTER>
Active Group = 1
Group Variable = 3
=>>
```

Note: The relay will be disabled momentarily while the group switch takes place.

The **GROUP** command at Access Level 1 shows the active group but does not allow changes. The **GROUP** command may also be accessed from the front panel (see **Group Selector** under **Front-Panel Operation**).

HISTORY

The **HISTORY** command displays up to 40 event summaries. Each summary shows the date, time, event type, fault location, active setting group, and relay targets.

The time is saved to the nearest millisecond and referenced to the Trigger row of data in the event report. If a long fault triggers two event reports, determine the duration by calculating the time difference between the first event report, generated at fault inception, and the second event report generated at the trip. The history is retained in nonvolatile EEPROM, so it is there through power failures. Enter **HISTORY C** to clear the history archive. Enter **HISTORY n**, where *n* is a positive number, to limit the history report to the most recent “*n*” events.

The date, time, and type of event are shown for each of the 40 most recent events. If the event is a fault, the distance and duration are also shown. An example of the display appears below. Note that in this example only eight events have occurred since the History was reset:

=>HISTORY <ENTER>						
EXAMPLE: BUS B, BREAKER 3			Date: 02/01/96	Time: 15:15:09.818		
#	DATE	TIME	EVENT	LOCAT	GRP	TARGETS
1	06/21/92	00:01:38.302	AG	94.45	1	INST A G
2	06/20/92	00:31:23.982	ABC	95.09	1	TIME A B C
3	06/20/92	00:31:22.905	AG	9.02	1	INST A G
4	06/20/92	00:31:21.811	BC	9.05	1	TIME B C
5	06/20/92	00:31:20.732	BC	36.01	2	TIME B C
6	06/20/92	00:31:19.655	BC	36.08	2	TIME B C
7	06/20/92	00:31:18.562	BC	35.98	2	TIME B C
8	06/20/92	00:31:17.482	BC	36.25	2	TIME B C

If there has been no event, the headings are displayed with the message: History Buffer Empty. Table 3.4 describes entries in the History report.

Table 3.4: History Report Description

Parameter	Entry	Comment
#	1	Event report number
DATE	06/21/95	Date event occurred
TIME	00:01:38.302	Time report triggered
EVENT	AG BG CG AB BC CA ABG BCG CAG ABC T	A ϕ to Ground Fault B ϕ to Ground Fault C ϕ to Ground Fault AB Two-Phase Fault BC Two-Phase Fault CA Two-Phase Fault AB Two-Phase to Ground Fault BC Two-Phase to Ground Fault CA Two-Phase to Ground Fault Three-Phase Faults (T=TPA, TPB, TPC, or 3PT assertion).
TRIP		Report triggered by TPA, TPB, TPC, or 3PT assertion, no fault.
EXT		Report triggered by assertion of EXT (external trigger) designated input.

Parameter	Entry	Comment
LOCAT	EXTC	Report triggered by TRIGGER command.
	ER	Report triggered by MER SELOGIC® control equations, but no fault detecting element asserted in event report.
GRP	94.95	Distance to fault. Entry may be \$\$\$\$\$ if the fault locator is unable to generate a reliable location.
TARGETS	1	Group number of active setting group at time event triggered.
	INST AG	Targets asserted for each event. Targets are identified just as they are on front panel.

IRIG

IRIG directs the relay to read the demodulated IRIG-B time-code input at the port on the back panel labeled “DEMODULATED IRIG-B.”

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

```
=>IRIG <ENTER>
EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 01:45:40.762
=>
```

If no IRIG-B signal is present or the code cannot be read successfully, the relay sends the error message “IRIG-B DATA ERROR.”

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

LOOP

The **LOOP** command is used for testing the MIRRORED BITS® communications channel. With the transmitter of the communications channel physically looped-back to the receiver, the MIRRORED BITS addressing will be wrong and ROK will be deasserted (refer to *Appendix H* for more information). The **LOOP** command tells the MIRRORED BITS software to temporarily expect to see its own data looped-back as its input. In this mode, LBOK will assert if error-free data are received.

The **LOOP** command without any additional parameters enables looped-back mode for 5 minutes, while the inputs are forced to the default values.

```

==>LOOP <ENTER>
Loopback will be enabled on the Mirrored Bits port for the next 5 minutes.
The RMB values will be forced to default values while loopback is enabled.

Are you sure (Y/N) ? Y <ENTER>

==>

```

To enable looped-back mode for other than the default 5 minutes, enter the desired number of minutes (1–5000) as a command parameter. To allow the looped-back data to modify the RMB values, include the DATA parameter.

```

==>LOOP 10 DATA <ENTER>
Loopback will be enabled on the Mirrored Bits port for the next 10 minutes.
The RMB values will be allowed to change while loopback is enabled.

Are you sure (Y/N) ? N <ENTER>

Canceled.

==>

```

To disable looped-back mode before the selected number of minutes, reissue the **LOOP** command with the R parameter.

```

==>LOOP R <ENTER>
Loopback is disabled.

==>

```

METER

A METER report displays the phase-to-neutral and phase-to-phase voltages and currents in primary kilovolts and amperes. It also displays real and reactive power in megawatts and megavars. An example is shown below.

Use the **METER** command with a number to repeatedly display the meter data that many times. To display a series of eight meter readings, type **METER 8 <ENTER>**.

```

=>METER <ENTER>
EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 15:15:24.640
          A           B           C           AB          BC          CA
I (A)    202        198        197        349        339        344
V (kV)   134.0     133.8     133.6     231.5     230.9     231.9
          P (MW)      78.61
          Q (MVAR)    13.85
=>

```

The **METER** command may also be executed from the front panel (see *Meter Display* in *Front-Panel Operations*).

OPEN

The 3PT element asserts in response to the **OPEN** command. If 3PT or TPA, TPB and TPC are assigned to outputs with the **SET L** command, the command will trip the breaker. The 3PT condition remains closed for a minimum duration (TDURD setting) starting with the rising edge of the TRIP output. The 3PT condition drops out only if the trip unlatch conditions are met or if you push the TARGET RESET button on the front panel.

If the TDURD setting is zero, the **OPEN** command is disabled.

To open the circuit breaker by command, type **OPEN <ENTER>**. The prompt “Open BREAKER (Y/N) ?” is transmitted. Answering **Y <ENTER>** yields a second prompt: “Are you sure (Y/N) ?” Answering **Y <ENTER>** again closes the TRIP output relay as described above. If the port is designated AUTO, a summary event report is displayed.

If the Breaker Jumper (P7: J106) is not in place, the relay responds: “Aborted: Breaker Jumper Not in Place.”

```
=>>OPEN <ENTER>
Open BREAKER (Y/N) ? Y <ENTER>
Are you sure (Y/N) ? Y <ENTER>
Breaker OPEN
=>>

EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 23:32:38.293
Event: TRIP    Location: +50.00    Frequency: 60.0
Target: EN          V1 Mem: 131.2 / 77
=>>
```

PASSWORD

The **PASSWORD** command allows you to inspect or change existing passwords. To inspect passwords, type **PASSWORD <ENTER>**. The password for Access Level 2 and all lower levels are displayed.

```
=>>PASSWORD <ENTER>
1:OTTER
B:EDITH
2:TAIL
=>>
```

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

```
=>>PASSWORD 1 BIKE <ENTER>
Set
=>>
```

The relay sets the password, pulses the ALARM relay closed for approximately one second, and transmits the response “Set” to the display.

After entering new passwords, type **PASSWORD <ENTER>** to inspect them. Make sure they are what you intended, and record the new passwords.

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

```
OTTER  Ot3456 +TAIL+ !@#$%^ 123456 12345. 12345
```

If the passwords are lost or you wish to operate the relay without password protection, install the Password Jumper (P7: J105) on the main board. See **Jumper Settings** in **Section 6: Installation** for details. With no password protection, you may gain access without knowing the passwords and view or change active passwords and settings. Passwords may not be changed from the front panel.

PULSE *n t*

PULSE closes an output contact for testing or control purposes. Close any output contact for 0.125–1.0 seconds by executing the command in Access Level 2.

Execute the command **PULSE *n t***, where *n* is the number of the contact you wish to close and *t* is the time, in seconds, the contact remains closed. The contact remains closed for 1 second unless you specify a shorter time. The example below closes output contact 3 for 0.5 seconds.

```
=> PULSE 3 0.5 <ENTER>
```

QUIT

QUIT returns control to Access Level 0 from Access Level 1, B, or 2. The command displays the relay ID, date, and time of **QUIT** command execution.

Use this command when you finish communicating with the relay to prevent unauthorized access. Control returns to Access Level 0 automatically after a settable interval (see **TIMEOUT** in Table 3.12) of no activity.

```
=>QUIT <ENTER>
EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96      Time: 15:15:32.161
=
```

RDMEM *m*

The **RDMEM** command allows you to read the contents of selected relay memory areas. This capability helps diagnose failure causes after a CR_RAM self-test failure. Use **RDMEM RAM** to download the information stored in relay RAM (use this command before you remove power from the relay). Use **RDMEM EEPROM** to download the contents of the relay nonvolatile memory. Use **RDMEM ALL** to download all the corrupted information associated with a critical RAM failure.

SET Commands

Configure the relay by using four **SET** commands. Table 3.5 lists the various **SET** commands, their formats and uses. Table 3.6 lists the editing keys that you use with all **SET** commands. Following these tables is a detailed discussion of each command.

Table 3.5: Variations on the SET Command

Command	Sets	Format	Application	Front Panel
Note: Parameters following all SET commands may be entered in any order.				
SET	Group settings (see settings sheet in Section 5: Applications for complete list)	SET SET 1 SET 2 CTR SET A	Set active group Set Group 1 Set Group 2 starting at entry CTR Access all settings, even if disabled	Yes
SET G	Global settings	SET G SET G IN1	Set input assignments Set front-panel timeout Set group change delay Set Global settings starting at entry IN1	Yes
SET P	Set communications port parameters	SET P SET P 1 SET P 1 RTS_CTS	Set active port Set Port 1 Set Port 1 starting at RTS_CTS entry	Yes
SET L	Program SELOGIC control equations	SET L SET L 1 SET L OUT2 SET L 1 OUT2	Program tripping, event reporting, and monitor- ing conditions for active logic group Program above condi- tions for Group 1 Program logic for active group starting at OUT2 entry Program logic for Group 1 starting at OUT2 entry	No (comm ports only)

Table 3.6: Editing Keys for SET Commands

Press Key(s)	Results
^ <ENTER>	Moves to previous entry in a setting category until you get to the first entry in the category and then it moves to previous category.
<<ENTER>	Moves to previous settings category when making group settings.
><ENTER>	Moves to next settings category when making group settings.
<ENTER>	Moves to next entry.
END <ENTER>	Exits editing session and displays all settings. Prompts: “SAVE CHANGES (Y/N)?”. Type Y <ENTER> to save changes and exit, N <ENTER> to exit without saving.
<CONTROL> X	Aborts editing session without saving changes.
OFF <ENTER>	Flags a setting as not applicable.

SET n

Use the **SET** command to enter group settings for the currently selected group. Edit any desired group with **SET n** where $n = 1\dots6$ corresponding to the group. Enter parameters following the **SET** command in any order.

Normally, as you go through the settings, those settings that are disabled are not shown. Enter **SET A** to access all settings in the active group, regardless of whether or not the setting is disabled. Enter **SET 4 A** to set all settings within Group 4. Enter **SET 4 EOOS A** to set all settings within Group 4, starting with the EOOS setting.

The following screen is displayed by typing **SET 2**. You are prompted to edit each setting by a (?). You are first prompted for a 17-character relay identifier string, then a 39-character terminal identifier string.

After you enter a setting, you are prompted for the next setting. Press <ENTER> to move from setting to setting. For a list of all group settings and their parameters, see the Settings Sheet in **Section 5: Applications**. The settings are arranged into families of related settings to simplify setting changes. You can start at a specific setting by entering the setting name as the indicated argument.

```
=>>SET 2 <ENTER>
GROUP 2

Line Terminal
Relay Identifier: (17 Characters)
RELID =SEL-321 POTT
?
Terminal Identifier: (39 Characters)
TRMID =EXAMPLE: BUS B, BREAKER 3
?
Positive-seq Line Impedance Magnitude: (ohms sec.) Z1MAG = 7.80
Positive-seq Line Impedance Angle: (degrees) Z1ANG = 83.97
Zero-sequence Line Impedance Magnitude: (ohms sec.) Z0MAG = 24.79
```

While entering settings, press <ENTER> to retain an existing setting, and to move to the next setting. Press ^ <ENTER> to retain an existing setting and to move to the previous setting. Press

<<ENTER> to move to the first setting of the previous family. Press ><ENTER> to move to the first setting of the next family. To flag a setting as Not Applicable, type OFF <ENTER>.

The relay checks each entry to ensure that it is within the allowable input range. If it is not, an “Out of Range” message is generated, and the relay prompts for the setting.

When you finish a setting, it is not necessary to scroll through the remaining settings. Type END <ENTER> after your last change to display the new settings and enable prompt.

After you enter all data, the relay displays the new settings and prompts for approval to enable them. Answer Y <ENTER> to approve the new settings. If you violate a rule for setting relationships, a fail message in Table 3.7 is displayed, and the settings prompt moves to the first setting that affects the failure. If settings are acceptable, the relay saves them. If a logic scheme was enabled that requires inputs assigned, a warning message in Table 3.8 is displayed. Assign the inputs with the SET G command. While the active settings are updated, the relay is disabled and the ALARM output contacts close and all timers and relay elements reset.

Table 3.7: Group SET Fail Messages

SET (Groups)	Comment
UBEND must be less than UBDURD.	Settings for UBEND or UBDURD timers improperly set.
Z2F must be less than Z2R by at least 0.1 ohms.	Z2F and/or Z2R are improperly set in setting procedure.
OSTD must be less than OSBD.	OSTD or OSBD entered wrong in setting procedure.
DIR3 must be R since POTT, DCUB, or DCB is enabled.	DIR3 not set to R in setting procedure.
DIR2 must be F since POTT, DCUB, or DCB is enabled.	DIR2 not set to F in setting procedure.
PLAR must be less than or equal to NLAR.	PLAR or NLAR set incorrectly in setting procedure.
PLAF must be greater than or equal to NLAF.	PLAF or NLAF set incorrectly in setting procedure.
Time dial setting out of range for selected curve family.	Curve family changed without updating time dial.
X1T must be at least 0.1 ohm greater than X1B.	X1T not set at least 0.1 ohm greater than X1B.
R1R must be at least 0.1 ohm greater than R1L.	R1R must be at least 0.1 ohm greater than R1L.
Enabled distance element must not be OFF.	Previously disabled distance element must be given a value.
Enabled supervisory element must not be OFF.	Previously disabled supervisory element must be given a value.

SET (Groups)	Comment
PMHOZ must be > 1 to torque-control 51P with M2P.	M2P is disabled if PMHOZ < 2.
PMHOZ must be > 1 to torque-control 51Q with M2P.	M2P is disabled if PMHOZ < 2.
GMHOZ or QUADZ must be > 1 to torque-control 51N with Z2G.	Z2G is disabled if GMHOZ and QUADZ < 2.
GMHOZ or QUADZ must be > 1 to torque-control 51Q with Z2G.	Z2G is disabled if GMHOZ and QUADZ < 2.
ELE must be Y to torque-control 51P with ZLIN or ZLOUT.	ZLIN and ZLOUT are disabled if ELE = N.

Table 3.8: SET or SET G Warning Messages

Message	Comment
EZ1EXT disabled until CLOSE assigned to an input contact.	Logic scheme disabled until CLOSE is assigned to an input.
BT must be assigned to an input contact since DCB is enabled.	DCB scheme disabled if BT is not assigned to an input.
EXTUL must be assigned to an input contact to use TULO = 4.	TULO is set to 4, but EXTUL is not assigned. Logic scheme disabled.
LOG must be assigned to an input contact since DCUB is enabled.	DCUB scheme disabled because LOG is not assigned to an input.
PT must be assigned to an input contact since POTT is enabled.	POTT scheme disabled because PT is not assigned to an input.
Assign PTXFR to an input contact to enable trip suspicion logic.	Trip suspicion logic disabled because PTXFR is not assigned to an input.
PROTOCOL = MB port setting required to use RMBn.	The inputs RMB1 through RMB8 are not updated unless Port 1 or 2 PROTOCOL = MB.

If setting changes were made to the active group, the relay enables them and pulses the ALARM contact.

The Settings Sheet in **Section 5: Applications** gives a complete list of settings made using the SET command. For an explanation of the use of the front-panel controls with the SET command, see **LCD Functions** and **Front-Panel Commands** in this section.

SHOWSET

SHOWSET displays the relay settings of the currently selected group. Type **SHOWSET** with a group number (1–6) to view the group settings for that particular group. Append this command with an “A” to cause all settings, including inactive settings, to be displayed; normally, settings for disabled functions are not shown. Enter parameters following **SHOWSET** command in any order.

Settings cannot be entered or modified with this command. Change settings with the **SET** command family under Level 2 access. The **SHOWSET** command results in the following display:

```
=>SHOWSET 2 <ENTER>
GROUP 2

RELIB =SEL-321 POTT
TRMID =EXAMPLE: BUS B, BREAKER 3
Z1MAG = 7.80    Z1ANG = 83.97    ZOMAG = 24.79    ZOANG = 81.46
LOCAT = Y       LL     = 100.00   CTR     = 200.0    PTR     = 2000.0
PMHOZ = 3       GMHOZ = 3       QUADZ = 3
DIR1  = F       DIR2  = F       DIR3  = R       DIR4  = F
Z1P   = 6.24    Z2P   = 9.36    Z3P   = 1.87
50PP1 = 2.55    50PP2 = 2.22    50PP3 = 2.45
Z1MG  = 6.24    Z2MG  = 9.36    Z3MG  = 1.87
XG1   = 6.24    XG2   = 9.36    XG3   = 1.87
RG1   = 2.50    RG2   = 5.00    RG3   = 6.00
50L1  = 0.90    50L2  = 0.90    50L3  = 1.30
50G1  = 0.90    50G2  = 0.60    50G3  = 0.50
K01M = 0.726   K01A = -3.69   k0M   = 0.726   k0A   = -3.69   T     = 0.00
EOOS  = N
ELE   = Y       ZLF   = 9.22    ZLR   = 9.22
PLAF  = 30      NLAF  = -30     PLAR  = 150     NLAR  = 210
Z2F   = 0.77    50QF  = 0.5     Z2R   = 5.45    50QR  = 0.5     a2   = 0.07
E51P  = N
E51N  = Y       51NP  = 0.74    51NC  = U3

Press RETURN to continue
51NTD = 2.00    51NRS = Y      51NTC = 32QF
E50N  = N
E51Q  = Y       51QP  = 2.20    51QC  = U3
51QTD = 2.00    51QRS = N      51QTC = 32QF
E50Q  = N
EVOLT = N
Z2PD  = 20.00   Z3PD  = 0.00
Z2GD  = 20.00   Z3GD  = 0.00
EPOTT = Y       Z3RBD = 5.00   EBLKD = 10.00
ETDPU = 2.00    EDURD = 4.00
EDCUB = N
EZ1EXT= N
EREJO = N
ESOTF = Y       ENCLO = Y      CLOEND= 10.00   EN52A = N
SOTFD = 30.00   50H   = 11.25
ELOP  = Y       LOPD  = 3.00    50M   = 2.37    59NL  = 14.00   59PL  = 14.00
EPOLD = N       ESPT  = N       ESP0  = N       OPO   = 52
3POD  = 1.50    ESTUB = Y      50MFD = 20.00   TULO  = 3
TDURD = 9.00    TOPD  = 0.00    TXPU  = 0.00    TXDO  = 0.00
TYPU  = 0.00    TYDO  = 0.00    TZPU  = 0.00    TZDO  = 0.00   ITTD  = 5.00

Press RETURN to continue
=>
```

SET G

Use the **SET G** command to configure relay inputs, set the front-panel time delay and the group switching time delay. You assign inputs equal to any of the elements listed in Table 2.9. The inputs are then dedicated to monitor those functions. Preceding an entry with (!) causes that input

to be treated as the inverse of the given entry. (For example, if connecting a 52B input, assign it as !52A1 to cause it to be interpreted correctly.) The relay displays entered data and prompts for a Y or N response. Enter Y to accept the settings.

IN1 through IN8 (IN1 through IN16 for two I/O board relays) and RMB1 through RMB8 define inputs. See **Section 2: Specifications, Contact Inputs** section, for a complete list of possible assignments for the inputs. FP_TIMEOUT sets the time, in minutes, that the front-panel LCD display waits before resetting. TGR defines the time, in seconds, the relay delays before switching groups. Below are shown the default Global settings (one I/O board version—8 inputs):

```
-->>SET G <ENTER>
Input Contact 1 Assignment:           IN1    = 52A1      ?
Input Contact 2 Assignment:           IN2    = PT        ?
Input Contact 3 Assignment:           IN3    = CLOSE     ?
Input Contact 4 Assignment:           IN4    = PTXFR     ?
Input Contact 5 Assignment:           IN5    = NA        ?
Input Contact 6 Assignment:           IN6    = NA        ?
Input Contact 7 Assignment:           IN7    = NA        ?
Input Contact 8 Assignment:           IN8    = NA        ?
Received Mirror Bit 1:                RMB1   = NA        ?
Received Mirror Bit 2:                RMB2   = NA        ?
Received Mirror Bit 3:                RMB3   = NA        ?
Received Mirror Bit 4:                RMB4   = NA        ?
Received Mirror Bit 5:                RMB5   = NA        ?
Received Mirror Bit 6:                RMB6   = NA        ?
Received Mirror Bit 7:                RMB7   = NA        ?
Received Mirror Bit 8:                RMB8   = NA        ?
Front Panel Timeout: (minutes)       FP_TIMEOUT= 5      ?
Group Change Delay: (seconds)         TGR    = 5        ?
CR RAM Diagnostics Action: Restart Enable (Y/N) ERESTART=Y  ?
IN1   = 52A1  IN2   = PT    IN3   = CLOSE   IN4   = PTXFR
IN5   = NA    IN6   = NA    IN7   = NA     IN8   = NA
RMB1  = NA    RMB2  = NA    RMB3  = NA    RMB4  = NA
RMB5  = NA    RMB6  = NA    RMB7  = NA    RMB8  = NA
FP_TIMEOUT= 5      TGR    = 5      ERESTART=Y
Save changes (Y/N) ? Y
Settings saved
=>>
```

To edit a specific global setting, enter that setting name after the **SET G** command. Type **SET G TGR** to edit the TGR global setting. These settings may also be changed from the front-panel.

Table 3.9: SET G Fail Messages

Message	Comment
Since a phase of 52A is assigned, all three phases for that breaker must be assigned.	One or more phases of 52A are not assigned for this breaker.
Since a phase of TCM is assigned, all three phases for that breaker must be assigned.	One or more phases are not assigned for this breaker.
Since TCM is assigned for a breaker, 52A must also be assigned for that breaker.	52A has not been assigned to an input contact.
Since some of PARA, PARB, and PARC are assigned, all must be assigned.	One or more of PARA, PARB, or PARC are not assigned.

SHOWSET G

SHOWSET G displays but does not allow you to set the relay Global settings.

```
=>SHOWSET G <ENTER>
IN1 = 52A1   IN2 = PT     IN3 = CLOSE   IN4 = PTXFR
IN5 = NA     IN6 = NA     IN7 = NA     IN8 = NA
RMB1 = NA    RMB2 = NA    RMB3 = NA    RMB4 = NA
RMB5 = NA    RMB6 = NA    RMB7 = NA    RMB8 = NA
FP_TIMEOUT= 5   TGR = 5      ERESTART=Y
=>
```

SET L

SET L manipulates settings made with **SELOGIC** control equations. See **SELOGIC Control Equations** in **Section 2: Specifications** for a detailed definition of the functions. Use **SET L** to edit the logic settings of the currently selected group. Use **SET L** with a group number (1–6) to edit the logic settings of a particular group. Go to a specific logic setting by entering the logic setting label after the group number. For example, enter **SET L 3 MTU** to edit the MTU logic setting within Group 3. Enter parameters following **SET** command in any order.

Press **<ENTER>** to retain an existing setting, and move to the next setting. Press **^ <ENTER>** to retain an existing setting and move to the previous setting. When you finish entering setting changes, it is not necessary to scroll through the remaining settings. Type **END <ENTER>** after your last change to display the new settings and the enable prompt. After you enter all data, the relay displays the new settings and prompts for approval to enable them. Answer **Y <ENTER>** to approve the new settings.

Settings V–Z can equal any combination of named elements listed in Table 2.7 and Table 2.9. Review **SELOGIC Control Equations Programming** in **Section 2: Specifications** if necessary. Some examples of function assignments are shown in the following illustration.

Settings OUT1–OUT15, TMB1–TMB8, MTU, MTO, MTCS, and MER may equal any combination of named elements listed in Table 2.7, Table 2.9, or Table 2.12. OUT16 is dedicated to ALARM and is not programmable. The 12 output I/O board option has settings for OUT1–OUT11. For the two I/O board version of the relay, the second I/O board output settings start with OUT17 regardless of the type of the first I/O board. Some examples of programmable mask and output assignments are as follows (one I/O board version—15 outputs—shown):

```
=>>SET L 1 <ENTER>
SELogic group 1

V =NA
?
W =NA
?
X =NA
?
Y =NA
?
Z =NA
?
MTCS =M2P + Z2G
?
MTU =M1P + Z1G + M2PT + Z2GT + 51NT + 51QT + 50MF
?
```

```
MTO    =M1P + M2P + Z1G + Z2G + 50H  
?  
MER    =M2P + Z2G + 51NP + 51QP + 50H + LOP*52AA1  
?  
OUT1   =3PT  
?  
OUT2   =3PT  
?  
OUT3   =CC  
?  
OUT4   =KEY  
?  
OUT5   =NA  
?  
OUT6   =NA  
?  
OUT7   =NA  
?  
OUT8   =NA  
?  
OUT9   =NA  
?  
OUT10  =NA  
?  
OUT11  =NA  
?  
OUT12  =NA  
?  
OUT13  =NA  
?  
OUT14  =NA  
?  
OUT15  =NA
```

```
?  
?  
TMB1  =NA  
?  
TMB2  =NA  
?  
TMB3  =NA  
?  
TMB4  =NA  
?  
TMB5  =NA  
?  
TMB6  =NA  
?  
TMB7  =NA  
?  
TMB8  =NA  
?  
V     =NA  
W     =NA  
X     =NA  
Y     =NA  
Z     =NA  
MTCS  =M2P + Z2G  
MTU   =M1P + Z1G + M2PT + Z2GT + 51NT + 51QT + 50MF  
MTO   =M1P + M2P + Z1G + Z2G + 50H  
MER   =M2P + Z2G + 51NP + 51QP + 50H + LOP*52AA1  
OUT1  =3PT
```

```

OUT2 =3PT
OUT3 =CC
OUT4 =KEY
OUT5 =NA
OUT6 =NA
OUT7 =NA
OUT8 =NA
OUT9 =NA
OUT10 =NA
OUT11 =NA

Press RETURN to continue
OUT12 =NA
OUT13 =NA
OUT14 =NA
OUT15 =NA
TMB1 =NA
TMB2 =NA
TMB3 =NA
TMB4 =NA
TMB5 =NA
TMB6 =NA
TMB7 =NA
TMB8 =NA

Save changes (Y/N) ? y
Settings saved
=>>

EXAMPLE: BUS B, BREAKER 3           Date: 02/01/96      Time: 02:03:04.578
Active Group = 1
Group Variable = 1
=>>

```

Table 3.10: SET L Fail Message

Message	Comment
Overall SELOGIC setting size too large. Try combining equations.	Maximum of 160 SELOGIC terms exceeded.

SHOWSET L

SHOWSET L displays, but does not allow you to set, the programmable logic settings of the currently selected group. Use the **SHOWSET L** command with a group number (1–6) to view the logic settings of any group. You may enter parameters in any order following the **SHOWSET** command. The following illustration shows a report from the one I/O board version (15 outputs) of the relay.

```

=>>SHO L 1 <ENTER>
SELogic group 1

V     =NA
W     =NA
X     =NA
Y     =NA
Z     =NA
MTCS =M2P + Z2G
MTU  =M1P + Z1G + M2PT + Z2GT + 51NT + 51QT + 50MF
MTO  =M1P + M2P + Z1G + Z2G + 50H
MER  =M2P + Z2G + 51NP + 51QP + 50H + LOP*52AA1
OUT1 =3PT
OUT2 =3PT
OUT3 =CC
OUT4 =KEY
OUT5 =NA
OUT6 =NA
OUT7 =NA
OUT8 =NA
OUT9 =NA
OUT10 =NA

```

```

OUT11 =NA
Press RETURN to continue
OUT12 =NA
OUT13 =NA
OUT14 =NA
OUT15 =NA
TMB1 =NA
TMB2 =NA
TMB3 =NA
TMB4 =NA
TMB5 =NA
TMB6 =NA
TMB7 =NA
TMB8 =NA

=>>

```

SET P

Use **SET P** to change settings for the active communications port; Table 3.12 explains the settings. To go to the settings for a particular port, enter the port number (1–3) after **SET P**. The following display shows an example for Port 1. To edit a particular setting, enter the setting label after the port number. For example, enter **SET P 3 AUTO** (enter parameters in any order) to edit the AUTO setting for Port 3. The following display shows setting prompts for Port 1. You can also make settings from the front panel (see *Setting Changes via Front Panel* under **Front-Panel Operation**).

Note: FAST_OP setting included in SEL-321-5 Relay only.

```

=>>SET P 1 <ENTER>
PROTOCOL= SEL      ?
SPEED = 2400      ?
DATA_BITS= 8       ?
PARITY= N         ?
STOP  = 1         ?
TIMEOUT= 0        ?
AUTO   = Y         ?
RTS_CTS= N        ?
FAST_OP= N        ?
PORT:1           XOFF RECEIVED:N      XOFF SENT:N
PROTOCOL= SEL
SPEED = 2400      DATA_BITS= 8        PARITY= N      STOP  = 1
TIMEOUT= 0        AUTO   = Y        RTS_CTS= N    FAST_OP= N
Save changes (Y/N) ? Y
Settings saved
=>>

```

Table 3.11: SET P Fail Messages

Message	Comment
MB only allowed on a single port. Port 1 is already using MB.	The MIRRORED BITS protocol can only be in use on a single port.
MB only allowed on a single port. Port 2 is already using MB.	The MIRRORED BITS protocol can only be in use on a single port.

SHOWSET P

SHOWSET P displays communications port settings and XON/XOFF handshaking status of active port without having to use the **SET P** command. To see the settings of a specific port, enter the port number (1–3) with the command. Enter **SHOWSET P 1** to view Port 1 settings (parameters may be entered in any order). Table 3.12 describes the settings displayed with the **SHOWSET P** command. See *Section 2: Specifications* for details on communications ports.

```
=>SHOWSET P <ENTER>

PORT:1      XOFF RECEIVED:N      XOFF SENT:N
PROTOCOL= SEL
SPEED = 2400   DATA_BITS= 8      PARITY= N      STOP   = 1
TIMEOUT= 0     AUTO   = Y      RTS_CTS= N      FAST_OP= N
=>
```

Table 3.12: SET P and SHOWSET P Description

Category	Status	Comment
PORT	1	PORT 1 data shown.
XOFF RECEIVED	N	N = XOFF command not received. Y = XOFF command (CTRL-S) received and no CTRL-Q command received from terminal. If XOFF = Y, relay does not send data.
XOFF SENT	N	N = XOFF message not sent by relay to connected terminal. Y = XOFF message sent to terminal. If data are sent faster than relay can receive, or buffer is 80% full, relay sends XOFF command and sets this setting to Y.
Category	Setting	Comment
PROTOCOL	SEL	SEL = Standard communications. LMD = Limited Multidrop (see LMD Application Guide). MB = Relay-to-Relay communication (7 bits). MB8 = Relay-to-Relay communication(8 bits).
SPEED	2400	Baud rate setting for modem.
DATA_BITS	8	Data bits setting for modem.
PARITY	N	Parity setting for modem.
STOP	1	Stop bit setting for modem.
TIMEOUT	0	Time relay waits after last command received before relay reverts to Access Level 0 and aborts any command in process (0.00–30.0 minutes). If set to 0, port never times out.

Category	Status	Comment
AUTO	Y	Y = Port set to AUTO.
RTS_CTS	N	N = EIA232 request to send—clear to send handshake protocol is OFF (see Communications Protocol earlier in this section).
FAST_OP	N	Y = Protocol on. Should be set to Y for use with modem. N = Disable Fast Operate command processing. Y = Enable Fast Operate command processing. (See Fast Operate Command Processing Application Guide).

STATUS

STATUS allows inspection of self-test status. The relay automatically executes the **STATUS** command whenever the self-test software enters a warning or failure state. If this occurs, the relay transmits a STATUS report from the port(s) designated automatic (see **SET** command, AUTO setting). Type **STATUS 4** to view the status information four times.

The STATUS report format appears below:

```
=>STATUS <ENTER>

EXAMPLE: BUS B, BREAKER 3      Date: 02/01/96    Time: 15:16:42.580
SELF TESTS

W=Warn    F=Fail

          IA        IB        IC        VA        VB        VC        MOF
OS       0         0         0         0         0         0         0
+5V_PS   4.96     5.10     -4.98    11.93    -12.09   15.02    -15.21
          TEMP      RAM       ROM      A/D      CR_RAM    EEPROM  SETTINGS
          26.1      OK        OK      OK       OK        OK       OK

Relay Enabled

=>
```

Table 3.13 describes the STATUS report. For a description of self-test and test parameters, see **Self-Test** in **Section 2: Specifications**.

Table 3.13: Status Report Description

Parameter	Status Displayed	Comment
OS:		
IA	0	DC offset voltages in millivolts for the analog channels (IA, IB, IC, VA, VB, VC) and master offset (MOF). F (Failure) or W (Warning) following value in Status Displayed column indicates an out-of-tolerance condition. Only MOF will show a failure condition.
IB	0	
IC	0	
VA	0	
VB	0	
VC	0	
MOF	0	
PS:		
+5V_PS	4.96	Power supply output voltages. W (Warning) or F (Failure) following value indicates out-of-tolerance condition.
+5V_REG	5.10	
-5V_REG	-4.98	
+12V_REG	11.93	
-12V_REG	-12.09	
+15V_PS	15.02	
-15V_PS	-15.12	
TEMP	26.1	Temperature inside the relay in degrees Celsius. W (Warning) or F (Failure) following value indicates out-of-tolerance condition.
RAM	OK	IC socket number in place of OK indicates failure.
ROM	OK	IC socket number in place of OK indicates failure.
A/D	OK	A self-test checks that all analog-to-digital conversion processes complete each sample period.
CR_RAM	OK	Critical RAM contents (Global, Group, and Calibration settings) are checked against their image in EEPROM. If normal, OK is displayed. If not, GLOBAL, LOGIC n, GROUP n, CAL, or CODE indicates failed area.
EEPROM	OK	Checksums of GLOBAL, GROUP, and CAL setting in EEPROM are checked. If agrees with initial checksum, OK is displayed. If not, GLOBAL, LOGIC n, GROUP n, CAL, CODE indicates failed area.
SETTINGS	OK	Settings self-test checks status of Group, Global, Logic, and Calibration valid settings, and Group LOGVAL settings. If any setting is set to NO, relay protection is disabled and GROUP, LOGIC, CAL, or GLOBAL indicates invalid settings class. Otherwise, OK is displayed.

The relay settings become invalid by either: (1) setting LOGVAL or VALID to N using the **SET** command, or (2) copying ROM default settings into EEPROM. This occurs when new EEPROMs are installed in the relay, or when the relay is turned off and on after an EEPROM failure.

TARGET

The **TARGET** command displays the target values, and defines the target group used for each target display. The relay maintains a separate target display for each relay display device (the serial ports and the front-panel display).

Entering **TARGET** displays the currently selected target group. To view a different target, enter the target number (0–45) after the target command: use **TAR 15** to see target 15. Subsequent **TARGET** commands will now show target 15 as the default. (Note: The number of targets varies with relay version and number of I/O boards— see *Relay Elements* in **Section 2: Specifications**.) To view a particular target without changing the default, enter an “X” after the target number. **TAR 3 X** shows target 3, but subsequent **TARGET** commands will continue to show target 15. To view a number of target samples, enter the number of times to view the target (1–32000) after the target number. Enter **TAR 44 1000** to repeatedly view the relay inputs on an SEL-321-5 Relay with one I/O board.

When showing multiple samples of targets, the target header repeats every eighth row.

The active target group for the particular display device defaults to TAR 1 when the device (port/panel) times out, the **QUIT** command is executed, or the **TAR R** command is executed.

The **TAR R** command, when executed from any display device, resets the front-panel targets to TAR 1. All targets are listed in Tables 2.6 through 2.17.

Target information may also be accessed from the front panel (see **Target Command** under **Front-Panel Operation**).

```
=>>TAR 3
Z4GT   Z3GT   Z2GT   LOP    M4PT   M3PT   M2PT   OPA
0       0       0       1       0       0       0       0
=>>
```

TIME

The **TIME** command displays and sets 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>
23:30:00
=>
```

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

TRIGGER

The **TRIGGER** command generates an event record. The command is a convenient way to record all inputs and outputs from the relay at any time you desire (e.g., testing or commissioning).

```
=>TRIGGER <ENTER>
Triggered
=>

EXAMPLE: BUS B, BREAKER 3      Date: 12/01/95      Time: 00:03:34.892
Event: EXTC      Location: $$$$$$      Frequency: 60.0
Targets: EN                      V1 Mem: 0.0 / 180
=>
```

FRONT-PANEL OPERATION

The SEL-321-5 Relay front panel, shown in Figure 3.2, includes a 2-line, 16-character LCD display, 16 LED target/indicators and eight pushbuttons for enhanced communications.

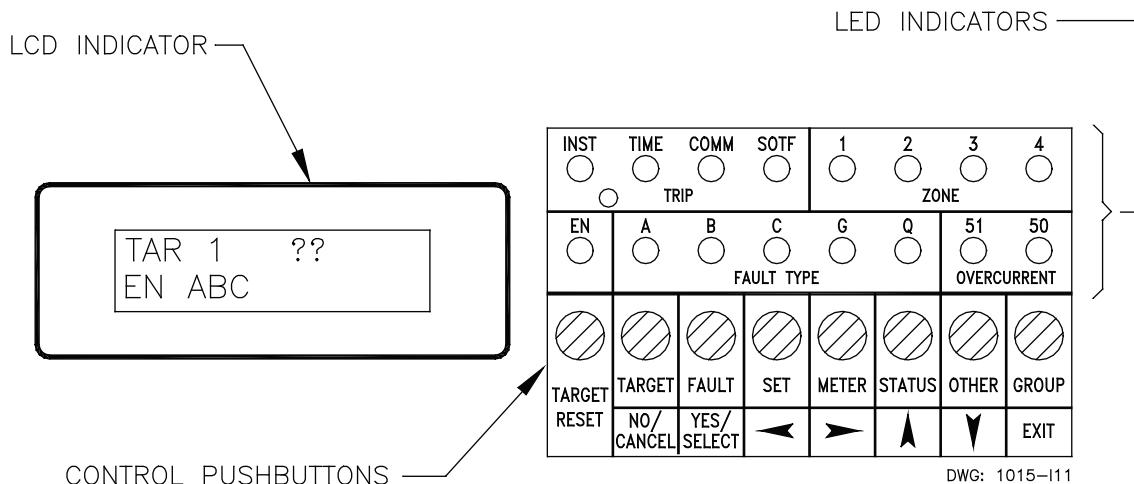


Figure 3.2: SEL-321-5 Relay Front-Panel Display

LCD FUNCTIONS AND FRONT-PANEL COMMANDS

The LCD display shows fault detection information, metering information, target reset and status display, and self-test status. The display is controlled with eight multi-function pushbuttons that have two corresponding sets of legends. The top row of legends describes button functions for command selection and the bottom row describes specific commands within dialogs. Pushbutton commands and the corresponding LCD displays are discussed below. Table 3.14 lists commands available from the front-panel control pushbuttons.

Table 3.14: Commands Available From Front Panel

Command	Buttons	See Table	Format	Application	Minimum Access Level
SET	SET	3.18	SET SET 1	Set active group Set Group 1	2
SET G	SET	3.19	SET G	Set input assignments Set front-panel timeout Set group change delay	2
SET P	SET	3.20	SET P 1	Set Port 1	2
TARGET	TARGET	3.15	TAR 1	View target row 1	1
TARGET RESET	TARGET RESET	None	TARGET RESET	LED lamp test target reset and trip unlatch	1
BRE 2AC QUI	OTHER	None	OTHER	BREAKER Level Access Access Level 2 access Return to Access Level 1	1
FAULT	FAULT	3.16	FAULT	View event history information	1
METER	METER	None	METER	View voltage and current inputs	1
STATUS	STATUS	3.17	STATUS	Display self-test status	1
GROUP	GROUP	3.18	GROUP	View group variable	1
			GROUP	Change group variable	B

Front-Panel Reset

If no buttons are pressed on the front panel, the relay waits a time period specified in the FP_TIMEOUT setting and then takes the following actions:

- The front-panel LCD display resets to the default target display.
- The front-panel access level reverts to Access Level 1.
- The LCD backlighting is turned off.
- Any routine being executed via a front-panel command is interrupted.
- The target LEDs revert to the default targets.

FP_TIMEOUT is set to 5 minutes at the factory and can be set from 0 to 30 minutes by using the SET G command.

Target Reset

The left-most button is dedicated to the TARGET RESET function. Pressing TARGET RESET causes the front-panel LEDs to illuminate for a one-second lamp test then all target LEDs are

cleared except for the LED labeled EN, which is illuminated. It clears trips (TPA, TPB, and TPC elements) if the trip condition has gone away. It clears automatic diagnostic messages from the front-panel LCD display.

Default Display

If no other display modes are selected, the first line of the LCD display shows the trip target string and the second line contains fault information.

Target Command

Press the TARGET button to display contents of the target registers. Push the Up and Down Arrow (\uparrow and \downarrow) buttons to change the target number and view the LEDs. Push the EXIT button or CANCEL button to return to the default display. While the target command is selected, the bottom row of LEDs and value in the LCD display follows the target values as they are updated, thus allowing a monitor function of the targets. Table 3.15 shows a typical TARGET command dialog. The last target row is 40 for a relay with one I/O board, and is 43 for a relay with two I/O boards.

Table 3.15: Target Command Description

Button Pushed	Results Displayed	Comment
TARGET	TAR 1 $\uparrow\downarrow$ EN	Target strings shown from TAR Row 1 in Logic Description <i>Section 2: Specifications</i> . EN (enabled) is displayed.
	TAR 0 $\uparrow\downarrow$	TAR Row 0 displayed.
	TAR 43 $\uparrow\downarrow$	The last target row is displayed. (\downarrow) starts counting down from the last target. (\uparrow) counts up from target 0.
	TAR 0 $\uparrow\downarrow$	Pressing (\uparrow) with target 43 displayed returns to the TAR 0 display.
SELECT	TAR 9 $\uparrow\downarrow$ MORE→ 50Q4 50Q3 50Q2	(\uparrow) was pressed until TAR 9 was displayed. Second line displays elements picked up. Scroll right to display more elements. Pressing CANCEL or EXIT while in this display causes selected target to revert to default display of TAR 1.
EXIT	DEFAULT DISPLAY	Defaults to display seen before TARGET button was pushed unless an event occurred that would normally update the display, in which case the updated information will be displayed.

Fault Command

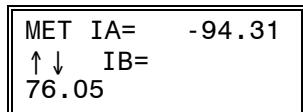
Push the FAULT button to display event history records. Use the (↑) and (↓) buttons to scroll between event records, and the (←) and (→) buttons to scroll between fields within a record. Push the EXIT or CANCEL button to return to the default display. The SELECT button has no effect in this mode. Table 3.16 shows a typical FAULT command dialog.

Table 3.16: Fault Command Description

Button Pushed	Results Displayed	Comment
FAULT	<div style="border: 1px solid black; padding: 5px;">1 DATE 12/01/92 TIME 2342:51.732</div>	Displays Date/Time of first event record.
→	<div style="border: 1px solid black; padding: 5px;">1 DATE 12/01/92 TYPE: 1ABC</div>	Displays second field of first event record, showing event faulted phase and type.
→	<div style="border: 1px solid black; padding: 5px;">1 DATE 12/01/92 DIST: 75.13</div>	Displays third field of first event record, showing distance to fault. \$\$\$\$\$\$ may be displayed under some conditions to indicate indeterminate fault location, or event is caused by TRIGGER command.
→	<div style="border: 1px solid black; padding: 5px;">1 DATE 12/01/92 GROUP 5</div>	Displays fourth field of first event record, showing setting group.
↑	<div style="border: 1px solid black; padding: 5px;">2 DATE 12/01/92 TIME 2356:31.238</div>	Displays Date/Time of second event record. Pressing (↓) displays previous event record, (↑) next event record.
EXIT	<div style="border: 1px solid black; padding: 5px;">DEFAULT DISPLAY</div>	Defaults to display seen before TARGET button was pushed unless an event occurred that would normally update the display, in which case the updated information will be displayed.

Meter Display

The METER display is updated every second. Two meter values are displayed at a time. Use the (↑) and (↓) keys to move between meter pairs.



Group Selector

When you select GROUP from Access Level 1, the active group and the group variable are shown. To change Groups from the front panel, you first enter Access Level 2 or Breaker Access

Level by using the **OTHER** command (see *Password Access*). To change the group, use the up arrow to increment the group variable, the down arrow to decrement it. When the desired group variable is displayed, press SELECT/YES. The display shows:

Execute Group x
Are you sure?

If you choose SELECT/YES again, the keyboard group changes to the group selected. If the group selection logic and inputs are in a state that uses the entered group as the active group, the active group will be switched to the entered group. If you choose CANCEL/NO, the group command is aborted and the default display is shown. (See also *Section 2: Specifications* for discussion of group selection.)

Status Display

When you select STATUS, a STATUS report is displayed. The first row indicates if a warning or failure state exists, or if all self-tests have passed. Use the (↑) and (↓) keys to scroll through the status display. For a complete description of the messages, see the *Self-Test* portion of *Section 2: Specifications*. An example STATUS command dialog is shown in Table 3.17. Front-panel status/failure messages include:

Status Messages

OS:IA = 0
OS:IB = 0
OS:IC = 0
OS:VA = 0
OS:VB = 0
OS:VC = 0
OS:MOF = 0
+5V_PS = 4.86
+5V_REG = 5.10
-5V_REG = -4.98
+12V_REG = 11.93
-12V_REG = -12.03
+15V_PS = 15.02
-15V_PS = -15.21
TEMP = 26.1
RAM = OK or U1-8
ROM = OK or U28-31
A/D = OK or FAIL
CR_RAM = OK, GRP1-6, GLO, CAL, or CODE
EEPROM = OK, GRP1-6, GLO, or CAL
SETTINGS = OK

If one of these items has failed or is in a warning state, a “F” or a “W” is appended to the message. (Also see Table 2.23: Self-Test Summary.)

Table 3.17: Status Command Description

Button Pushed	Results Displayed	Comment
STATUS	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> STATUS: FAIL TEMP 20.1 </div>	If there is no failure STATUS: OK is displayed. In either event the temperature in degrees Celsius is displayed. Use the (↓ and ↑) to display status categories in groups of two.
↑	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> OS:IA= 0 OS:IB= 0 </div>	Pressing (↑) selects the next categories.
↑	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> OS:IC= 0 OS:VA= 0 </div>	
↑	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> OS:VB= 0 OS:VC= 0 </div>	

Diagnostic Messages

The first line of the front-panel display may contain a diagnostics message; the second line will then show the former first line.

Password Access

Press OTHER. A three-command OTHER MENU is displayed: 2AC, BRE, and QUI. QUI returns the front-panel to Access Level 1. With BRE or 2AC displayed, press SELECT and enter your password for Breaker Access Level or Access Level 2 by scrolling through the set of valid password characters displayed with the (↑) and (↓) buttons. Use the (←) and (→) buttons to move the cursor between characters. Use the SELECT button to deposit the selected character in the password position and advance the active password character. Press EXIT to complete the password entry and validate the password. If you press CANCEL before the password is completely entered, the cursor moves to the active password position and you must use the arrow buttons and the SELECT button to select a new active password character position.

Setting Changes via Front Panel

To make settings from the front panel, you first enter Access Level 2 by using the **OTHER** command (see **Password Access**). There are three settings options: SET GROUP (group settings, Table 3.18), SET G (Global settings, Table 3.19), and SET P (port settings, Table 3.20). When you select the setting dialog, the relay comes up in SET GROUP. Push the Left or Right (← →) buttons to scroll the change settings options. The following example begins after Level 2 is accessed.

Table 3.18: Status Command Description

Button Pushed	Results Displayed	Comment
SET	<div style="border: 1px solid black; padding: 5px; text-align: center;"> SET GROUP SELECT ↑ ↓ ← → </div>	Pressing SET causes the display to come up in SET GROUP. Press SELECT to enter the editing mode for GROUP settings.
SELECT	<div style="border: 1px solid black; padding: 5px; text-align: center;"> SET GROUP 1 SELECT ↑ ↓ ← → </div>	The active setting group is shown. Press the (↑) button to move to higher setting group, or the (↓) button to go to lower setting group.
↑	<div style="border: 1px solid black; padding: 5px; text-align: center;"> SET GROUP 2 SELECT ↑ ↓ ← → </div>	Setting group next higher in order is selected. When the desired choice is in the display, press SELECT. See Section 5: Applications for a complete list of Group Settings.
SELECT	<div style="border: 1px solid black; padding: 5px; text-align: center;"> Line Terminal SELECT ↑ ↓ ← → </div>	<p>Use the (→) or (↓) buttons to move down the list of settings categories and (←) or (↑) to move back up the list. Use the SELECT button to select a settings category. The setting categories appear in the order listed below.</p> <p style="margin-left: 40px;">Line Terminal Dist Zone Enable Zones/Levels Dir Phase Distance Phase Dist OC Mho Ground Dist Quad Ground Dist Gnd Dist O/C Sup Zero-Seq Comp Out-of-Step Load Encroach Neg-Seq Direct Phase TOC Residual TOC Residual O/C Negative-Seq TOC Neg-Seq O/C Elem Voltage Elements Time-Step Backup Perm Overreach DCUB Scheme Zone 1 Extension REJO SOTF LOP Logic Misc Scheme Logic</p>

Button Pushed	Results Displayed	Comment
		Misc Timers
→	Dist Zone Enable SELECT ↑ ↓ ← →	If you press the (→) or (↓) button at the bottom of the list, relay displays Save Settings YES/NO prompt to end session.
→	Zone/Levels Dir SELECT ↑ ↓ ← →	Next category on list selected.
→	Phase Distance SELECT ↑ ↓ ← →	Next category selected again. Press SELECT button to enter the edit mode. Pressing SELECT after making settings saves the settings when the session ends. Pressing NO/CANCEL at any time terminates existing setting.
SELECT	Phase Distance Z1P = 6.24	Once you select a settings category, use the (↑ ↓) button to scroll among settings in the category. Use the (←) and (→) arrow to select the previous or following category.
↓	Phase Distance Z2P = 9.36	Next variable Z2P is displayed within Phase Distance settings.
SELECT	Phase Distance Z2P = +00009.3 <u>6</u>	Press SELECT to enter edit mode. Use the (←) and (→) buttons to select character to edit. Character selected is underscored.
←	Phase Distance Z2P = +00009. <u>36</u>	Use arrow buttons to edit setting values. For settings with limited number of choices, use the (→) or (←) buttons to move within lists. An (*) indicates an item from a list. For numerical values, use the (←) and (→) buttons to move between digit positions. In each position, use the ↑ button to increment the digit, the ↓ button to decrement. When the desired value is displayed, push SELECT to move to the next setting.
↑	Phase Distance Z2P = +00009. <u>4</u> 6	Pressing (↑) incremented the selected digit.

Button Pushed	Results Displayed	Comment
SELECT	Phase Distance Z3P = 1.87	After you have set the last variable of a subgroup, the next upper-level menu item is displayed. Repeat the process until all desired changes are made. To exit, saving all changes, push the EXIT button, followed by the SELECT button.
EXIT	Save Settings Yes/No?	If you press YES/SELECT, an internal diagnostic checks settings for allowable ranges, and if the resultant settings are OK, the settings are changed. If settings are NOT OK, one of the next displays appears.
	FAIL MORE→	See Table 3.7 for an interpretation of failure messages. Use ($\leftarrow \rightarrow$) keys to read message, then EXIT or CANCEL to resume. The settings editing process is re-entered so you may change the setting.
	WARN MORE→ Warning:	Scheme requirements are checked for and, if not found, a warning message is displayed. See Table 3.7 for a list of warning messages. Use ($\leftarrow \rightarrow$) keys to read warning messages then EXIT or CANCEL to resume.
EXIT	DEFAULT DISPLAY	If settings are OK, changes are saved and display defaults to information shown before SET button was pushed.

Table 3.19: Set G Command Description

Button Pushed	Results Displayed	Comment
SET	SET GROUP SELECT ↑ ↓ ← →	Pressing SET causes the display to come up in SET GROUP. Press (\leftarrow) to get to SET G.
←	SET G SELECT ↑ ↓ ← →	Press SELECT to enter the editing mode for SET G settings.
SELECT	SET G IN1 = 52A1	Shows present setting for first setting category: IN1. Press (\downarrow or \rightarrow) to move to next category.
↓	SET G IN2 = PT	Next setting category is displayed. Press (\uparrow or \leftarrow) to return to previous category.

Button Pushed	Results Displayed	Comment
↑	SET G IN1 = 52A1	Returns to previous category. Press SELECT to display possible selections for this category.
SELECT	SET G IN1 = 52A1 *	(*) at end of line shows you are in list function. Press (← or →) to move through list of entries.
→	SET G IN1 = 52A2 *	New entry is shown for IN1. While in list function, press (↑ or ↓) to insert or remove NOT (!) function in front of entry.
SELECT	SET G IN2 = Pt	List function is exited, new setting for IN1 was saved, and next category (IN2) is displayed.

Table 3.20: Set P Command Description

Button Pushed	Results Displayed	Comment
SET	SET GROUP SELECT ↑ ↓ ← →	Pressing SET causes the display to come up in SET GROUP.
→	SET P SELECT ↑ ↓ ← →	Press (→) to step through setting choices.
SELECT	SET P 1 SELECT ↑ ↓ ← →	Press (→) to select the port desired. Shows Port 1 selected. Press SELECT to enter edit mode.
SELECT	SET P 1 PROTOCOL = SEL	Shows present protocol setting for this port. Press (↓) to move to next setting category for Port 1.
↓	SET P 1 SPEED = 19.2	Shows present baud rate setting for this port. Press SELECT to enter list mode and select new baud rate.
SELECT	SET P 1 SPEED = 19.2 *	(*) at end of line indicates list mode entered. Press (← or →) to step through list of baud rate selections.
→	SET P 1 SPEED = 300 *	New baud rate is displayed. Press SELECT to save new baud rate and move to next setting category for Port 1.
SELECT	SET P 1 DATA_BITS = 8	Shows present DATA_BITS setting for this port. Press SELECT to enter list mode and select new DATA_BITS.

Button Pushed	Results Displayed	Comment
→	SET P 1 DATA_BITS = 7 *	New DATA_BITS is displayed. Press SELECT to save this choice and move to next setting category for Port 1.
SELECT	SET P 1 PARITY = N	Shows present PARITY setting for this port. Press SELECT to enter list mode and select new setting.
SELECT	SET P 1 PARITY = N *	(*) at end of line indicates list mode entered. Press (← or →) to step through list of PARITY selections.
→	SET P 1 PARITY = E *	New PARITY is displayed. Press SELECT to save this choice and move to next setting category for Port 1.
SELECT	SET P 1 STOP = 1	Shows present STOP bits setting for this port. Press SELECT to enter the list mode and select new setting.
SELECT	SET P 1 STOP = 1 *	(*) at end of line indicates list mode entered. Press (← or →) to step through list of STOP selections.
→	SET P 1 STOP = 2 *	New STOP Bits is displayed. Press SELECT to save this choice and move to next setting category for Port 1.
SELECT	SET P 1 TIMEOUT = 0	Shows present TIMEOUT setting for this port. Press SELECT to enter edit mode and select new setting.
SELECT	SET P 1 TIMEOUT=+0000000	Seven digit number is displayed with an underscored digit representing a cursor. Press (← or →) to move from digit to digit. Press (↑ or ↓) to change the underscored digit. Press SELECT to save this setting and move to next category.
SELECT	SET P 1 AUTO = N	Shows Port 1 not presently designated AUTO. Press SELECT to enter list mode and select new setting.
SELECT	SET P 1 AUTO = N *	(*) at end of line indicates list mode entered. Press (← or →) to step through list of AUTO selections.
→	SET P 1 AUTO = Y *	New AUTO setting is displayed. Press SELECT to save this choice and move to next setting category for Port 1.

Button Pushed	Results Displayed	Comment
SELECT	<pre data-bbox="523 304 833 382">SET P 1 RTS_CTS = N</pre>	Shows RTS_CTS for Port 1 set to N. Press SELECT to enter list mode and select new setting.
SELECT	<pre data-bbox="523 424 833 502">SET P 1 RTS_CTS = N *</pre>	(*) at end of line indicates list mode entered. Press (\leftarrow or \rightarrow) to step through list of RTS_CTS selections.
\rightarrow	<pre data-bbox="523 544 833 623">SET P 1 RTS_CTS = Y *</pre>	New RTS_CTS setting is displayed. Press SELECT to save this choice and move to next setting category for Port 1.
SELECT	<pre data-bbox="523 665 752 734">Save Settings Yes/No?</pre>	Press SELECT again to save settings and exit the SET P edit session. Press CANCEL to abort new settings.

SEL-321-5 TARGET INFORMATION

SEL-321-5 Relay

TAR	Status Indicators							
0	INST	TIME	COMM	SOTF	ZONE1	ZONE2	ZONE3	ZONE4
1	EN	A	B	C	G	Q	51	50
2	Z4G	Z3G	Z2G	Z1G	M4P	M3P	M2P	M1P
3	Z4GT	Z3GT	Z2GT	LOP	M4PT	M3PT	M2PT	OPA
4	67Q4	67Q3	67Q2	67Q1	67N4	67N3	67N2	67N1
5	67Q4T	67Q3T	67Q2T	OST	67N4T	67N3T	67N2T	OSB
6	PD1	3P27	27L	50H	50MF	51NT	51QT	51PT
7	ZLOAD	SOTFE	TCM	CC	3PO	SPO	REJO	PD2
8	3P50R	51NP	51QP	51PP	50G	50PP	50M	50L
9	50Q4	50Q3	50Q2	50Q1	50N4	50N3	50N2	50N1
10	50ABC	X6ABC	X5ABC	3PT	TPC	TPB	TPA	32QF
11	3P59	59L	59N	59PR	59PB	59NL	59PL	50Q
12	BTX	GDS	STOP	START	FIDEN	FSC	FSB	FSA
13	32QR	KEY3	KEY1	EKEY	Z3RB	ATB	ECTT	KEY
14	XAG4	XAG3	XAG2	XAG1	MAG4	MAG3	MAG2	MAG1
15	XBG4	XBG3	XBG2	XBG1	MBG4	MBG3	MBG2	MBG1
16	XCG4	XCG3	XCG2	XCG1	MCG4	MCG3	MCG2	MCG1
17	MBC4	MBC3	MBC2	MBC1	MAB4	MAB3	MAB2	MAB1
18	SPOC	SPOB	SPOA	*	MCA4	MCA3	MCA2	MCA1
19	50HH	OSTI	50CA	50BC	50AB	*	*	*
20	Z1X	27C	27B	27A	USOSB	ROK	3PSOTF	TOP
21	LP1	SS3	SS2	SS1	EXT	DT	BT	PT
22	EXTUL	PARC	PARB	PARA	SPTE	PTXFR	LP2	LOG
23	LP3	CLOSE	52AC2	52AC1	52AB2	52AB1	52AA2	52AA1
24	LP5	LP4	TCMC2	TCMC1	TCMB2	TCMB1	TCMA2	TCMA1
25	DTA	DTB	DTC	LP6	LP7	LP8	LP9	LP10
26	RB8	RB7	RB6	RB5	RB4	RB3	RB2	RB1
27	RB16	RB15	RB14	RB13	RB12	RB11	RB10	RB9
28	ZT	Z	YT	Y	XT	X	W	V
29	RAG4	RAG3	RAG2	RAG1	MER	MTO	MTU	MTCS
30	RCG4	RCG3	RCG2	RCG1	RGB4	RGB3	RGB2	RGB1
31	50AL4	50AL3	50AL2	50AL1	VPOLV	N3PT	L3PT	PTRX
32	50CL4	50CL3	50CL2	50CL1	50BL4	50BL3	50BL2	50BL1
33	50G4	50G3	50G2	50G1	50CL	50BL	50AL	CBAD
34	OSB4	OSB3	OSB2	OSB1	50PP4	50PP3	50PP2	50PP1
35	TS	TC	TB	TA	ZLOUT	ZLIN	ILOP	50P
36	SPT_EN	OSBC	OSBB	OSBA	LBOK	52AC	52AB	52AA
37	50AB4	50AB3	50AB2	50AB1	ATPC	ATPB	ATPA	50PPL
38	50CA4	50CA3	50CA2	50CA1	50BC4	50BC3	50BC2	50BC1
39	RBAD	51NR	51QR	51PR	FTG	FTA	FTB	FTC

SEL-321-5 TARGET INFORMATION

SEL-321-5 Relay—One I/O Board Version

TAR	Status Indicators							
40	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8
41	OUT9	OUT10	OUT11	OUT12	OUT13	OUT14	OUT15	!ALARM
42	TMB8	TMB7	TMB6	TMB5	TMB4	TMB3	TMB2	TMB1
43	MIRBRK	MIRFRA	MIRPAR	MIROVR	MIRIN	MIRSYC	MIRDAT	MIRDIS
44	IN8	IN7	IN6	IN5	IN4	IN3	IN2	IN1
45	RMB8	RMB7	RMB6	RMB5	RMB4	RMB3	RMB2	RMB1

SEL-321-5 Relay—Two I/O Board Version

TAR	Status Indicators							
40	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8
41	OUT9	OUT10	OUT11	OUT12	OUT13	OUT14	OUT15	!ALARM
42	OUT17	OUT18	OUT19	OUT20	OUT21	OUT22	OUT23	OUT24
43	OUT25	OUT26	OUT27	OUT28	OUT29	OUT30	OUT31	OUT32
44	TMB8	TMB7	TMB6	TMB5	TMB4	TMB3	TMB2	TMB1
45	MIRBRK	MIRFRA	MIRPAR	MIROVR	MIRIN	MIRSYC	MIRDAT	MIRDIS
46	IN8	IN7	IN6	IN5	IN4	IN3	IN2	IN1
47	IN16	IN15	IN14	IN13	IN12	IN11	IN10	IN9
48	RMB8	RMB7	RMB6	RMB5	RMB4	RMB3	RMB2	RMB1

SEL-321-5 RELAY 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 for one second.

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 for one second.

BREAKER Answer password prompt (if password protection is enabled) to enter breaker control Access Level B. Allows execution of OPEN, CLOSE, GROUP *n*, and Access Level 1 commands.

COMM Displays MIRRORED BITS® communications summary data.

COMM C Clears MIRRORED BITS communications data.

COMM L Displays MIRRORED BITS communications data.

DATE Shows or sets date. DATE 2/3/92 sets date to Feb. 3, 1992. IRIG-B time code input overrides existing month and day settings. DATE pulses ALARM contacts when year entered differs from year stored.

EVENT Shows event record. EVE 1 shows newest event; EVE 12 shows oldest. Default report is 1/4-cycle standard, EVE *n* L = 1/16-cycle standard, EVE *n* R = 1/16-cycle unfiltered, EVE *n* C = 1/16-cycle SEL-5601-2 SYNCHROWAVE® Event Software Report, EVE *n* U = 1/16-cycle unfiltered.

GROUP Shows setting group to use in lieu of active group.

HISTORY Shows DATE, TIME, ZONE/TYPE, LOCATION (distance), GROUP, and front-panel targets for the last 40 events.

IRIG Force immediate attempt to synchronize internal relay clock to time code input. Reports ID, Date, Time, or Error Message.

METER Displays meter data.

QUIT Returns control to Access Level 0; returns target display to Relay Targets TAR O. Displays ID, Date, and Time.

SHOWSET *n* Shows active group settings for Group *n*. Shows active relay group settings if *n* omitted.

SHOWSET C Shows calibration settings.

SHOWSET G Shows Global settings.

SHOWSET L Displays active logic settings. Append group number (1–6) to display the logic settings of that group.

SHOWSET P	Shows the settings of the active port. Append port number (1–3) to display the settings of that port.
STATUS	Shows self-test status.
TIME	Shows or sets time. TIME 13/32/00 sets clock to 1:32:00 p.m. IRIG-B synchronization overrides this setting.
TRIGGER	Triggers an event report.

Access Level B

CLOSE	Asserts the CLOSE condition.
GROUP	Specifies currently selected group. Use GROUP <i>n</i> to change selected group to <i>n</i> .
OPEN	Asserts trip condition.

Access Level 2

COPY <i>m n</i>	Copies settings and logic from setting Group <i>m</i> to Group <i>n</i> .
LOOP	Enables MIRRORED BITS loopback mode for testing communications.
LOOP R	Disables MIRRORED BITS loopback.
PASSWORD	Shows or sets passwords. Command pulses ALARM contacts closed momentarily after password entry. PAS 1 OTTER sets Access Level 1 password to OTTER. PAS 2 TAIL sets Access Level 2 password to TAIL.
PULSE <i>n t</i>	Closes an output contact for testing and control purposes.
RDMEM <i>m</i>	Use to download contents of selected memory areas. <i>m</i> = RAM, EEPROM or ALL.
SET <i>n</i>	Use to enter group settings. If <i>n</i> argument omitted, edits active group.
SET G	Use to enter new Global settings.
SET L	Use SET L <i>n</i> to edit the logic settings of Group <i>n</i> . Selects active logic group to edit.
SET P	Use SET P <i>n</i> to edit the settings of Port <i>n</i> . Changes settings of the active port.
TARGET	Shows target values, and defines target group for display. TAR <i>n</i> displays target row <i>n</i> . TAR R command resets front-panel targets to TAR 1.

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SECTION 4: EVENT REPORTING

EVENT REPORT GENERATION

The relay generates event reports in response to the actions listed in Table 4.1. Four different event report formats are available. Which event report format you select to review depends upon the amount of data resolution you require. These formats are:

- Summary Quick review of critical fault information for operations personnel
- Default 1/4-cycle data resolution for quick review of routine relay operations
- Long 1/16-cycle data resolution for detailed review
- Computer Use with the SEL-5601-2 SYNCHROWAVE® Event Software for detailed review and oscilloscope plotting

All summary event reports are automatically sent to all communications ports designated as AUTO in the relay setting communications port settings. The relay can store up to 12 event reports (see the **EVENT** subsection in *Section 3: Communications* for more details).

Table 4.1: Event Report Triggering Actions

- | |
|---|
| <ul style="list-style-type: none">• Any tripping element assertions (TPA, TPB, TPC, or 3PT)• TRIGGER command execution• Assertion of any element in the MER (mask for event report trigger) logic variable• External Trigger input assertions |
|---|

For event reports triggered by TPA, TPB, TPC, or 3PT assertion, the TYPE designation is appended with a “T.” This makes it easy to distinguish between event reports that involve a trip and those which do not.

Table 4.2 lists relay elements that must assert for the relay to record a fault type and fault location in the event report. If none of these elements assert and any action listed in Table 4.1 is true, the relay generates an event report but does not list a fault type or calculate a fault location.

Table 4.2: Event Report Fault Type and Fault Location Enabling Elements

Fault Type	Elements				
Phase-to-phase or three-phase	M1P	M2P	M3P	M4P	
Single-Line-Ground	Z1G 67N1	Z2G 67N2	Z3G 67N3	Z4G 67N4	51NP

Event records taken with no triggering relay elements have the type shown in Table 4.3.

Table 4.3: Event Record Type

Type	Comment
TRIP	Report triggered by TPA, TPB, TPC, or 3PT assertion, no fault.
EXT	Report triggered by assertion of EXT (external trigger) designated input.
EXTC	Report triggered by TRIGGER command.
ER	Report triggered by MER SELOGIC® control equations, but no fault detecting element asserted at trigger instant.

The MER mask triggers event reports on the rising-edge of the first element in the mask. The relay does not generate multiple event reports when additional relay elements within MER pick up; only the first relay element of any continuous sequence triggers an event report.

Tripping and External Trigger events are rising-edge sensitive. For these events, event reports are generated independent of the state of MER. The relay triggers a second report for the same event if TPA, TPB, TPC, or 3PT asserts. Thus, the relay records the beginning and end of each event. A second event report is not provided, however, if TPA, TPB, TPC, or 3PT first assert at or less than 7 cycles after the first report is triggered.

Event report triggering and time stamping is referenced to the 16th quarter-cycle of data with 1/8-cycle resolution.

SUMMARY EVENT REPORT

The summary report is automatically transmitted to port(s) designated AUTO regardless of access level. The summary event report includes:

- Line terminal identifier (set in the relay setting procedure)
- Date and time
- Event type (see Table 4.4) and fault location
- System frequency at the time of the trip (this is 1/16th of the sampling frequency at the time of the trip)
- Front-panel relay targets asserted at the last row of the event report
- The magnitude and angle of positive-sequence polarizing voltage memory at the time of trigger

Table 4.4: Event Types

Event Type	Comment
AG	A ϕ to Ground Fault
BG	B ϕ to Ground Fault
CG	C ϕ to Ground Fault
AB	AB Two-Phase Fault
BC	BC Two-Phase Fault
CA	CA Two-Phase Fault
ABG	AB Two-Phase to Ground Fault
BCG	BC Two-Phase to Ground Fault
CAG	CA Two-Phase to Ground Fault
ABC	Three-Phase Faults

The following shows an example summary event report:

```
-----  
Example: BUS B, BREAKER 3          Date: 02/01/96      Time: 01:36:50.070  
Event   : AG T  Location:  2.43  Frequency: 50.2  
Targets: INST ZONE 1 EN AG        V1 Mem: 131.2/77  
=>  
-----
```

The relay retains the summary event report buffer when control power is removed. Long event report data are cleared when control power is removed.

DEFAULT EVENT REPORT

Generate the default event report by using the **EVENT x** command, with no format specifier. These reports default to 11-cycle duration, four samples/cycle, and resemble the reports from the SEL-100/200 series relays. Each report contains voltages, currents, factory selected relay elements, inputs and outputs. These reports support analysis of most relay operations. The default report analog data are sampled every 1/16-cycle, but display every quarter-cycle. Binary elements (relay elements, contact inputs, and contact outputs) are displayed as follows:

- If an element is set at any time during a quarter-cycle period, it is displayed as set; otherwise, it is cleared. Given that elements A and B pick up in alternate 1/8-cycles, but not simultaneously, and assuming that element C = A*B, the filtered report would show A and B true, but C false, because A and B were not picked up at the same time.

LONG EVENT REPORT

The long event report is output in response to the **EVENT x L** command. The Header, Summary, and Settings sections of the long report are identical to the default report. The event report body differs as follows:

The “L” format option increases the event report resolution to 16 samples/cycle. The bodies of the 4 and 16 samples/cycle reports differ as follows:

- The 16 samples/cycle report has four times as many data rows (total of 11 cycles · 16 rows/cycle = 176 rows).
- The element and contact input and output columns are sampled every 1/8-cycle, and displayed in 1/16-cycle format. If an element asserts for 1/8-cycle, it would indicate assertion for two rows in the long event report.

COMPUTER EVENT REPORT

Generate the computer event report by using the **EVENT n C** command. This format provides complete relay element data by attaching a hexadecimal representation of the relay elements on a per processing interval basis. This report is a 16-samples/cycle report. All inputs, outputs, and relay elements are shown in the computer event report.

UNFILTERED EVENT REPORT

Generate the unfiltered event report by using the **EVENT x U** command. These reports are identical to the EVE C event report, except that the analog data are not digitally filtered. Use the unfiltered event report in computer analysis of data.

MIRRORED BITS[®] DISPLAY EVENT REPORT

Generate an event report where TMB1 through TMB8 replaces OUT1 through OUT8 and RMB1 through RMB8 replaces IN1 through IN8 by appending any of the event report commands listed above with a space M. With the exception of the display of the first eight inputs and outputs, the remainder of the M form of the event report is identical.

INTERPRETATION OF QUARTER-CYCLE VOLTAGE AND CURRENT DATA

The relay uses secondary quantities presented to the input terminals of the relay. One line of data is displayed for each quarter-cycle. Voltages and currents are shown in primary quantities. The value in each column of the default event report is calculated and scaled as follows:

I_R Calculated I_R value, multiplied by CTR from group active at time of trigger.

I_A, I_B, I_C Sampled, filtered value, multiplied by CTR from group active at time of trigger.

V_A, V_B, V_C Sampled, filtered value, multiplied by PTR from group active at time of trigger.

Analog data are filtered by an analog low-pass filter with a cutoff frequency of 540 Hz. A digital filter processes the sampled data and removes dc and ramp components. The digital filter is a full cycle long, cosine filter centered on the sensed frequency.

Successive lines of the event report occur every 90 degrees. With respect to the present value, the previous value was taken one quarter-cycle earlier and appears to be leading the present value by 90 degrees.

Quarter-cycle event report values can be used to represent the signals as phasors:

The previous value of the output is the Y-component.

The present value of the output is the X-component.

It may seem confusing to refer to the older data as the leading component of the phasor. The following example may help.

Consider a sine wave 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 $t + 90^\circ$ are 1 and 0; its phasor representation is $(0, 1)$. The phasor $(0, 1)$ leads the phasor $(1, 0)$ by 90° . This coincides with a 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 from an area of interest in the quarter-cycle event report. On Cartesian coordinates, plot the lower row (newer data) as the X-components and the upper row (older data) as the Y-components. Rotate the completed diagram to any angle of reference. The magnitude of any phasor equals the square root of the sum of its squares.

Note that moving forward one quarter-cycle rotates all phasors 90° degrees. You can verify this by plotting the phasor diagram with rows 1 and 2, then rows 2 and 3 of an event report. Example Event 1 shows the process of converting the rectangular format voltages and currents displayed in the event report to polar format.

RELAY ELEMENT COLUMNS DATA

The states of all relay elements are indicated in the columns headed “Relay Elements.” Active states of the various relay elements are indicated by designator symbols, which correspond with the relay element names. The contents of the columns for active relay elements appear as follows.

<u>Column</u>	<u>Value</u>	<u>Description</u>
ZAB	.	If no AB phase-to-phase distance element set
	1	If Zone 1 AB phase-to-phase distance element (MAB1) set
	2	If Zone 2 AB phase-to-phase distance element (MAB2) set, not ZAB1
	3	If Zone 3 AB phase-to-phase distance element (MAB3) set, not ZAB1 or ZAB2
	4	If Zone 4 AB phase-to-phase distance element (MAB4) set, not ZAB1 or ZAB2 or ZAB3
ZBC	.	If no BC phase-to-phase distance element set
	1	If Zone 1 BC phase-to-phase distance element (MBC1) set
	2	If Zone 2 BC phase-to-phase distance element (MBC2) set, not ZBC1
	3	If Zone 3 BC phase-to-phase distance element (MBC3) set, not ZBC1 or ZBC2
	4	If Zone 4 BC phase-to-phase distance element (MBC4) set, not ZBC1 or ZBC2 or ZBC3
ZCA	.	If no CA phase-to-phase distance element set
	1	If Zone 1 CA phase-to-phase distance element (MCA1) set
	2	If Zone 2 CA phase-to-phase distance element (MCA2) set, not ZCA1
	3	If Zone 3 CA phase-to-phase distance element (MCA3) set, not ZCA1 or ZCA2
	4	If Zone 4 CA phase-to-phase distance element (MCA4) set, not ZCA1 or ZCA2 or ZCA3
ZAG	.	If no AG mho or quadrilateral ground distance element asserted
	1	If Zone 1 AG element (XAG1 + MAG1) set
	2	If Zone 2 AG element (XAG2 + MAG2) set, not ZAG1
	3	If Zone 3 AG element (XAG3 + MAG3) set, not ZAG1 or ZAG2
	4	If Zone 4 AG element (XAG4 + MAG4) set, not ZAG1 or ZAG2 or ZAG3
ZBG	.	If no BG mho or quadrilateral ground distance element asserted
	1	If Zone 1 BG element (XBG1 + MBG1) set
	2	If Zone 2 BG element (XBG2 + MBG2) set, not ZBG1
	3	If Zone 3 BG element (XBG3 + MBG3) set, not ZBG1 or ZBG2
	4	If Zone 4 BG element (XBG4 + MBG4) set, not ZBG1 or ZBG2 or ZBG3

<u>Column</u>	<u>Value</u>	<u>Description</u>
ZCG	.	If no CG mho or quadrilateral ground distance element asserted
	1	If Zone 1 CG element ($XCG1 + MCG1$) set
	2	If Zone 2 CG element ($XCG2 + MCG2$) set, not ZCG1
	3	If Zone 3 CG element ($XCG3 + MCG3$) set, not ZCG1 or ZCG2
	4	If Zone 4 CG element ($XCG4 + MCG4$) set, not ZCG1 or ZCG2 or ZCG3
OOS	t	OOS timing
	B	OOS Block ($OSB * !OST$)
	T	OOS Trip (OST)
32		Negative-sequence directional element decision.
		There are two negative-sequence directional elements. Both directional elements cannot be asserted at the same time. The following labeling system is used in the 32 column:
	F	forward (32QF)
	R	reverse (32QR)
	.	none
51N	.	No 51N condition ($!51NT * !51NP$)
	p	51N timing ($51NP * !51NT$)
	T	51N tripped (51NT)
51Q	.	No 51Q condition ($!51QP * !51QT$)
	p	51Q timing ($51QP * !51QT$)
	T	51Q tripped (51QT)
51P	.	No 51P condition ($!51PP * !51PT$)
	p	51P timing ($51PP * !51PT$)
	T	51P tripped (51PT)
50P	.	No 50P condition ($!50L * !50M * !50H$)
	L	Low-set overcurrent ($50L * !50M * !50H$)
	M	Medium-set overcurrent ($50M * !50H$)
	H	High-set overcurrent (50H)
67N	.	No 67N elements set ($!67N1 * !67N2 * !67N3 * !67N4$)
	1	Zone 1 67N (67N1)
	2	Zone 2 67N ($!67N1 * 67N2$)
	3	Zone 3 67N ($!67N1 * !67N2 * 67N3$)
	4	Zone 4 67N ($!67N1 * !67N2 * !67N3 * 67N4$)

<u>Column</u>	<u>Value</u>	<u>Description</u>
67Q	.	No 67Q elements set (!67Q1 * !67Q2 * !67Q3 * !67Q4)
	1	Zone 1 67Q (67Q1)
	2	Zone 2 67Q (!67Q1 * 67Q2)
	3	Zone 3 67Q (!67Q1 * !67Q2 * 67Q3)
	4	Zone 4 67Q (!67Q1 * !67Q2 * !67Q3 * 67Q4)
LOP	.	No LOP condition (!LOP)
	*	LOP condition (LOP)

CONTACT INPUTS AND OUTPUTS COLUMNS

The columns headed “Outputs” and “Inputs” show the states of the first eight outputs and the first eight inputs. (These are either the physical outputs and inputs or the MIRRORED BITS outputs and inputs. The **EVE 1 L M** command shows the long form the event report with TMB1 through TMB8 and RMB1 through RMB8 occupying the last columns of the event report.)

Since there are only four columns under each heading, the outputs and inputs are paired in groups of two. If an output is asserted in the first column, a “1” or “2” appears in the column to indicate which output is asserted. If both inputs are asserted, a “B” would appear under the associated column. A period indicates deassertion. All outputs and inputs are assignable. The most important output functions should be assigned to the first eight outputs because they are the only outputs displayed in the standard event report. The following list shows the contents of these columns:

<u>Outputs</u>	<u>Inputs</u>
1 & 2: Output 1 and Output 2	1 & 2: Input 1 and Input 2
3 & 4: Output 3 and Output 4	3 & 4: Input 3 and Input 4
5 & 6: Output 5 and Output 6	5 & 6: Input 5 and Input 6
7 & 8: Output 7 and Output 8	7 & 8: Input 7 and Input 8

EXAMPLE EVENT REPORTS

Example Event Report 1

Example: BUS B, BREAKER 3 FID=SEL-321-5-R951-V516124pb-D960409								Date: 02/01/96	Time: 08:54:29.577
CURRENTS (pri)				VOLTAGES (kV pri)		RELAY	ELEMENTS	OUT	IN
IR	IA	IB	IC	VA	VB	VC	BCAGGGG	555566L	1357 1357
-4	-447	320	123	-129.3	89.1	40.7
-2	-112	-328	438	-27.8	-98.5	125.8
3	447	-320	-124	129.3	-89.1	-40.7
-1	111	327	-439	27.8	98.4	-125.8

One cycle of data
(Quarter-cycle event report)

SEL DIRECTION AND POLARITY CHECK FORM

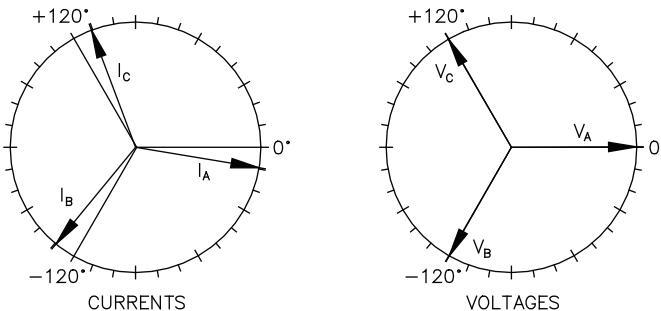
STATION Example 230 kV Line DATE: 02/01/93 TESTED BY _____
 SWITCH NO. _____ EQUIPMENT SEL-321
 INSTALLATION _____ ROUTINE OTHER X

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(a)	I(b)	I(c)	V(a)	V(b)	V(c)
1st LINE CHOSEN (Y COMPONENT)	-447	320	123	-129.3	89.1	40.7
2nd LINE CHOSEN (X COMPONENT)	-112	-328	438	-27.8	-98.5	125.8
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$	460.8	458.2	454.9	132.3	132.8	132.2
ANGLE IN DEGREES ARCTAN Y/X	-104.1	135.7	15.7	-102.1	137.9	17.9
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0	+102.1	+102.1	+102.1	+102.1	+102.1	+102.1
④ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM	-2.0	-122.2	117.8	0	-120.0	+120.0

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



DWG: A7-0446.321

Example Event Report 2

BUS B, BREAKER 3								Date: 02/01/96	Time: 08:54:29.577	Date and time-tag correspond to the 16th quarter-cycle of this event report.	
								Firmware Identification Code			
CURRENTS (pri)				VOLTAGES (kV pri)				RELAY ELEMENTS	OUT	IN	
								ZZZZZZO	555566L	1357	1357
								ABCABCO	31110770	&&&	&&&
								BCAGGGS	2NQPPNQP	2468	2468
-4	-447	320	123	-129.3	89.1	40.7L....	1....	
-2	-112	-328	438	-27.8	-98.5	125.8L....	1....	
3	447	-320	-124	129.3	-89.1	-40.7L....	1....	
-1	111	327	-439	27.8	98.4	-125.8L....	1....	
											One cycle of data
-6	-448	319	123	-129.3	89.1	40.7L....	1....	
-3	-113	-328	438	-27.8	-98.4	125.8L....	1....	
3	447	-320	-124	129.3	-89.1	-40.7L....	1....	
0	112	327	-439	27.8	98.4	-125.8L....	1....	
											Input 1 (1) is energized
-5	-447	319	123	-129.3	89.1	40.7L....	1....	
-3	-113	-328	438	-27.8	-98.4	125.8L....	1....	
2	446	-320	-124	129.3	-89.1	-40.7L....	1....	
0	112	327	-439	27.8	98.4	-125.8L....	1....	
											50L element asserted
-6	-448	319	123	-129.3	89.1	40.6L....	1....	
-2	-112	-328	438	-27.9	-98.4	125.8L....	1....	
-582	-138	-320	-124	118.9	-93.4	-44.8L....	1....	
1345	1457	327	-439	21.3	95.3	-129.0	Fpp.M...	1....	
											32QF element asserts 51N element asserts, event trigger
810	368	319	123	-93.4	104.0	55.3	Fpp.M...	1....	
-3301	-3411	-328	438	-14.7	-92.1	132.2	-1....	Fpp.H...	B4..	1....	
-459	-15	-320	-124	78.4	-110.4	-61.6	-1....	Fpp.H...	B4..	1....	
3905	4017	327	-439	14.7	92.0	-132.2	-1....	Fpp.H...	B4..	1....	
											50M element asserts Zone 1, A-phase ground distance asserted
456	14	319	123	-78.4	110.4	61.6	-1....	Fpp.H...	B4..	1....	
-3907	-4017	-328	438	-14.7	-92.0	132.2	-1....	Fpp.H...	B4..	1....	
-460	-15	-321	-124	78.3	-110.5	-61.6	-1....	Fpp.H...	B4..	1....	
3904	4016	327	-439	14.7	92.0	-132.3	-1....	Fpp.H...	B4..	1....	
											50H element asserted
459	16	320	123	-78.3	110.4	61.6	-1....	Fpp.H...	B4..	1....	
-3907	-4017	-328	438	-14.8	-92.0	132.3	-1....	Fpp.H...	B4..	1....	
126	479	-206	-147	80.1	-108.5	-46.7	-1....	Fpp.H...	B4..	1....	
2555	2610	228	-283	35.0	82.3	-129.8	-1....	Fpp.H...	B4..	1....	
											KEY bit asserted
-359	-489	45	85	-98.0	111.4	15.1	-1....	Fpp.H...	B4..	1....	
-604	-602	-65	63	-61.5	-69.0	130.1	-1....	Fpp.M...	B4..	
0	1	-1	0	114.2	-116.3	1.5	Fpp.M...	B4..	
-2	-1	-1	0	67.8	65.3	-132.8	Fpp...	B4..	
											Both OUT1 and OUT2 outputs asserted by 3PT bit
-2	-2	0	0	-114.2	116.4	-1.6	B4..	
-1	0	0	-1	-67.8	-65.2	132.8	B4..	
1	2	-1	0	114.2	-116.4	1.6	B4..	
-1	-1	0	0	67.8	65.2	-132.8	B4..	
-4	-3	0	-1	-114.2	116.4	-1.6	B4..	
0	1	0	-1	-67.9	-65.2	132.8	B4..	
2	2	0	0	114.2	-116.4	1.6	B4..	
-3	-2	-1	0	67.8	65.2	-132.8	B4..	
-2	-2	0	0	-114.2	116.4	-1.6	B4..	
0	1	0	-1	-67.9	-65.2	132.8	B4..	
-1	1	-1	-1	114.2	-116.4	1.6	B4..	
-3	-2	-1	0	67.9	65.2	-132.8	B4..	
Event: AG Location: +14.92 Frequency: 50.0								A-phase ground fault at 14.92, system frequency is 50 Hz			
Targets: INST ZONE1 EN A G								Front panel targets, V1 memory mag [kV] and angle referenced to A-phase at the trigger instant			
V1 Mem: 132.1 / 77								continued to next page			

continued from previous page

GROUP 1
RELID =SEL-321 POTT
TRMID =BUS B, BREAKER 3
Z1MAG = 39.00 Z1ANG = 83.97 ZOMAG = 123.95 ZOANG = 81.46
LOCAT = Y LL = 100.00 CTR = 200.0 PTR = 2000.0
PMHOZ = 3 GMHOZ = 3 QUADZ = 3
DIR1 = F DIR2 = F DIR3 = R DIR4 = F
Z1P = 31.19 Z2P = 46.79 Z3P = 9.35
50PP1 = 0.51 50PP2 = 0.44 50PP3 = 0.49
Z1MG = 31.20 Z2MG = 46.79 Z3MG = 9.35
XG1 = 31.20 XG2 = 46.79 XG3 = 9.35
RG1 = 12.50 RG2 = 25.00 RG3 = 30.00
50L1 = 0.18 50L2 = 0.18 50L3 = 0.26
50G1 = 0.18 50G2 = 0.12 50G3 = 0.10
K01M = 0.726 k01A = -3.69 k0M = 0.726 k0A = -3.69 T = 0.00
E00S = N
ELE = Y ZLF = 46.09 ZLR = 46.09
PLAF = 30 NLAF = -30 PLAR = 150 NLAR = 210
Z2F = 3.85 50QF = 0.10 Z2R = 27.25 50QR = 0.10 a2 = 0.07
E51P = N
E51N = Y 51NP = 0.15 51NC = C2
51NTD = 2.00 51NRS = Y 51NTC = 32QF
E50N = N
E51Q = Y 51QP = 0.44 51QC = C2
51QTD = 0.20 51QRS = N 51QTC = 32QF
E50Q = N
EVOLT = N
Z2PD = 20.00 Z3PD = 0.00
Z2GD = 20.00 Z3GD = 0.00
EPOTT = Y Z3RBD = 5.00 EBLKD = 10.00
ETDPU = 2.00 EDURD = 4.00
EDCUB = N
EZ1EXT= N
EREJO = N
ESOTF = Y ENCLO = Y CLOEND= 10.00 EN52A = N
SOTFD = 30.00 50H = 2.25
ELOP = Y LOPD = 3.00 50M = 0.47 59QL = 14.00 59PL = 14.00
EPOLD = N ESPT = N ESP0 = N OPO = 52
3POD = 1.50 ESTUB = Y 50MFD = 20.00 TULO = 3
TDURD = 9.00 TOPD = 0.00 TXPU = 0.00 TXDO = 0.00
TYPY = 0.00 TYDO = 0.00 TZPU = 0.00 TZDO = 0.00 ITTD = 5.00

SELogic group 1 ————— SELOGIC Control Equations for Group 1

V =NA
W =NA
X =NA
Y =NA
Z =NA
MTCS =M2P + Z2G
MTU =M1P + Z1G + M2PT + Z2GT + 51NT + 51QT + 50MF
MTO =M1P + M2P + Z1G + Z2G + 50H
MER =M2P + Z2G + 51NP + 51QP + 50H + LOP*52AA1
OUT1 =3PT
OUT2 =3PT
OUT3 =CC
OUT4 =KEY
OUT5 =NA
OUT6 =NA
OUT7 =NA
OUT8 =NA
OUT9 =NA
OUT10 =NA
OUT11 =NA
OUT12 =NA
OUT13 =NA
OUT14 =NA
OUT15 =NA

IN1 = 52A1 IN2 = PT IN3 = CLOSE IN4 = NA
IN5 = NA IN6 = NA IN7 = NA IN8 = PTXFR
FP_TIMEOUT= 5 TGR = 5

————— Global Settings

FIRMWARE IDENTIFICATION

The SEL-321-5 Relay provides a means of interpreting Firmware Identification Data (FID). The FID string is included near the top of each long event report. The string format is as follows:

$$\text{FID} = [\text{PN}] - \text{R}[\text{RN}] - \text{V}[\text{VS}] - \text{D}[\text{RD}],$$

Where:

- [PN] = Product Name (e.g., SEL-321-5)
- [RN] = Revision Number (e.g., 100)
- [VS] = Version Specifications (e.g., 516112)
- [RD] = Release Date (e.g., YYMMDD = 960201)

For the SEL-321-5 Relay, version specifications are interpreted as follows:

$$\text{V}[\text{VS}] = \text{V}[\text{ABCDEFG}]$$

Option	Specifier	Specifier Meaning	Option Description
A	5	50 Hz	Power System Frequency
B	1	1 A	Nominal Amperes per Phase
C	6	67 V	Nominal Volts per Phase
D	1	Standard 300	Front-Panel Type
E	1, 2	1 bank, 2 banks	Number of Banks of Digital Inputs
F	2, 4	2 banks, 4 banks	Number of Banks of Contact Outputs
G	p, n	abc, abc	Phase Rotation Sequence

Contact Schweitzer Engineering Laboratories for more information concerning available versions of the relay (see **Technical Support** in **Section 7: Maintenance and Testing**). Version specifications provided above are not intended for ordering purposes but to help users identify software installed in a relay.

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SECTION 5: APPLICATIONS

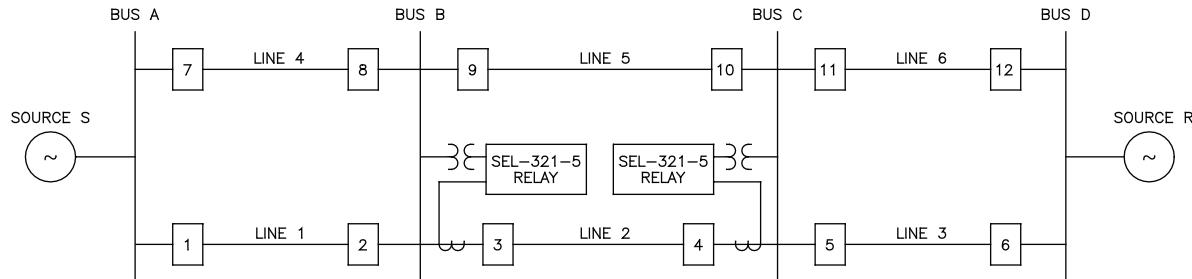
A 230 kV APPLICATION EXAMPLE FOR POTT SCHEME WITH TIME-STEPPED BACKUP

Purpose

The following is an example of a possible SEL-321-5 Relay installation. The example shown is for a 1 A nominal relay.

This example shows the steps for setting the relay at Breaker 3 to protect Line 2 in Figure 5.1 between Buses B and C. The basic criteria for protecting this line appear below:

- The communications scheme is permissive overreaching transfer trip.
- Zone 2 serves as time-step backup.
- Current reversals may occur at the Breaker 3 location.
- The maximum expected load is less than 450 A.



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Figure 5.1: 230 kV Setting Example System Single-Line Diagram

System Data

The pertinent system information for this setting example is presented in Table 5.1.

Table 5.1: System Data for 230 kV Setting Example

Nominal System Voltage	: 230 kV (132.8 kV line-neutral)	
Line Length	: 100 miles	
Line 2 and Line 5 Impedances:		
Positive-sequence	: $Z_1 = 78.03 \angle 83.97^\circ$	(primary Ω)
Zero-sequence	: $Z_0 = 247.95 \angle 81.46^\circ$	(primary Ω)
Line 1 and Line 4 Impedances	: $Z_1 = 78.24 \angle 83.72^\circ$	(primary Ω)
	: $Z_0 = 239.55 \angle 81.56^\circ$	(primary Ω)
Line 3 and Line 6 Impedances	: $Z_1 = 39.12 \angle 83.72^\circ$	(primary Ω)
	: $Z_0 = 119.78 \angle 81.56^\circ$	(primary Ω)
Source S Impedance	: $Z_{1S} = 17.95 \angle 87.67^\circ$	(primary Ω)
	: $Z_{0S} = 14.99 \angle 80.86^\circ$	(primary Ω)
Source R Impedance	: $Z_{1R} = 3.80 \angle 87.69^\circ$	(primary Ω)
	: $Z_{0R} = 6.02 \angle 80.90^\circ$	(primary Ω)
Current Transformer Ratio	: 1000:1	
Potential Transformer Ratio	: 2000:1	

Relay Settings

Fault voltages and currents in this example are derived from a fault study of the system in Figure 5.1.

Values entered during the actual setting procedure appear in bold immediately after the = prompt in the dashed boxes. A list of all possible relay settings appears in the settings sheet at the end of this section. Use the settings sheet as a worksheet and record for settings.

Relay Terminal Settings

Identifier

The SEL-321-5 Relay has two identifier strings: the Relay Identifier (RELID) and the Terminal Identifier (TRMID). The RELID is typically used to identify the relay or the type of protection scheme. Typical terminal identifiers include an abbreviation of the substation name and line terminal.

The relay tags each event report with the terminal identifier string. This allows you to distinguish the event report as one generated for a specific breaker and substation. The date of the last functional test may also be included for maintenance purposes.

Positive- and Zero-Sequence Line Impedances

The positive- and zero-sequence secondary impedance values should match those calculated for Line 2. All settings for the SEL-321-5 Relay are in secondary quantities. The primary impedances must be divided by the ratio of the selected potential transformer ratio (PTR) to the current transformer ratio (CTR).

Fault Locator Enable and Line Length

This setting allows you to enable or disable the fault locating function or use a radial fault locating method. In this example, as with most applications, the fault locating capability of the relay is desired. The line length is selected to match the distance between Bus B and Bus C.

Current and Potential Transformer Ratios

The CTR selected for this example is 1000:1. The PTR selected for this example is 2000:1.

For the relay at Breaker 3:

```
RELIID = SEL-321 POTT
TRMID = EXAMPLE: BUS B, BREAKER 3
Z1MAG = 39.00
Z1ANG = 83.97
Z0MAG = 123.95
Z0ANG = 81.46
LOCAT = Y
LL = 100.00
CTR = 1000.0
PTR = 2000.0
```

Relay Elements and Other Settings Affected

Values entered for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL are used in the fault locator calculations. Z1ANG also sets the maximum torque angle for the phase and ground mho distance elements.

Enable Desired Distance Zones and Directional Sense

The number of phase mho, ground mho, and quadrilateral distance zones is selectable from zero to four. Each number of distance elements is independently selectable. For example, if the quadrilateral ground distance element is not used, set the QUADZ to N.

Once the number of distance element zones is selected, only the elements necessary for the number of selected zones require settings. This includes the distance element reaches and the supervisory overcurrent settings.

Each distance element zone and residual and negative-sequence overcurrent level direction is independently set for forward or reverse directional sense. All four distance element zones and residual and negative-sequence overcurrent levels must be selected for forward (F) or reverse (R) direction sense.

Each directional setting determines the direction for that distance zone and residual or negative-sequence overcurrent level. For example, with DIR1 = F, the Zone 1 phase and ground distance

elements and the Access Level 1 residual and negative-sequence elements are set in the forward-reaching direction.

For this application, three zones of phase and ground distance protection are required. Zone 1, Zone 2, and Zone 4 elements are set in the forward direction. Zone 3 elements are used in the current reversal block logic and are set in the reverse direction.

```
PMHOZ = 3
GMHOZ = 3
QUADZ = 3

DIR1 = F
DIR2 = F
DIR3 = R
DIR4 = F
```

Relay Elements and Other Settings Affected

Number of distance element and supervisory overcurrent settings.

Phase and Ground Distance Element Setting Criteria

Zone 1 Setting

The Zone 1 elements provide instantaneous protection for phase-to-phase, three-phase, and phase-ground faults in the first 80%–90% of the transmission line. The remainder of the line is protected by the overreaching Zone 2 elements. While the percent error of the impedance element reach is less than 5%, errors in the CT and PT ratios, modeled transmission line data, and fault study data do not permit Zone 1 element settings of 100%.

In this example, the Zone 1 distance elements at Breaker 3 must not reach past Bus C. To prevent overreaching due to the sources of error listed above, the required reach for the Zone 1 three-phase, phase-to-phase, and phase-ground mho distance elements are 80% of the positive-sequence impedance of Line 2.

$$\text{Zone 1 Reach} = 0.80 \cdot 78.03 \Omega \text{ primary } \angle 84^\circ = 62.42 \Omega \text{ primary } \angle 84^\circ$$

The Zone 1 quadrilateral element setting is based upon the same requirements established for the Zone 1 mho elements. The reactive reach is set the same as the mho distance setting. The resistive reach determines sensitivity for high resistance faults on a radial basis. For this example, the Zone 1 resistive reach is set for 25 ohms primary.

Zone 2 Setting

The Zone 2 elements must have adequate reach to detect all phase-to-phase, three-phase, and phase-ground faults along Line 2, but cannot overreach the Zone 1 elements for faults on either Line 3 or Line 6. In this example, the impedances for Lines 3 and 6 are identical.

$$ZL \text{ for Line 2} = 78.03 \Omega \text{ primary}$$

$$ZL \text{ for Line 3} = ZL \text{ for Line 6} = 39.12 \Omega \text{ primary}$$

Zone 2 element settings with a reach of 120% of protected line impedance account for the effects of infeed. This point must be verified by using a fault study to calculate the apparent ohms at the

local terminal for a fault at the remote end of the transmission line. In the example system, 120% is selected for the Zone 2 elements with assurance that all faults in line 2 are detectable, even with infeed from the remote terminals.

Assuming the Zone 1 reach for the line protection at Breakers 5 and 11 is set for 80% of the line impedances of Lines 3 and 6, respectively, verify that a Zone 2 reach of 120% for Breaker 3 does not overreach the Zone 1 elements at Breakers 5 and 11.

$$\begin{aligned}\text{Line 2 Impedance} + [0.8 \cdot \text{Line 3 Impedance}] &= 78.03 \Omega + [0.8 \cdot 39.12 \Omega] \\ &= 109.33 \Omega \text{ primary}\end{aligned}$$

When Zone 2 at Breaker 3 has a set reach of 120%, the effective reach is:

$$\text{Zone 2 at Bkr. 3} = 1.20 \cdot 78.03 \Omega = 93.64 \Omega \text{ primary } \angle 84^\circ$$

Since $93.64 \Omega < 109.33 \Omega$, the Zone 2 setting of 120% at Breaker 3 does not overreach the Zone 1 protection of Lines 3 and 6. Any effect of infeed tends to increase the apparent ohms seen at Breaker 3 for faults on Lines 3 and 6.

The Zone 2 quadrilateral element setting is based upon the same requirement established for the Zone 2 mho elements. The reactive reach is set the same as the mho distance setting. The resistive reach determines sensitivity for high resistance faults on a radial basis. For this example, the Zone 2 resistive reach is set for 50 ohms primary.

Zone 3 Setting

This example uses a permissive overreaching transfer trip (POTT) communications scheme. The current reversal block, echo, and weak-infeed logic require reversal of the Zone 3 elements. The Zone 3 element reach at Breaker 3 must be selected to detect all out-of-section faults also detected by the overreaching elements at Breaker 4. At a minimum, the Zone 3 reach setting must equal the impedance the overreaching element at Breaker 4 sees beyond Breaker 3.

Assuming the Zone 2 reach for the line protection at Breaker 4 is set for 120% of the line impedance of Line 2, the Zone 3 reach at Breaker 3 is set at 120% of the Zone 2 overreach from Breaker 4.

When Zone 2 at Breaker 4 has a set reach of 120%, the effective reach is:

$$\text{Zone 2 at Bkr. 4} = 1.20 \cdot 78.03 \Omega = 93.64 \Omega \angle 84^\circ$$

The Breaker 4 overreach is equal to the Zone 2 setting minus the line impedance:

$$93.64 - 78.03 \Omega = 15.61 \Omega \text{ primary}$$

$$\text{Zone 3 Reach} = 1.2 \cdot 15.61 \Omega \text{ primary } \angle 84^\circ = 18.73 \Omega \text{ primary } \angle 84^\circ$$

The Zone 3 quadrilateral element setting is based upon the same requirement established for the Zone 3 mho elements. The reactive reach is set the same as the mho distance setting. The resistive reach determines sensitivity for high resistance faults on a radial basis. The Zone 3 resistive reach must be set greater than the Zone 2 overreach from the remote end, in this case Breaker 4.

Assuming the same criteria for the relays at Breaker 4, a conservative setting is to set the Zone 3 resistive reach at 120% of the remote Zone 2 setting. For this example, the Zone 3 resistive reach is set for 120% of 50 ohms primary or 60 ohms primary.

Phase Distance Overcurrent Supervision Setting Criteria

The 50PP elements provide fault detector supervision of the phase distance elements and must pick up for all fault conditions where a phase distance element is expected to operate. Each phase distance element is supervised by independent fault detectors.

The ideal setting for the 50PP element is above load but below minimum fault duty for the most remote three-phase or phase-to-phase fault that the distance element zone must detect. Although it is not ideal, you can set 50PP below load to permit distance element operation for end-of-line faults with magnitudes below load.

The 50PP elements are set based upon the phase-to-phase current for both three-phase and phase-to-phase faults. For three-phase faults, the phase current magnitude must be multiplied by the square root of three to determine the phase-to-phase current magnitude. Phase-to-phase currents for phase-to-phase faults can be derived directly from a fault study. In either case, the lowest current magnitude must be used for the fault detector.

Zone 1 Setting

For the relay at Breaker 3, the governing fault condition for the Zone 1 element is a phase-to-phase fault at Bus C with Line 1 or 4 removed from service. The fault study shows that the lowest phase-to-phase fault current equals 850 A primary for this fault. To ensure that the 50PP1 element picks up for the calculated fault current, select some current value below 850 A. In this example, the value selected for the 50PP1 setting is 510 A (approximately 60% of the minimum fault current).

Zone 2 Setting

The governing fault condition for the Zone 2 elements is a phase-to-phase fault at Bus D with Line 1 or 4 removed from service. The fault study shows that the lowest phase-to-phase fault current equals 743 A primary for this fault. To ensure that the 50PP2 element picks up for the calculated fault current, select some current value below 743 A. In this example, the value selected for the 50PP2 setting is 445 A (approximately 60% of the minimum fault current).

Zone 3 Setting

The governing fault condition for the Zone 3 elements is a phase-to-phase fault at Bus A with Line 1 or 4 removed from service. The fault study shows that the lowest phase-to-phase fault current equals 817 A primary for this fault. To ensure that the 50PP3 element picks up for the calculated fault current, select some current value below 817 A. In this example, the value selected for the 50PP3 setting is 490 A (approximately 60% of the minimum fault current).

Ground Distance Overcurrent Supervision Setting Criteria

The ground distance elements are supervised by phase and ground fault detector overcurrent elements. Each zone has an independent phase and ground fault detector overcurrent element.

Before any ground distance element can pick up, the relay must detect phase and residual current greater than the 50L and 50G settings, respectively. Calculate the phase and residual current for the most remote ground fault or highest expected ground fault resistance in which the distance element zone must operate.

Zone 1 Setting

For the relay at Breaker 3 in the system shown in Figure 5.1, the minimum fault condition for the Zone 1 element is a phase-ground fault at Bus C with Line 1 or 4 removed from service. The fault study shows that for this fault, $I_A = 307$ A primary and $I_R = 308$ A primary. To ensure that the 50L1 and 50G1 elements pick up for the calculated fault current, select some current value below the calculated phase and residual current magnitudes.

This value for the 50L1 setting may be below load. In this example, the value selected for the 50L1 setting is 180 A (approximately 60% of the minimum fault current). The value selected for the 50G1 setting is 180 A (approximately 60% of the minimum fault current).

Zone 2 Setting

The minimum fault condition for the Zone 2 element is a phase-ground fault at Bus D with Line 1 or 4 removed from service. The fault study shows that for this fault, $I_A = 306$ A primary and $I_R = 202$ A primary. To ensure that the 50L2 and 50G2 elements pick up for the calculated fault current, select some current value below the calculated phase and residual current. This setting accounts for arc resistance and errors in fault study calculations.

This value for the 50L2 setting may be below load. In this example, the value selected for the 50L2 setting is 180 A (approximately 60% of the minimum fault current). In this example, the value selected for the 50G2 setting is 120 A (approximately 60% of the minimum fault current).

Zone 3 Setting

The minimum fault condition for the Zone 3 element is a phase-ground fault at Bus A with Line 3 or 6 removed from service. The fault study shows that for this fault, $I_A = 432$ A primary and $I_R = 170$ A primary. To ensure that the 50L3 and 50G3 elements pick up for the calculated fault current, select some current value below the phase and residual current magnitudes.

This value for the 50L3 setting may be below load. In this example, the value selected for the 50L3 setting is 260 A (approximately 60% of the minimum fault current). In this example, the value selected for the 50G3 setting is 100 A (approximately 60% of the minimum fault current.)

Distance Element Setting Calculations

All settings for the SEL-321-5 Relay are in secondary quantities. For example, the Zone 1 phase distance element is set as follows:

$$\begin{aligned} \text{Calculations: PTR} &= 2000:1 \quad \text{PTR/CTR} = 2 \\ \text{CTR} &= 1000:1 \end{aligned}$$

$$\text{Zone 1 secondary ohms} = \frac{62.42 \Omega \text{ primary}}{2} = 31.20 \Omega \text{ secondary along the line angle}$$

All phase and ground distance element secondary settings are calculated in the same manner.

All distance elements are supervised by overcurrent elements. For example, the Zone 1 phase distance fault detector is set as follows:

Calculations: CTR = 1000:1

$$50 \text{ PP1 secondary amps} = \frac{510 \text{ A primary}}{1000} = 0.51 \text{ A secondary}$$

All supervisory overcurrent element secondary settings are calculated in the same manner.

Z1P = **31.20**
Z2P = **46.80**
Z3P = **9.35**

50PP1= **0.51**
50PP2= **0.44**
50PP3= **0.49**

Z1MG = **31.20**
Z2MG = **46.80**
Z3MG = **9.35**

XG1 = **31.20**
XG2 = **46.80**
XG3 = **9.35**
RG1 = **12.50**
RG2 = **25.00**
RG3 = **30.00**

50L1 = **0.18**
50L2 = **0.18**
50L3 = **0.26**
50G1 = **0.18**
50G2 = **0.12**
50G3 = **0.10**

Relay Elements and Other Settings Affected

All set distance and overcurrent supervision elements.

Zero-Sequence Compensation Factor and Nonhomogeneous Angle Settings

Zero-Sequence Compensation Factor Setting

The relay uses two zero-sequence compensation factors. The Zone 1 ground distance element has a dedicated zero-sequence compensation factor (k01), and the remaining zones of ground distance protection use a separately set zero-sequence compensation factor (k0).

The zero-sequence compensation factor is set using the following formula:

$$k_0 = (Z_0 - Z_1)/(3 \cdot Z_1)$$

Where:

Z_0 = Zero-sequence impedance
 Z_1 = Positive-sequence impedance

For this example, both zero-sequence compensation factors are set the same and are based upon the protected line impedance.

$$k01 = k0 = [(247.95\Omega \angle 81.47^\circ) - (78.03\Omega \angle 84^\circ)] / (3 \cdot 78.03\Omega \angle 84^\circ) = 0.726 \angle -3.69^\circ$$

Nonhomogeneous Angle Setting

The relay also has a nonhomogeneous angle setting (T) that improves the response of the quadrilateral ground distance element. This may be needed when the source impedances at either end of the line and the line itself all have different impedance angles. This angle setting compensates the reactance characteristic of the quadrilateral element to improve the element accuracy.

To determine a setting for T, run single phase-to-ground faults where potential overreach may be a concern. These locations are typically at the end of the Zone 1 quadrilateral reach or at the remote bus. Compare the total zero-sequence fault current angle at the fault location and the fault current angle from the relay location. If the angles compare closely, the system is considered homogeneous and compensation is not required.

For our setting example, critical fault locations are those at the end of the Zone 1 reach or remote bus fault where Zone 1 overreach is a concern.

For a single phase-to-ground fault at Bus C, the total zero-sequence fault current is 1474 A $\angle -82.7^\circ$. The zero-sequence current contribution from Breaker 3 is 150 A $\angle -82.7^\circ$. Note that the angle between the total fault current and the fault contribution from Breaker 3 is zero. Therefore, the nonhomogeneous compensation is not required and T is set to zero.

```
K01M = 0.726
K01A = -3.69
K01M = 0.726
K01A = -3.69
T = 0
```

Relay Elements and Other Settings Affected

All set ground distance elements.

Out-of-Step Setting

Out-of-step tripping or blocking is not required for this application. The out-of-step elements are disabled by setting EOOS = N.

```
EOOS = N
```

Relay Elements and Other Settings Affected

Relay Elements OSB, OST, X5ABC, X6ABC, and 50ABC.

Load-Encroachment Logic Setting

The relay uses a load-encroachment feature, which prevents operation of the three-phase elements under high load conditions. This unique feature permits load to enter a predefined area of the three-phase distance characteristic without causing a tripout.

The load-encroachment characteristic is defined by a load impedance setting in the forward and reverse directions. Defined angle settings determine the load sector in the forward and reverse direction.

The load-encroachment setting should be based upon maximum load flow conditions on the protected line. The maximum short time load flow could be as high as 900 amperes with Line 5 removed. The maximum conductor current rating is 1200 A. Assuming a 20% short time overload factor, set the load impedance for 1440 A load. Nominal system voltage is 230 kV line-to-line or 132.8 kV line-to-neutral. Assume a load angle range of $\pm 30^\circ$. Both forward and reverse load ranges are assumed to be the same.

Calculations: CTR = 1000:1
PTR = 2000:1

$$I_{load} = \frac{1440}{1000} = 1.44 \text{ A secondary}$$

$$V_{bus} = \frac{138790}{2000} = 66.4 \text{ volts secondary}$$

$$Z_{load} = \frac{V_{bus}}{I_{load}} = \frac{66.4}{1.44} = 46.10 \Omega \text{ secondary}$$

ELE = Y
ZLF = 46.1
ZLR = 46.1
PLAF = 30
NLAF = -30
PLAR = 150
NLAR = 210

Relay Elements and Other Settings Affected

Relay element ZLOAD.

Negative-Sequence Directional Element Settings

The SEL-321-5 Relay uses a unique negative-sequence zero-sequence directional element. The directional element calculates the negative-sequence or zero-sequence impedance at the relaying point and determines the fault direction from the magnitude and sign of the calculated impedance. The relay automatically shifts between sequence impedances depending on fault conditions and available quantities.

To set the forward direction threshold, simply divide the line positive-sequence impedance by three. To determine the reverse directional threshold, multiply the line positive-sequence impedance by two-thirds or 0.66.

This methodology works for most applications. Consult the factory for other setting guidelines for unique applications.

Z2F must be less than Z2R to avoid any overlap where measured Z2 satisfies both forward and reverse conditions. For security reasons, Z2F and Z2R thresholds must be separated by at least 0.1 Ω secondary.

The negative-sequence overcurrent elements, 50QF and 50QR, are set at the minimum setting to provide the maximum sensitivity.

The a2 factor is used to compensate for highly unbalanced systems. This is typical of systems that have many untransposed lines. The a2 compensation is a ratio of the negative-sequence current to the positive-sequence current.

The a2 compensation is typically set based upon the sensitivity requirements of the 50QF and 50QR elements. The a2 factor must be set so that any load derived positive-sequence current does not prevent operation of the directional element at the minimum negative-sequence current value.

Calculation: PTR = 2000:1
CTR = 1000:1

Calculate Z2F for forward faults:

$$\begin{aligned}Z_2F &= \frac{1}{3} \cdot |Z_{1L}| \\&= \frac{1}{3} \cdot (78.03) \cdot \frac{2000}{1000} \\&= 13.0 \Omega \text{ secondary}\end{aligned}$$

Calculate Z2R for reverse faults:

$$\begin{aligned}Z_2R &= \frac{2}{3} \cdot |Z_{1L}| \\&= \frac{2}{3} \cdot (78.03) \cdot \frac{2000}{1000} \\&= 26.0 \Omega \text{ secondary}\end{aligned}$$

For our example, 50QF = 50QR = 0.1 A (3I2). The maximum load on Line 2 is 450 A. For the negative-sequence directional element to operate $I_2 > a_2 \cdot I_1$.

Therefore, the highest a2 setting is:

$$\frac{I_2 \min}{I_1 \text{ load}} = \frac{0.033}{0.45} = 0.074$$

Set a2 to some value less than the calculated values; for our example a2 is selected for 0.07.

Z2F = 13.0
50QF = 0.1
Z2R = 26.0
50QR = 0.1
a2 = 0.07

Relay Elements and Other Settings Affected

Relay Elements 32QF and 32QR

All ground distance elements and all directionally controlled residual and negative-sequence overcurrent elements.

Phase Time-Overcurrent Element Setting

The phase time-overcurrent element is not required for this application. The phase time-overcurrent element is disabled by setting E51P = N.

E51P = N

Relay Elements and Other Settings Affected

Relay elements 51PT and 51PP depend on the 51PP, 51PC, 51PTD, 51PRS, and 51PTC settings.

Residual Overcurrent Settings

Residual Time-Overcurrent Settings.

The residual time-overcurrent element provides current dependent, time-delayed clearance of faults along the protected line and provides backup protection for remote terminals. Because the measure of residual current varies with system switching configuration, fault location, and fault resistance, a complete fault study is necessary to determine the minimum pickup setting, appropriate time dial, and curve characteristic. When the element is directionally controlled, consider only faults in front of the line terminal for coordinating purposes.

For the relay at Breaker 3, a single line-to-ground fault at Bus C with Line 1 or 4 removed dictates the sensitivity required for the residual time-overcurrent pickup. The residual current magnitude for this fault is 308 A primary. To allow for ground fault resistance, a value of 50% of 308 A is selected as the residual time-overcurrent element pickup. The pickup (51NP), time dial (51NTD), and curve family (51NC) selections are assumed to coordinate with the remaining residual time-overcurrent elements of the example system.

Instantaneous/Definite-Time Residual Overcurrent Settings

The residual instantaneous/ definite-time overcurrent elements are not required for this application. The residual overcurrent elements are disabled by setting E50N = N.

Calculations: CTR = 1000:1

$$51\text{NP secondary amps} = \frac{150 \text{ A primary}}{1000} = 0.15 \text{ A secondary}$$

```

E51N = Y
51NP = 0.15
51NC = U3
51NTD = 2.00
51NRS = Y
51NTC = 32QF

E50N = N

```

Relay Elements and Other Settings Affected

Relay elements 51NT and 51NP depend on the 51NP, 51NTD, 51NC and 51NTC settings. Relay elements 50N1, 50N2, 50N3, 50N4, 67N1, 67N2, 67N3, 67N4, 67N2T, 67N3T, 67N4T.

Negative-Sequence Overcurrent Settings

Negative-Sequence Time-Overcurrent Settings

The negative-sequence time-overcurrent element provides current dependent, time-delayed clearance of faults along the protected line and provides backup protection for remote terminals. Because the measure of negative-sequence current varies with system switching configuration, fault location, and fault resistance, a complete fault study is necessary to determine the minimum pickup setting, appropriate time dial, and curve characteristic. When the element is directionally controlled, consider only faults in front of the line terminal for coordinating purposes.

The negative-sequence overcurrent element can provide backup for phase-to-phase or phase-ground faults. For this example, the negative-sequence element provides backup for phase-to-phase faults. Phase-ground faults need only be considered for coordination purposes.

For the relay at Breaker 3, a phase-to-phase fault at Bus C with Line 1 or 4 open dictates the sensitivity required for the negative-sequence time-overcurrent pickup. The negative-sequence ($3I_2$) current magnitude for this fault is 736 A primary. To allow for fault resistance, a value of 60% of 736 A is selected as the negative-sequence time-overcurrent element pickup. The pickup (51QP), time dial (51QTD), and curve family (51QC) selections are assumed to coordinate with the remaining negative-sequence and residual time-overcurrent elements of the example system.

Instantaneous/Definite-Time Negative-Sequence Setting

The negative-sequence instantaneous/definite-time overcurrent elements are not required for this application. The negative-sequence overcurrent elements are disabled by setting E50Q = N.

Calculations: CTR = 1000:1

$$51QP \text{ secondary amps} = \frac{440 \text{ A primary}}{1000} = 0.44 \text{ A secondary}$$

```

E51Q = Y
51QP = 0.44
51QC = U3
51QTD = 2.00
51QRS = N
51QTC = 32QF

E50Q = N

```

Relay Elements and Other Settings Affected

Relay elements 51QT and 51QP depend on the 51QP, 51QTD, 51QC and 51QTC settings. Relay elements 50Q1, 50Q2, 50Q3, 50Q4, 67Q1, 67Q2, 67Q3, 67Q4, 67Q2T, 67Q3T, and 67Q4T.

Voltage Elements

Voltage elements are not required for this application. The voltage elements are disabled by setting EVOLT = N.

```
EVOLT = N
```

Relay Elements and Other Settings Affected

Relay elements 27L, 3P27, 59PB, 59PR, 59N, 59L, and 3P59.

Time-Step Backup Time Delay Settings

The relay provides time-delayed pickup timers for time-stepped backup protection. Separate timers are provided for the Zone 2, 3, and 4 phase and ground distance elements. Timers are provided for all four levels of the residual and negative-sequence overcurrent elements. The residual and negative-sequence overcurrent time delays are independently set.

For our example, three zones of phase and ground distance elements are selected. In this case, the Zone 2 and 3 phase and ground distance time delays must be set. Zone 2 elements must coordinate with downstream Zone 1 elements, plus downstream breaker operating time, plus a safety margin. A typical Zone 2 phase and ground distance time delay setting is 20 cycles.

The Zone 3 element is reverse-reaching and is not required for backup protection. The Zone 3 element is set for a zero time delay and is not set in the tripping mask.

For the relay at Breaker 3:

```
Z2PD = 20.00  
Z3PD = 0.00  
Z2GD = 20.00  
Z3GD = 0.00
```

Relay Elements and Other Settings Affected

Relay elements M2PT, M3PT, Z2GT, and Z3GT.

Permissive Overreaching Scheme Logic

For our application, the tripping scheme is permissive overreaching transfer trip. Setting EPOTT = Y enables the permissive overreaching transfer trip logic and settings. With the permissive tripping logic selected, no settings are required for the Directional Comparison Blocking logic.

The Zone 3 Reverse Block Delay (Z3RBD) timer extends the block signal issued by reverse looking elements after a current reversal occurs and Zone 3 elements drop out. Zone 3 relay elements do not encompass the origin. The recommended time setting for the Z3RBD timer is the remote faulted terminal breaker time plus communications channel reset time, plus remote Zone 2 relay reset time. Assume a typical breaker operation time of three cycles, communications channel reset time of one cycle, and remote Zone 2 relay reset time of one cycle. The sum of these times gives a conservative Z3RBD timer setting of 5 cycles.

The SEL-321-5 Relay includes logic that echoes the received permissive signal back to the remote end after certain conditions are met. This is used in conjunction with the weak-infeed logic so that the relay at the strong terminal may trip even if the relay at the weak terminal does not have any protective elements picked up.

In some applications, with all sources in, one terminal may not contribute enough fault current to operate the protective elements. If the fault lies within the Zone 1 reach of the strong terminal, the fault currents may redistribute after the strong terminal line breaker opens to permit sequential tripping of the weak-infeed terminal line breaker. If currents do not redistribute sufficiently to operate the protective elements at the weak-infeed terminal, it is still desirable to open the local breaker. This prevents the low-level currents from maintaining the fault arc and allows successful autoreclosure from the strong terminal. When the fault location is near the weak terminal, the Zone 1 elements of the strong terminal do not pick up, and the fault does not clear rapidly. This is because the weak terminal protective elements do not operate. Note that while the weak-infeed terminal contributes little fault current, the phase voltage(s) are depressed.

The SEL-321-5 Relay provides additional logic for weak-infeed terminals to permit rapid tripping of both line terminals for internal faults near the weak terminal. The strong terminal is permitted to trip via the permissive signal echoed back from the weak terminal. The weak terminal is tripped by converting the echoed permissive signal to a trip signal after the following conditions are met:

1. No reverse looking elements have picked up. For faults behind the relay location, the reverse elements operate to inhibit the operation of the weak-infeed and echo logic.
2. At least one single-phase undervoltage or the residual overvoltage element operates.
3. The line terminal breaker is closed.
4. A permissive trip signal is received for ETDPU time period. The received PT signal is initiated by the overreaching remote terminal Zone 2 elements.

After these four conditions are met, the weak-infeed logic sets the Echo Conversion To Trip (ECTT) element. This element may be masked in the MTU logic mask to permit tripping the local breaker under the conditions described above.

The echo logic includes timers for qualifying the permissive signal as well as timers for blocking the echo logic for certain conditions. The Echo Block Time Delay (EBLKD) is used to block the echo logic after dropout of local permissive elements. The recommended time setting for the EBLKD timer is the remote faulted terminal breaker time, plus communications channel round trip time, plus some safety margin. Assume a typical breaker operation time of three cycles and communications channel round trip time of two cycles, and a safety margin of 5 cycles to give a conservative EBLKD timer setting of 10 cycles.

An echo delay ensures that the reverse elements at the receiving end have sufficient time to operate and block the echo repeat for faults behind that terminal. It also insulates the Echo and

Weak-Infeed logic (discussed later) against noise bursts that can occur on the communications channel during close-in external faults. Typically, these noise bursts coincide with faults external to the line section.

Since the pickup time of the reverse elements and duration of these noise bursts are very short, the system requires a received permissive signal to be present for a short time before the permissive signal can be echoed back to the remote terminal or used in the Echo Conversion To Trip (ECTT) logic. The Echo Time Delay Pickup (ETDPU) timer specifies the time a permissive trip signal must be present. The ETDPU setting depends upon your communications equipment, but a typical setting for this timer is approximately 2 cycles.

The Echo Duration Time Delay (EDURD) limits the duration of the echoed permissive signal. Once the echo signal is initiated, it should be maintained for a minimum period. The echo signal should be cut off after some time, even if the permissive signal is continuously received. This prevents permissive trip signal lockup between the two line ends. Assume a three-cycle breaker at the remote terminal and half-cycle channel delay. The summation of remote breaker operation time plus channel delay gives an EDURD setting of 4 cycles.

The EWFC setting enables or disables the weak-infeed feature of the relay. When the EWFC setting is Y, the Echo Conversion To Trip (ECTT) logic is enabled. When the setting is N, ECTT logic is disabled.

When weak-infeed tripping is used, typical single-phase undervoltage settings (27L) are 70%–80% of the lowest expected system operating voltage. The residual overvoltage setting should be set to approximately twice the expected standing V_0 voltage. With the 59N element set at twice the nominal standing V_0 voltage, the instrument measures only fault induced zero-sequence voltage. These elements are set in the voltage element settings (EVOLT = Y).

In the sample application, the weak-infeed feature is not required.

```
EPOTT = Y  
Z3RBD = 5.00  
EBLKD = 10.00  
ETDPU = 2.00  
EDURD = 4.00
```

Relay Elements and Other Settings Affected

Relay elements KEY, ECTT, and EKEY.

Directional Comparison Unblocking Scheme Logic

For this application the Directional Comparison Unblocking logic is not required.

The Directional Comparison Unblocking logic is disabled by setting EDCUB = N.

```
EDCUB = N
```

Relay Elements and Other Settings Affected

Relay elements KEY, ECTT, ATB and EKEY.

Zone 1 Extension Logic Setting

For our example the Zone 1 extension logic is not required. Setting EZ1EXT = N, disables the scheme logic.

EZ1EXT = N

Other Relay Elements and Settings Affected

Relay element Z1X.

Remote-End-Just-Opened (REJO) Enable Setting (EREJO)

In the example for the relay at Breaker 3, we select EREJO = N. This disables the REJO logic.

EREJO = N

Other Relay Elements and Settings Affected

Relay elements TA, TB, TC, and 3PT.

Switch-Onto-Fault Logic Setting

The 50H element is intended for use as a high-set nondirectional phase overcurrent detector in the Switch-Onto-Fault logic. If a line breaker is closed into a close-in three-phase bolted fault where line-side potential transformers are used, polarizing voltage for the three-phase distance elements is never established. In this situation, the distance elements do not operate. In this instance, the 50H element is provided to help prevent a failure to trip the line breaker.

The 50H element measures current magnitude in each phase with no dependence on polarizing voltages. This element is nondirectional and should be used only in the switch-onto-fault logic mask (MTO) when the line breaker is closed to test the line on a radial basis. If fault duty in front of the line terminal is much greater than behind it, the 50H element can also be used in the unconditional trip logic mask (MTU) to provide rapid clearance of close-in faults.

Typical 50H settings are 50%–70% of three-phase fault duty at the local bus.

The three-phase fault duty for a fault at Bus B is 4456 A. To ensure rapid clearance of this fault, a 50H setting of 2250 A is selected for this example.

Calculations: CTR = 1000:1

$$50\text{ H secondary amps} = \frac{2250\text{ A primary}}{1000} = 2.25\text{ A secondary}$$

The Switch-Onto-Fault logic may be enabled by change in the 52A status showing the breaker has just closed or by asserting the close input to the relay from the breaker close bus.

The 52A method works well for single or multiple breaker applications.

For a single breaker configuration, using the close bus enable is a better selection. The close enable delay (CLOEND) should be set less than the shortest reclose open interval. The Switch-On-To-Fault Delay (SOTFD) determines how long the SOTF logic is allowed to trip after the breaker is closed.

For our example, the close method is used.

```

ESOTF = Y
ENCLO = Y
CLOEND = 10.00
EN52A = N
SOTFD = 30.00
50H = 2.25

```

Relay Elements and Other Settings Affected

Relay element 50H.

Loss-of-Potential (LOP) Enable Setting (ELOP)

Fuses or molded case circuit breakers often protect the secondary windings of the power system potential transformers. An operation of one or more fuses or molded case circuit breakers results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly discriminating fault direction.

Because occasional loss-of-potential to the relay is unavoidable, detection of this condition is desirable. Once a true LOP condition is detected, you may elect to block distance element operation and issue an alarm.

The relay discriminates between faults (which may reduce voltage magnitudes to nearly zero) and loss-of-potential conditions. The following equation shows the LOP detection logic for the relay:

$$\begin{aligned}
 \text{SET LOP} = & [\text{NOT}(50\text{NF} + 50\text{NR}) * 59\text{NL}] && \text{Detects the presence of zero-sequence voltage in} \\
 & && \text{the absence of zero-sequence current} \\
 & + [\text{NOT}(59\text{PL}) * \text{NOT}(50\text{M})] && \text{Detects the absence of positive-sequence voltage} \\
 & && \text{in the absence of current above the 50M setting}
 \end{aligned}$$

Where:

- 59NL ≡ Low-set zero-sequence overvoltage detector
- 50NF ≡ Low-set residual overcurrent detector
- 50NR ≡ Low-set residual overcurrent detector
- 59PL ≡ Low-set positive-sequence overvoltage detector
- 50M ≡ Low-set phase overcurrent element

For one or more blown PT fuses, the relay declares an LOP condition when the measured zero-sequence voltage exceeds the 59NL setting and the residual current is below the 50NF and 50NR settings. These conditions must exist for the LOPD time delay for the LOP element to set.

For three blown PT fuses, the relay declares an LOP condition when the measured positive-sequence voltage is below the 59PL, and the low-set phase overcurrent detector (50M) is not picked up.

You determine how the relay uses loss-of-potential detection by selecting the ELOP setting. The ELOP setting choices and their associated results are:

- N Relay sets LOP element when LOP condition is detected.
Distance and directional elements are not blocked.
Set the LOP element in a SELOGIC® control equation to indicate condition, if desired.
- Y Relay sets LOP element when LOP condition is detected.
Distance elements are blocked and directional elements default forward.
Set the LOP element in a SELOGIC control equation to indicate the LOP condition, if desired.

The 50NF, 50NR, and 59NL elements are required to be set above the normal expected system unbalance.

The setting for the 50M pickup value requires that the element must never be picked up for load current conditions. The setting must also be below the minimum fault current level for which the relay is required to trip following an LOP condition. In this example, the application should detect a fault at Bus C after an LOP condition is detected. The maximum expected load for this circuit is 450 A. The minimum fault current level for a fault at Bus C is 491 A. Faults at Bus C do not drop the positive-sequence voltage at Bus B below 14 V. With a small margin for fault study and CT performance error, the 50M setting for this example is 475 A.

$$50\text{ M secondary amps} = \frac{475 \text{ A primary}}{1000} = 0.47 \text{ A secondary}$$

For the relay at Breaker 3:

```
ELOP = Y
LOPD = 3.00
50M = 0.47
59NL = 14.00
59PL = 14.00
```

Relay Elements and Other Settings Affected

All set distance and directionally controlled overcurrent elements.

Miscellaneous Scheme Logic

In our application, we are using three-pole tripping only and pole-discordance is not required. To disable the Pole-Discordance logic, set EPOLD = N.

The relay is required to trip three-pole only for this application. Setting ESPT = N and ESPO = N disables the single-pole tripping logic.

In this bus-side PT application, we use the breaker auxiliary status and undercurrent element logic to determine pole-open conditions. Thus, we set the open-pole option setting (OPO) equal to 52.

The 3POD dropout delay timer is used to prevent operation of the ground distance element when all three poles do not close simultaneously. When a breaker is closed, the ground distance

elements are blocked for 3POD time. The 3POD dropout time delay should be set for the worst case pole scatter upon breaker closure. For our application a setting of 1.5 cycles is required.

In applications where a portion of the bus (or stub of the bus) is energized by a closed breaker, yet the line is de-energized and isolated by an open disconnect switch, the relay provides definite-time phase overcurrent protection. Distance protection is not applicable if line-side PTs are employed. This logic can only be performed if LOP is enabled.

The stub protection may also be used for definite-time overcurrent protection when the relay detects a loss-of-potential. With ESTUB = Y, set the 50MFD timer to the appropriate delay. The Stub Protection logic is only allowed to trip when the relay detects an LOP condition and the phase current exceeds the 50M pickup threshold.

The relay also provides four methods of trip unlatch (open the trip contact) logic. If no trip unlatch logic is selected, trip output remains closed for the greater duration of the fault or the trip duration timer. The four trip unlatch methods are as follows:

- Option 1 allows the trip contact to open if the trip condition has reset, the minimum trip duration (TDURD) expires, and the lowest set 50L, 50QF, or 50QR element is not picked up.
- Option 2 allows the trip contact to open if the trip condition has reset, the minimum trip duration (TDURD) expires, and the 52A contact has changed state showing the breaker has opened.
- Option 3 allows the trip contact to open if the trip condition has reset, the minimum trip duration (TDURD) expires, the 52A contact has changed state showing the breaker has opened, and the lowest set 50L, 50QF, or 50QR element is not picked up.
- Option 4 allows the trip contact to open if the trip condition has reset, the minimum trip duration (TDURD) expires, and the input assigned to EXTUL is asserted.

For our example, Option 3 is used.

```
EPOLD = N
ESPT  = N
ESPO  = N
OPO   = 52
3POD  = 1.50
ESTUB = Y
50MFD = 20.00
TULO  = 3
```

Relay Elements and Other Settings Affected

Relay element 50MF.

Miscellaneous Timers

The SEL-321-5 Relay provides dedicated timers for additional relay element variables so that you may create your own scheme logic. The minimum trip duration, trip during open pole, and instantaneous trip time declaration timers are also included in these settings.

The minimum Trip Duration timer (TDURD) setting determines the minimum length of time the TA, TB, TC, and 3PT relay element asserts. These relay elements are used to control a designated

trip contact. The trip output contacts close for the greater of the TDURD time or the duration of the trip condition. A typical setting for this timer is 150 ms or nine cycles.

The trip during Pole Open Time Delay (TOPD) is not used in the three-pole tripping logic and is set to zero.

Timers are provided for the X, Y, and Z SELOGIC control equation variables. This allows you to invent your own protection or control schemes by using the internal relay elements.

The Instantaneous Trip Time (ITT) declaration delay qualifies a maximum time for instantaneous targeting. This is determined by the time an element set in the trip equation is picked up before the trip output is asserted. If the element is picked up for less than the ITT time before the trip output, it is declared an instantaneous trip for targeting purposes.

For our example, we have to set the minimum trip duration timer and the instantaneous trip time declaration delay.

```
TDURD = 9.00
TOPD  = 0.00
TXPU  = 0.00
TXDO  = 0.00
TYPU  = 0.00
TYDO  = 0.00
TZPU  = 0.00
TZDO  = 0.00
ITTD   = 5.00
```

Relay Elements and Other Settings Affected

XT, YT, and ZT time-delayed SELOGIC control equations variable outputs.

SELOGIC Control Equations

Programming SELOGIC control equations consists of assigning functions to the programmable inputs, designing the internal logic functions your application requires, expressing the logic in terms of the relay element and internal logic variables, and finally defining the output functions.

Additionally, you may program intermediate logic points and the output contacts with SELOGIC control equations. This permits you to combine any element in Tables 2.7, 2.9, or 2.12 in **Section 2: Specifications**. Use nondedicated timers for special applications, and assign these combinations to output contacts.

Logic Variable Equations

Five programmable logic variables are provided, which allow you to design your own internal logic conditions. For our example, these variables are not required.

Tripping Logic Equations

There are three logic equations that must be set for tripping.

The MTCS logic equation determines which elements trip via the communications-based logic. Typically the overreaching Zone 2 elements are set in the MTCS logic equation.

The MTU logic equation determines which elements trip unconditionally. Typically all direct tripping and time-delayed tripping elements are set in the MTU logic equation.

The MTO logic equation defines which elements are enabled to trip while SOTFE is asserted. All elements set in this equation trip instantaneously, if they assert during the SOTFD time. This is referred to as the Switch-On-Fault logic.

For our example, all of the instantaneous and time-delayed tripping elements are set in MTU. The overreaching Zone 2 elements are set in MTCS. Since the elements set in the MTO are enabled to trip for SOTFD time, the 50H and all overreaching and underreaching instantaneous elements are set in this equation.

Event Report Trigger Condition Logic

The relay allows selection of which elements trigger an event report (MER logic mask). An event report is always generated when the relay issues a trip. However, there may be other conditions that require event report generation.

For our example, event reports are generated when the time-delayed tripping elements time out, when the high-set phase overcurrent element picks up, and on loss-of-potential when the breaker is closed.

Output Contact Logic

Each output contact is programmed using SELLOGIC control equations. For our example, the relay is required to trip three-pole, close the breaker via the **CLOSE** command, and key the permissive trip signal.

The remaining contacts can be used for local substation annunciation, sequence-of-events recording, or SCADA indication. These requirements are dictated by your particular relay application.

```
V      =  NA
W      =  NA
X      =  NA
Y      =  NA
Z      =  NA
MTCS   =  M2P + Z2G
MTU    =  M1P + Z1G + M2PT + Z2GT + 51NT + 51QT + 50MF
MTO    =  M1P + M2P + Z1G + Z2G + 50H
MER    =  M2P + Z2G + 51NP + 51QP + 50H + LOP * 52AA1
OUT1   =  3PT
OUT2   =  3PT
OUT3   =  CC
OUT4   =  KEY
OUT5   =  NA
OUT6   =  NA
OUT7   =  NA
OUT8   =  NA
OUT9   =  NA
OUT10  =  NA
OUT11  =  NA
OUT12  =  NA
OUT13  =  NA
OUT14  =  NA
OUT15  =  NA
TMB1   =  NA
TMB2   =  NA
TMB2   =  NA
TMB3   =  NA
TMB4   =  NA
```

TMB5	= NA
TMB6	= NA
TMB7	= NA
TMB8	= NA

Global Input Settings

The eight logic inputs may be assigned to any of the variables listed in Table 2.9 in **Section 2: Specifications**. For our example, the relay logic requires a 52A input, the received permissive trip signal, the breaker close signal, and an indication from the potential transfer switch.

Miscellaneous Global Settings

Settings are also required for the front-panel time-out and the group switching delay.

The front-panel time-out defines a time duration in which the relay takes certain actions if no activity occurs via the front panel after the set time period. The actions taken are as follows:

- The front-panel LCD display is reset to the default display.
- The front-panel access level reverts to Access Level 1.
- The backlighting for the LCD is turned off.
- Any routine that is being executed via a front-panel command is interrupted.
- Target LEDs revert to the default targets.

The factory-default setting is five minutes. The setting range is from 0 to 30 minutes.

The group switching delay defines a time interval in which the relay delays switch group setting via logic input assertion.

IN1	= 52A1
IN2	= PT
IN3	= CLOSE
IN4	= NA
IN5	= NA
IN6	= NA
IN7	= NA
IN8	= PTXFR
RMB1	= NA
RMB2	= NA
RMB3	= NA
RMB4	= NA
RMB5	= NA
RMB6	= NA
RMB7	= NA
RMB8	= NA
FP_TIMEOUT	= 5
TGR	= 5

SETTINGS SHEET FOR SEL-321-5 RELAY SETTING EXAMPLE

Following is a filled out example settings sheet for this application.

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Line Terminal Settings

Relay Identifier: (17 Characters) RELID = _____
 Terminal Identifier: (39 Characters) TRMID = _____

Positive-Seq. Line Impedance Magnitude: (0.25–1275 Ω sec.)	Z1MAG = <u>39.00</u>
Positive-Seq. Line Impedance Angle: (40°–90°)	Z1ANG = <u>83.97</u>
Zero-Seq. Line Impedance Magnitude: (0.25–1275 Ω sec.)	Z0MAG = <u>123.95</u>
Zero-Seq. Line Impedance Angle: (40°–90°)	Z0ANG = <u>81.46</u>
Fault Location Enable: (Y,R,N)	LOCAT = <u>Y</u>
Line Length: (0.1–999 unitless)	LL = <u>100.00</u>
Current Transformer Ratio: (1–6000)	CTR = <u>1000</u>
Potential Transformer Ratio: (1–10000)	PTR = <u>2000</u>

Enable Zones of Distance Settings

Number Distance Zones: Mho Phase: (N,1,2,3,4)	PMHOZ = <u>3</u>
Mho Ground: (N,1,2,3,4)	GMHOZ = <u>3</u>
Quad. Ground: (N,1,2,3,4)	QUADZ = <u>3</u>

Distance Zones and Overcurrent Levels Direction Settings

Distance Zone 1/Overcurrent Level 1 Direction: (F/R)	DIR1 = <u>F</u>
Distance Zone 2/Overcurrent Level 2 Direction: (F/R)	DIR2 = <u>F</u>
Distance Zone 3/Overcurrent Level 3 Direction: (F/R)	DIR3 = <u>R</u>
Distance Zone 4/Overcurrent Level 4 Direction: (F/R)	DIR4 = <u>F</u>

Mho Phase Distance Settings

Impedance Reach: Zone 1: (0.25–320 Ω sec.)	Z1P = <u>31.20</u>
Zone 2: (0.25–320 Ω sec.)	Z2P = <u>46.80</u>
Zone 3: (0.25–320 Ω sec.)	Z3P = <u>9.35</u>
Zone 4: (0.25–320 Ω sec.)	Z4P = _____

Mho Phase Distance Overcurrent Supervision Settings

Phase-to- Phase Overcurrent: Zone 1: (0.2–34 A sec.)	50PP1 = <u>0.51</u>
Zone 2: (0.2–34 A sec.)	50PP2 = <u>0.44</u>
Zone 3: (0.2–34 A sec.)	50PP3 = <u>0.49</u>
Zone 4: (0.2–34 A sec.)	50PP4 = _____

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Mho Ground Distance Settings

Impedance Reach:	Zone 1: (0.25–320 Ω sec.)	Z1MG = <u>31.20</u>
	Zone 2: (0.25–320 Ω sec.)	Z2MG = <u>46.80</u>
	Zone 3: (0.25–320 Ω sec.)	Z3MG = <u>9.35</u>
	Zone 4: (0.25–320 Ω sec.)	Z4MG = _____

Quadrilateral Ground Distance Settings

Reactive Reach:	Zone 1: (0.25–320 Ω sec.)	XG1 = <u>31.20</u>
	Zone 2: (0.25–320 Ω sec.)	XG2 = <u>46.80</u>
	Zone 3: (0.25–320 Ω sec.)	XG3 = <u>9.35</u>
	Zone 4: (0.25–320 Ω sec.)	XG4 = _____
Resistive Reach:	Zone 1: (0.25–250 Ω sec.)	RG1 = <u>12.50</u>
	Zone 2: (0.25–250 Ω sec.)	RG2 = <u>25.00</u>
	Zone 3: (0.25–250 Ω sec.)	RG3 = <u>30.00</u>
	Zone 4: (0.25–250 Ω sec.)	RG4 = _____

Ground Distance Overcurrent Supervision Settings

Phase Overcurrent Supervision:	Zone 1: (0.1–20 A sec.)	50L1 = <u>0.18</u>
	Zone 2: (0.1–20 A sec.)	50L2 = <u>0.18</u>
	Zone 3: (0.1–20 A sec.)	50L3 = <u>0.26</u>
	Zone 4: (0.1–20 A sec.)	50L4 = _____
Residual Overcurrent Supervision:	Zone 1: (0.1–20 A sec.)	50G1 = <u>0.18</u>
	Zone 2: (0.1–20 A sec.)	50G2 = <u>0.12</u>
	Zone 3: (0.1–20 A sec.)	50G3 = <u>0.10</u>
	Zone 4: (0.1–20 A sec.)	50G4 = _____

Zero-Sequence Compensation Factor Settings

Zone 1 Zero-Sequence Comp. Factor 1 Magnitude:	(0–4 unitless)	k01M = <u>0.726</u>
Zone 1 Zero-Sequence Comp. Factor 1 Angle:	(±45°)	k01A = <u>-3.69</u>
Zones 2, 3, & 4 Zero-Sequence Comp. Factor 2 Mag.:	(0–4 unitless)	k0M = <u>0.726</u>
Zones 2, 3, & 4 Zero-Sequence Comp. Factor 2 Angle:	(±45°)	k0A = <u>-3.69</u>
Nonhomogeneous Correction Angle:	(±20°)	T = <u>0</u>

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Out-of-Step Blocking and Tripping Settings

Enable OOS: (Y/N)	EOOS	= <u>N</u>
OOSB Enable:	OOSB1	= <u> </u>
Block Zone 1: (Y/N)	OOSB2	= <u> </u>
Block Zone 2: (Y/N)	OOSB3	= <u> </u>
Block Zone 3: (Y/N)	OOSB4	= <u> </u>
Block Zone 4: (Y/N)	OSBD	= <u> </u>
Out-of-Step Block Time Delay (TDPU): (0.5–8000 cycles)	EOOST	= <u> </u>
Enable OOST: (I/O/N)	OSTD	= <u> </u>
Out-of-Step TOWI Time Delay (TDPU): (0.5–8000 cycles)	X1T5	= <u> </u>
Zone 5 Reactive Reach:	X1B5	= <u> </u>
Top: (0 to $\pm 480 \Omega$ sec.)	R1R5	= <u> </u>
Bottom: (0 to $\pm 480 \Omega$ sec.)	R1L5	= <u> </u>
Zone 5 Resistive Reach:	X1T6	= <u> </u>
Right: (0 to $\pm 350 \Omega$ sec.)	X1B6	= <u> </u>
Left: (0 to $\pm 350 \Omega$ sec.)	R1R6	= <u> </u>
Zone 6 Reactive Reach:	R1L6	= <u> </u>
Top: (0 to $\pm 480 \Omega$ sec.)	50ABC	= <u> </u>
Bottom: (0 to $\pm 480 \Omega$ sec.)	UBD	= <u> </u>
Zone 6 Resistive Reach:		
Right: (0 to $\pm 350 \Omega$ sec.)		
Left: (0 to $\pm 350 \Omega$ sec.)		
Zone 6 Positive-Sequence Overcurrent Supervision: (0.2–20 A sec., I ₁)		
Negative-Sequence Current Unblock Delay (0.5–120 cycles)		

Load-Encroachment Settings

Enable Load-Encroachment: (Y/N)	ELE	= <u>Y</u>
Load Impedance:	ZLF	= <u>46.10</u>
Forward: (0.25–320 Ω sec.)	ZLR	= <u>46.10</u>
Reverse: (0.25–320 Ω sec.)	PLAF	= <u>30</u>
Load Angle:	NLAF	= <u>-30</u>
Positive Forward: (-90° to +90°)	PLAR	= <u>150</u>
Negative Forward: (-90° to +90°)	NLAR	= <u>210</u>
Positive Reverse: (+90° to +270°)		
Negative Reverse: (+90° to +270°)		

Negative-Sequence Directional Element Settings

Forward Directional Z2 Threshold: ($\pm 320 \Omega$ sec.)	Z2F	= <u>13.00</u>
Forward Directional Current Threshold: (0.05–1 A sec., 3I ₂)	50QF	= <u>0.10</u>
Reverse Directional Z2 Threshold: ($\pm 320 \Omega$ sec.)	Z2R	= <u>26.00</u>
Reverse Directional Current Threshold: (0.05–1 A sec., 3I ₂)	50QR	= <u>0.10</u>
Positive-Sequence Current Restraint Factor: (0.02–0.5 unitless)	a2	= <u>0.07</u>

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Phase Time-Overcurrent Element Settings

Phase Time-Overcurrent Element: Enable: (Y/N)

Pickup: (0.1–3.2 A sec.)

Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)

Time Dial: (US 0.5–15, IEC 0.05–1)

Reset Delay: (Y/N)

Torque Control: (ZLIN, ZLOUT, M2P, N)

Residual Time-Overcurrent Element Settings

E51P = N

51PP = _____

51PC = _____

51PTD = _____

51PRS = _____

51PTC = _____

Residual Time-Overcurrent Element: Enable: (Y/N/S)

Pickup: (0.1–3.2 A sec., 3I₀)

Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)

Time Dial: (US 0.5–15, IEC 0.05–1)

Reset Delay: (Y/N)

Torque Control: (32QF, 32QR, Z2G, N)

Residual Overcurrent Element Settings

E51N = Y

51NP = 0.15

51NC = U3

51NTD = 2.00

51NRS = Y

51NTC = 32QF

Enable Number of Residual Instantaneous Overcurrent Levels: (N,1,2,3,4)

Residual Inst. Overcurrent Pickup: Level 1: (0.05–16 A sec., 3I₀)

Level 2: (0.05–16 A sec., 3I₀)

Level 3: (0.05–16 A sec., 3I₀)

Level 4: (0.05–16 A sec., 3I₀)

E50N = N

50N1 = _____

50N2 = _____

50N3 = _____

50N4 = _____

Negative-Sequence Time-Overcurrent Element Settings

Negative-Sequence Time-Overcurrent: Enable: (Y/N/S)

Pickup: (0.1–3.2 A sec., 3I₂)

Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)

Time Dial: (US 0.5–15, IEC 0.05–1)

Reset Delay: (Y/N)

Torque Control: (32QF, 32QR, M2P, Z2G, N)

Negative-Sequence Overcurrent Element Settings

E51Q = Y

51QP = 0.44

51QC = U3

51QTD = 2.00

51QRS = N

51QTC = 32QF

Enable Number of Neg.-Sequence Inst. Overcurrent Levels: (N,1,2,3,4)

Neg.-Seq. Inst. Overcurrent Pickup: Level 1: (0.05–16 A sec., 3I₂)

Level 2: (0.05–16 A sec., 3I₂)

Level 3: (0.05–16 A sec., 3I₂)

Level 4: (0.05–16 A sec., 3I₂)

E50Q = N

50Q1 = _____

50Q2 = _____

50Q3 = _____

50Q4 = _____

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Voltage Element Settings

Enable Voltage Elements: (Y/N)	EVOLT	= <u>N</u>
Zero-Sequence Overvoltage: (0–150 V sec., 3V0)	59N	=
Bus Phase Undervoltage: (0–100 V sec.)	27L	=
Bus Phase Overvoltage: (0–100 V sec.)	59L	=
Positive-Sequence Bus Overvoltage: (0–150 V sec., V1)	59PB	=
Positive-Sequence Bus Overvoltage Time Delay (TDPU): (0–8000 cyc)	59PBD	=
Positive-Sequence Remote Bus Overvoltage: (0–150 V sec., V1)	59PR	=
Current Comp. Remote Overvoltage Time Delay (TDPU): (0–8000 cyc)	59PRD	=
Current Compensated Remote Overvoltage Adjustment: (0–2 unitless)	a1	=

Time Step Backup Time Delay Settings

Zone 2 Phase Long Time Delay (TDPU): (0–2000 cycles)	Z2PD	= <u>20.00</u>
Zone 3 Phase Time Delay (TDPU): (0–2000 cycles)	Z3PD	= <u>0.00</u>
Zone 4 Phase Time Delay (TDPU): (0–2000 cycles)	Z4PD	=
Zone 2 Ground Long Time Delay (TDPU): (0–2000 cycles)	Z2GD	= <u>20.00</u>
Zone 3 Ground Time Delay (TDPU): (0–2000 cycles)	Z3GD	= <u>0.00</u>
Zone 4 Ground Time Delay (TDPU): (0–2000 cycles)	Z4GD	=
Level 1 Residual Time Delay (TDPU): (0–2000 cycles)	67NL1D	=
Level 2 Residual Long Time Delay (TDPU): (0–2000 cycles)	67NL2D	=
Level 3 Residual Time Delay (TDPU): (0–2000 cycles)	67NL3D	=
Level 4 Residual Time Delay (TDPU): (0–2000 cycles)	67NL4D	=
Level 1 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL1D	=
Level 2 Negative-Sequence Long Time Delay (TDPU): (0–2000 cycles)	67QL2D	=
Level 3 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL3D	=
Level 4 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL4D	=

Permissive Overreaching Scheme Settings

Enable Permissive Overreaching Transfer Trip Scheme: (Y/N)	EPOTT	= <u>Y</u>
Zone 3 Reverse Block Time Delay (TDDO): (0–2000 cycles)	Z3RBD	= <u>5.00</u>
Echo Block Time Delay (TDDO): (0–2000 cycles)	EBLKD	= <u>10.00</u>
Echo Time Delay Pickup Time Delay (TDPU): (0–2000 cycles)	ETDPU	= <u>2.00</u>
Echo Duration Time Delay (TDDO): (0–2000 cycles)	EDURD	= <u>4.00</u>
Weak-Infeed Enable: (Y/N)	EWFC	=

Directional Comparison Unblocking Scheme Settings

Enable DCUB: (Y/N)	EDCUB	= <u>N</u>
Guard Present Security Time Delay (TDDO): (0–2000 cycles)	GARD1D	=
DCUB Disabling Time Delay (TDPU): (0.25–2000 cycles)	UBDURD	=
DCUB Duration Time Delay (TDPU): (0–2000 cycles)	UBEND	=

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Directional Comparison Blocking Scheme Settings

Enable DCB: (Y/N)	EDCB	=
Zone 3 Dropout Extension Time Delay (TDDO): (0–2000 cycles)	Z3XD	=
Block Trip Receive Extension Time Delay (TDDO): (0–2000 cycles)	BTXD	=
Zone 2 Phase Distance Short Delay Time Delay (TDPU): (0–60 cycles)	Z2PSD	=
Zone 2 Ground Distance Short Delay Time Delay (TDPU): (0–60 cycles)	Z2GSD	=
Level 2 Residual Short Delay Time Delay (TDPU): (0–60 cycles)	67N2SD	=
Level 2 Neg.-Seq. Short Delay Time Delay (TDPU): (0–60 cycles)	67Q2SD	=

Zone 1 Extension Settings

Enable Zone 1 Extension: (Y/N)	EZ1EXT	= <u>N</u>
Enable Time Delay (TDPU): (0–2000 cycles)	Z1EXTD	=
Multiplier: (1–5 unitless)	Z1EXTM	=

Remote-End-Just-Opened Settings

Enable: (Y/N)	EREJO	= <u>N</u>
Pickup Time Delay (TDPU): (0–2000 cycles)	REJOD	=
Overcurrent Element Pickup: (0.1–20 A sec.)	3P50R	=
Switch-On-to-Fault Settings		

Enable: (Y/N)	ESOTF	= <u>Y</u>
Enable Close Logic: (Y/N)	ENCLO	= <u>Y</u>
Close Enable Time Delay (TDPU): (0–8000 cycles)	CLOEND	= <u>10.00</u>
Enable 52A Logic: (Y/N)	EN52A	= <u>N</u>
52A Enable Time Delay (TDPU): (0–8000 cycles)	52AEND	=
Time Duration (TDDO): (0.5–8000 cycles)	SOTFD	= <u>30.00</u>
High-Set Phase Overcurrent Pickup: (0.1–20 A sec.)	50H	= <u>2.25</u>

Loss-of-Potential Settings

Enable Loss-of-Potential: (Y/N)	ELOP	= <u>Y</u>
Loss-of-Potential Time Delay (TDPU): (1–60 cycles)	LOPD	= <u>3</u>
Medium-Set Phase Overcurrent Pickup: (0.1–20 A sec.)	50M	= <u>0.47</u>
Zero-Sequence Voltage LOP Supervision: (0–150 V sec., V0)	59NL	= <u>14.00</u>
Positive-Sequence Voltage LOP Supervision: (0–150 V sec., V1)	59PL	= <u>14.00</u>

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Miscellaneous Scheme Settings

Pole-Discordance Enable: (Y/N)	EPOLD	=	<u>N</u>
Single-Pole Trip Pole-Discordance Time Delay (TDPU): (0–8000 cycles)	SPPDD	=	<u> </u>
Single-Pole Trip Enable: (Y/N/Y1/N1)	ESPT	=	<u>N</u>
Single-Pole Open Enable: (Y/N)	ESPO	=	<u>N</u>
Open-Pole Option: (52,27)	OPO	=	<u>52</u>
Single-Pole Open Time Delay (TDDO): (0–8000 cycles)	SPOD	=	<u> </u>
Three-Pole Open Time Delay (TDDO): (0–8000 cycles)	3POD	=	<u>1.50</u>
Enable Stub Protection: (Y/N)	ESTUB	=	<u>Y</u>
Stub Protection Time Delay (TDPU): (0–2000 cycles)	50MFD	=	<u>20.00</u>
Trip Unlatch Option: (N,1,2,3,4)	TULO	=	<u>3</u>

Miscellaneous Timers

Minimum Trip Duration Time Delay (TDDO): (0–2000 cycles)	TDURD	=	<u>9.00</u>
Trip During Open Pole Time Delay (TDDO): (0–8000 cycles)	TOPD	=	<u>0.00</u>
Relay Element X Time Delay Pickup (TDPU): (0–8000 cycles)	TXPU	=	<u>0.00</u>
Relay Element X Time Delay Dropout (TDDO): (0–8000 cycles)	TXDO	=	<u>0.00</u>
Relay Element Y Time Delay Pickup (TDPU): (0–8000 cycles)	TYPU	=	<u>0.00</u>
Relay Element Y Time Delay Dropout (TDDO): (0–8000 cycles)	TYDO	=	<u>0.00</u>
Relay Element Z Time Delay Pickup (TDPU): (0–8000 cycles)	TZPU	=	<u>0.00</u>
Relay Element Z Time Delay Dropout (TDDO): (0–8000 cycles)	TZDO	=	<u>0.00</u>
Instantaneous Trip Time Declaration Delay (TDPU): (0–60 cycles)	ITTD	=	<u>5.00</u>

Logic Variables

LOGIC V	=	<u>NA</u>	<u> </u>
LOGIC W	=	<u>NA</u>	<u> </u>
LOGIC X	=	<u>NA</u>	<u> </u>
LOGIC Y	=	<u>NA</u>	<u> </u>
LOGIC Z	=	<u>NA</u>	<u> </u>

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Tripping Logic

MTCS = M2P + Z2G
MTU = M1P + Z1G + M2PT + Z2GT + 51NT + 51QT + 50MF
MTO = M1P + M2P + Z1G + Z2G + 50H

Event Report Trigger Condition Logic

MER = M2P + Z2G + 51NP + 51QP + 50H * 52AA1

Output Contact Logic

OUT1 = 3PT
OUT2 = 3PT
OUT3 = CC
OUT4 = KEY
OUT5 = NA
OUT6 = NA
OUT7 = NA
OUT8 = NA
OUT9 = NA
OUT10 = NA
OUT11 = NA
OUT12 = NA
OUT13 = NA
OUT14 = NA

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OUT15 = NA
* OUT17 =
* OUT18 =
* OUT19 =
* OUT20 =
* OUT21 =
* OUT22 =
* OUT23 =
* OUT24 =
* OUT25 =
* OUT26 =
* OUT27 =
* OUT28 =
* OUT29 =
* OUT30 =
* OUT31 =
* OUT32 =
TMB1 =
TMB2 =
TMB3 =
TMB4 =
TMB5 =

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TMB6 = _____
 TMB7 = _____
 TMB8 = _____

Global Contact Input Settings

Input Contact 1 Assignment:	IN1	=	<u>52A1</u>
Input Contact 2 Assignment:	IN2	=	<u>PT</u>
Input Contact 3 Assignment:	IN3	=	<u>CLOSE</u>
Input Contact 4 Assignment:	IN4	=	<u>NA</u>
Input Contact 5 Assignment:	IN5	=	<u>NA</u>
Input Contact 6 Assignment:	IN6	=	<u>NA</u>
Input Contact 7 Assignment:	IN7	=	<u>NA</u>
Input Contact 8 Assignment:	IN8	=	<u>PTXFR</u>
* Input Contact 9 Assignment:	IN9	=	_____
* Input Contact 10 Assignment:	IN10	=	_____
* Input Contact 11 Assignment:	IN11	=	_____
* Input Contact 12 Assignment:	IN12	=	_____
* Input Contact 13 Assignment:	IN13	=	_____
* Input Contact 14 Assignment:	IN14	=	_____
* Input Contact 15 Assignment:	IN15	=	_____
* Input Contact 16 Assignment:	IN16	=	_____

Received MIRRORED BIT 1:	RMB1	=	_____
Received MIRRORED BIT 2:	RMB2	=	_____
Received MIRRORED BIT 3:	RMB3	=	_____
Received MIRRORED BIT 4:	RMB4	=	_____
Received MIRRORED BIT 5:	RMB5	=	_____
Received MIRRORED BIT 6:	RMB6	=	_____
Received MIRRORED BIT 7:	RMB7	=	_____
Received MIRRORED BIT 8:	RMB8	=	_____

Miscellaneous Global Settings

Front-panel time-out: (0–30 minutes)	FP_TIMEOUT	=	<u>5</u>
Group change delay: (0–900 seconds)	TGR	=	<u>5</u>

* OUT17–OUT32 available only on two I/O board relays.

* INPUT9–INPUT16 available only on two I/O board relays.

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**SETTINGS SHEET
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Line Terminal Settings

Relay Identifier: (17 Characters) RELID = _____
Terminal Identifier: (39 Characters) TRMID = _____

Positive-Seq. Line Impedance Magnitude: (0.05–255 Ω sec.) Z1MAG = _____
Positive-Seq. Line Impedance Angle: (40°–90°) Z1ANG = _____
Zero-Seq. Line Impedance Magnitude: (0.05–255 Ω sec.) Z0MAG = _____
Zero-Seq. Line Impedance Angle: (40°–90°) Z0ANG = _____
Fault Location Enable: (Y,R,N) LOCAT = _____
Line Length: (0.1–999 unitless) LL = _____
Current Transformer Ratio: (1–6000) CTR = _____
Potential Transformer Ratio: (1–10000) PTR = _____

Enable Zones of Distance Settings

Number Distance Zones: Mho Phase: (N,1,2,3,4) PMHOZ = _____
 Mho Ground: (N,1,2,3,4) GMHOZ = _____
 Quad. Ground: (N,1,2,3,4) QUADZ = _____

Distance Zones and Overcurrent Levels Direction Settings

Distance Zone 1/Overcurrent Level 1 Direction: (F/R) DIR1 = _____
Distance Zone 2/Overcurrent Level 2 Direction: (F/R) DIR2 = _____
Distance Zone 3/Overcurrent Level 3 Direction: (F/R) DIR3 = _____
Distance Zone 4/Overcurrent Level 4 Direction: (F/R) DIR4 = _____

Mho Phase Distance Settings

Impedance Reach: Zone 1: (0.05–64 Ω sec.) Z1P = _____
 Zone 2: (0.05–64 Ω sec.) Z2P = _____
 Zone 3: (0.05–64 Ω sec.) Z3P = _____
 Zone 4: (0.05–64 Ω sec.) Z4P = _____

Mho Phase Distance Overcurrent Supervision Settings

Phase-to-Phase Overcurrent:

Zone 1: (1–170 A sec.) 50PP1 = _____
Zone 2: (1–170 A sec.) 50PP2 = _____
Zone 3: (1–170 A sec.) 50PP3 = _____
Zone 4: (1–170 A sec.) 50PP4 = _____

**SETTINGS SHEET
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Mho Ground Distance Settings

Impedance Reach:	Zone 1: (0.05–64 Ω sec.)	Z1MG	=	_____
	Zone 2: (0.05–64 Ω sec.)	Z2MG	=	_____
	Zone 3: (0.05–64 Ω sec.)	Z3MG	=	_____
	Zone 4: (0.05–64 Ω sec.)	Z4MG	=	_____

Quadrilateral Ground Distance Settings

Reactive Reach:	Zone 1: (0.05–64 Ω sec.)	XG1	=	_____
	Zone 2: (0.05–64 Ω sec.)	XG2	=	_____
	Zone 3: (0.05–64 Ω sec.)	XG3	=	_____
	Zone 4: (0.05–64 Ω sec.)	XG4	=	_____
Resistive Reach:	Zone 1: (0.05–50 Ω sec.)	RG1	=	_____
	Zone 2: (0.05–50 Ω sec.)	RG2	=	_____
	Zone 3: (0.05–50 Ω sec.)	RG3	=	_____
	Zone 4: (0.05–50 Ω sec.)	RG4	=	_____

Ground Distance Overcurrent Supervision Settings

Phase Overcurrent Supervision:	Zone 1: (0.5–100 A sec.)	50L1	=	_____
	Zone 2: (0.5–100 A sec.)	50L2	=	_____
	Zone 3: (0.5–100 A sec.)	50L3	=	_____
	Zone 4: (0.5–100 A sec.)	50L4	=	_____
Residual Overcurrent Supervision:	Zone 1: (0.5–100 A sec.)	50G1	=	_____
	Zone 2: (0.5–100 A sec.)	50G2	=	_____
	Zone 3: (0.5–100 A sec.)	50G3	=	_____
	Zone 4: (0.5–100 A sec.)	50G4	=	_____

Zero-Sequence Compensation Factor Settings

Zone 1 Zero-Sequence Comp. Factor 1 Magnitude: (0–4 unitless)	k01M	=	_____
Zone 1 Zero-Sequence Comp. Factor 1 Angle: ($\pm 45^\circ$)	k01A	=	_____
Zones 2, 3, & 4 Zero-Sequence Comp. Factor 2 Mag.: (0–4 unitless)	k0M	=	_____
Zones 2, 3, & 4 Zero-Sequence Comp. Factor 2 Angle: ($\pm 45^\circ$)	k0A	=	_____
Non-Homogeneous Correction Angle: ($\pm 20^\circ$)	T	=	_____

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Out-of-Step Blocking and Tripping Settings

Enable OOS: (Y/N)	EOOS	=	_____
OOSB Enable:	OOSB1	=	_____
Block Zone 1: (Y/N)	OOSB2	=	_____
Block Zone 2: (Y/N)	OOSB3	=	_____
Block Zone 3: (Y/N)	OOSB4	=	_____
Block Zone 4: (Y/N)			
Out-of-Step Block Time Delay (TDPU): (0.5–8000 cycles)	OSBD	=	_____
Enable OOST: (I/O/N)	EOOST	=	_____
Out-of-Step TOWI Time Delay (TDPU): (0.5–8000 cycles)	OSTD	=	_____
Zone 5 Reactive Reach:	X1T5	=	_____
Top: (0 to $\pm 96 \Omega$ sec.)	X1B5	=	_____
Bottom: (0 to $\pm 96 \Omega$ sec.)			
Zone 5 Resistive Reach:	R1R5	=	_____
Right: (0 to $\pm 70 \Omega$ sec.)	R1L5	=	_____
Left: (0 to $\pm 70 \Omega$ sec.)			
Zone 6 Reactive Reach:	X1T6	=	_____
Top: (0 to $\pm 96 \Omega$ sec.)	X1B6	=	_____
Bottom: (0 to $\pm 96 \Omega$ sec.)			
Zone 6 Resistive Reach:	R1R6	=	_____
Right: (0 to $\pm 70 \Omega$ sec.)	R1L6	=	_____
Left: (0 to $\pm 70 \Omega$ sec.)			
Zone 6 Positive-Sequence Overcurrent Supervision: (1–100 A sec., I_1)	50ABC	=	_____
Negative-Sequence Current Unblock Delay (0.5–120 cycles)	UBD	=	_____

Load-Encroachment Settings

Enable Load-Encroachment: (Y/N)	ELE	=	_____
Load Impedance:	ZLF	=	_____
Forward: (0.05–64 Ω sec.)	ZLR	=	_____
Reverse: (0.05–64 Ω sec.)			
Load Angle:	PLAF	=	_____
Positive Forward: (-90° to +90°)	NLAF	=	_____
Negative Forward: (-90° to +90°)	PLAR	=	_____
Positive Reverse: (+90° to +270°)	NLAR	=	_____
Negative Reverse: (+90° to +270°)			

Negative-Sequence Directional Element Settings

Forward Directional Z2 Threshold: ($\pm 64 \Omega$ sec.)	Z2F	=	_____
Forward Directional Current Threshold: (0.25–5 A sec., $3I_2$)	50QF	=	_____
Reverse Directional Z2 Threshold: ($\pm 64 \Omega$ sec.)	Z2R	=	_____
Reverse Directional Current Threshold: (0.25–5 A sec., $3I_2$)	50QR	=	_____
Positive-Sequence Current Restraint Factor: (0.02–0.5 unitless)	a2	=	_____

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Phase Time-Overcurrent Element Settings

Phase Time-Overcurrent Element: Enable: (Y/N)	E51P	=	_____
Pickup: (0.5–16 A sec.)	51PP	=	_____
Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)	51PC	=	_____
Time Dial: (US 0.5–15, IEC 0.05–1)	51PTD	=	_____
Reset Delay: (Y/N)	51PRS	=	_____
Torque Control: (ZLIN, ZLOUT, M2P, N)	51PTC	=	_____

Residual Time-Overcurrent Element Settings

Residual Time-Overcurrent Element: Enable: (Y/N/S)	E51N	=	_____
Pickup: (0.5–16 A sec., $3I_0$)	51NP	=	_____
Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)	51NC	=	_____
Time Dial: (US 0.5–15, IEC 0.05–1)	51NTD	=	_____
Reset Delay: (Y/N)	51NRS	=	_____
Torque Control: (32QF, 32QR, Z2G, N)	51NTC	=	_____

Residual Overcurrent Element Settings

Enable Number of Residual Instantaneous Overcurrent Levels: (N,1,2,3,4)	E50N	=	_____
Residual Inst. Overcurrent Pickup: Level 1: (0.25–80 A sec., $3I_0$)	50N1	=	_____
Level 2: (0.25–80 A sec., $3I_0$)	50N2	=	_____
Level 3: (0.25–80 A sec., $3I_0$)	50N3	=	_____
Level 4: (0.25–80 A sec., $3I_0$)	50N4	=	_____

Negative-Sequence Time-Overcurrent Element Settings

Negative-Sequence Time-Overcurrent: Enable: (Y/N/S)	E51Q	=	_____
Pickup: (0.5–16 A sec., $3I_2$)	51QP	=	_____
Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)	51QC	=	_____
Time Dial: (US 0.5–15, IEC 0.05–1)	51QTD	=	_____
Reset Delay: (Y/N)	51QRS	=	_____
Torque Control: (32QF, 32QR, M2P, Z2G, N)	51QTC	=	_____

Negative-Sequence Overcurrent Element Settings

Enable Number of Neg.-Sequence Inst. Overcurrent Levels: (N,1,2,3,4)	E50Q	=	_____
Neg.-Seq. Inst. Overcurrent Pickup: Level 1: (0.25–80 A sec., $3I_2$)	50Q1	=	_____
Level 2: (0.25–80 A sec., $3I_2$)	50Q2	=	_____
Level 3: (0.25–80 A sec., $3I_2$)	50Q3	=	_____
Level 4: (0.25–80 A sec., $3I_2$)	50Q4	=	_____

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Voltage Element Settings

Enable Voltage Elements: (Y/N)	EVOLT	=	_____
Zero-Sequence Overvoltage: (0–150 V sec., 3V0)	59N	=	_____
Bus Phase Undervoltage: (0–100 V sec.)	27L	=	_____
Bus Phase Overvoltage: (0–100 V sec.)	59L	=	_____
Positive-Sequence Bus Overvoltage: (0–150 V sec., V1)	59PB	=	_____
Positive-Sequence Bus Overvoltage Time Delay (TDPU): (0–8000 cyc)	59PBD	=	_____
Positive-Sequence Remote Bus Overvoltage: (0–150 V sec., V1)	59PR	=	_____
Current Comp. Remote Overvoltage Time Delay (TDPU): (0–8000 cyc)	59PRD	=	_____
Current Compensated Remote Overvoltage Adjustment: (0–2 unitless)	a1	=	_____

Time Step Backup Time Delay Settings

Zone 2 Phase Long Time Delay (TDPU): (0–2000 cycles)	Z2PD	=	_____
Zone 3 Phase Time Delay (TDPU): (0–2000 cycles)	Z3PD	=	_____
Zone 4 Phase Time Delay (TDPU): (0–2000 cycles)	Z4PD	=	_____
Zone 2 Ground Long Time Delay (TDPU): (0–2000 cycles)	Z2GD	=	_____
Zone 3 Ground Time Delay (TDPU): (0–2000 cycles)	Z3GD	=	_____
Zone 4 Ground Time Delay (TDPU): (0–2000 cycles)	Z4GD	=	_____
Level 1 Residual Time Delay (TDPU): (0–2000 cycles)	67NL1D	=	_____
Level 2 Residual Long Time Delay (TDPU): (0–2000 cycles)	67NL2D	=	_____
Level 3 Residual Time Delay (TDPU): (0–2000 cycles)	67NL3D	=	_____
Level 4 Residual Time Delay (TDPU): (0–2000 cycles)	67NL4D	=	_____
Level 1 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL1D	=	_____
Level 2 Negative-Sequence Long Time Delay (TDPU): (0–2000 cycles)	67QL2D	=	_____
Level 3 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL3D	=	_____
Level 4 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL4D	=	_____

Permissive Overreaching Scheme Settings

Enable Permissive Overreaching Transfer Trip Scheme: (Y/N)	EPOTT	=	_____
Zone 3 Reverse Block Time Delay (TDDO): (0–2000 cycles)	Z3RBD	=	_____
Echo Block Time Delay (TDDO): (0–2000 cycles)	EBLKD	=	_____
Echo Time Delay Pickup Time Delay (TDPU): (0–2000 cycles)	ETDPU	=	_____
Echo Duration Time Delay (TDDO): (0–2000 cycles)	EDURD	=	_____
Weak-Infeed Enable: (Y/N)	EWFC	=	_____

Directional Comparison Unblocking Scheme Settings

Enable DCUB: (Y/N)	EDCUB	=	_____
Guard Present Security Time Delay (TDDO): (0–2000 cycles)	GARD1D	=	_____
DCUB Disabling Time Delay (TDPU): (0.25–2000 cycles)	UBDURD	=	_____
DCUB Duration Time Delay (TDPU): (0–2000 cycles)	UBEND	=	_____

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Directional Comparison Blocking Scheme Settings

Enable DCB: (Y/N)	EDCB	=	_____
Zone 3 Dropout Extension Time Delay (TDDO): (0–2000 cycles)	Z3XD	=	_____
Block Trip Receive Extension Time Delay (TDDO): (0–2000 cycles)	BTXD	=	_____
Zone 2 Phase Distance Short Delay Time Delay (TDPU): (0–60 cycles)	Z2PSD	=	_____
Zone 2 Ground Distance Short Delay Time Delay (TDPU): (0–60 cycles)	Z2GSD	=	_____
Level 2 Residual Short Delay Time Delay (TDPU): (0–60 cycles)	67N2SD	=	_____
Level 2 Neg.-Seq. Short Delay Time Delay (TDPU): (0–60 cycles)	67Q2SD	=	_____

Zone 1 Extension Settings

Enable Zone 1 Extension: (Y/N)	EZ1EXT	=	_____
Enable Time Delay (TDPU): (0–2000 cycles)	Z1EXTD	=	_____
Multiplier: (1–5 unitless)	Z1EXTM	=	_____

Remote-End-Just-Opened Settings

Enable: (Y/N)	EREJO	=	_____
Pickup Time Delay (TDPU): (0–2000 cycles)	REJOD	=	_____
Overcurrent Element Pickup: (0.5–100 A sec.)	3P50R	=	_____

Switch-On-to-Fault Settings

Enable: (Y/N)	ESOTF	=	_____
Enable Close Logic: (Y/N)	ENCLO	=	_____
Close Enable Time Delay (TDPU): (0–8000 cycles)	CLOEND	=	_____
Enable 52A Logic: (Y/N)	EN52A	=	_____
52A Enable Time Delay (TDPU): (0–8000 cycles)	52AEND	=	_____
Time Duration (TDDO): (0.5–8000 cycles)	SOTFD	=	_____
High-Set Phase Overcurrent Pickup: (0.5–100 A sec.)	50H	=	_____

Loss-of-Potential Settings

Enable Loss-of-Potential: (Y/N)	ELOP	=	_____
Loss-of-Potential Time Delay (TDPU): (1–60 cycles)	LOPD	=	_____
Medium-Set Phase Overcurrent Pickup: (0.5–100 A sec.)	50M	=	_____
Zero-Sequence Voltage LOP Supervision: (0–150 V sec., V0)	59NL	=	_____
Positive-Sequence Voltage LOP Supervision: (0–150 V sec., V1)	59PL	=	_____

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Miscellaneous Scheme Settings

Pole-Discordance Enable: (Y/N)	EPOLD	=	_____
Single-Pole Trip Pole-Discordance Time Delay (TDPU): (0–8000 cycles)	SPPDD	=	_____
Single-Pole Trip Enable: (Y/N/Y1/N1)	ESPT	=	_____
Single-Pole Open Enable: (Y/N)	ESPO	=	_____
Open-Pole Options: (52, 27)	OPO	=	_____
Single-Pole Open Time Delay (TDDO): (0–8000 cycles)	SPOD	=	_____
Three-Pole Open Time Delay (TDDO): (0–8000 cycles)	3POD	=	_____
Enable Stub Protection: (Y/N)	ESTUB	=	_____
Stub Protection Time Delay (TDPU): (0–2000 cycles)	50MFD	=	_____
Trip Unlatch Option: (N,1,2,3,4)	TULO	=	_____

Miscellaneous Timers

Minimum Trip Duration Time Delay (TDDO): (0–2000 cycles)	TDURD	=	_____
Trip During Open Pole Time Delay (TDDO): (0–8000 cycles)	TOPD	=	_____
Relay Element X Time Delay Pickup (TDPU): (0–8000 cycles)	TXPU	=	_____
Relay Element X Time Delay Dropout (TDDO): (0–8000 cycles)	TXDO	=	_____
Relay Element Y Time Delay Pickup (TDPU): (0–8000 cycles)	TYPU	=	_____
Relay Element Y Time Delay Dropout (TDDO): (0–8000 cycles)	TYDO	=	_____
Relay Element Z Time Delay Pickup (TDPU): (0–8000 cycles)	TZPU	=	_____
Relay Element Z Time Delay Dropout (TDDO): (0–8000 cycles)	TZDO	=	_____
Instantaneous Trip Time Declaration Delay (TDPU): (0–60 cycles)	ITTD	=	_____

Logic Variables

LOGIC V	=	_____
LOGIC W	=	_____
LOGIC X	=	_____
LOGIC Y	=	_____
LOGIC Z	=	_____

Tripping Logic

MTCS	=	_____
MTU	=	_____
MTO	=	_____

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Event Report Trigger Condition Logic

MER = _____

Output Contact Logic

OUT1 = _____
OUT2 = _____
OUT3 = _____
OUT4 = _____
OUT5 = _____
OUT6 = _____
OUT7 = _____
OUT8 = _____
OUT9 = _____
OUT10 = _____
OUT11 = _____
OUT12 = _____
OUT13 = _____
OUT14 = _____
OUT15 = _____
* OUT17 = _____
* OUT18 = _____
* OUT19 = _____
* OUT20 = _____
* OUT21 = _____

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* OUT22 = _____
* OUT23 = _____
* OUT24 = _____
* OUT25 = _____
* OUT26 = _____
* OUT27 = _____
* OUT28 = _____
* OUT29 = _____
* OUT30 = _____
* OUT31 = _____
* OUT32 = _____
TMB1 = _____
TMB2 = _____
TMB3 = _____
TMB4 = _____
TMB5 = _____
TMB6 = _____
TMB7 = _____
TMB8 = _____

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Global Contact Input Settings

Input Contact 1 Assignment:	IN1	=	_____
Input Contact 2 Assignment:	IN2	=	_____
Input Contact 3 Assignment:	IN3	=	_____
Input Contact 4 Assignment:	IN4	=	_____
Input Contact 5 Assignment:	IN5	=	_____
Input Contact 6 Assignment:	IN6	=	_____
Input Contact 7 Assignment:	IN7	=	_____
Input Contact 8 Assignment:	IN8	=	_____
* Input Contact 9 Assignment:	IN9	=	_____
* Input Contact 10 Assignment:	IN10	=	_____
* Input Contact 11 Assignment:	IN11	=	_____
* Input Contact 12 Assignment:	IN12	=	_____
* Input Contact 13 Assignment:	IN13	=	_____
* Input Contact 14 Assignment:	IN14	=	_____
* Input Contact 15 Assignment:	IN15	=	_____
* Input Contact 16 Assignment:	IN16	=	_____
Received MIRRORED BIT® 1:	RMB1	=	_____
Received MIRRORED BIT 2:	RMB2	=	_____
Received MIRRORED BIT 3:	RMB3	=	_____
Received MIRRORED BIT 4:	RMB4	=	_____
Received MIRRORED BIT 5:	RMB5	=	_____
Received MIRRORED BIT 6:	RMB6	=	_____
Received MIRRORED BIT 7:	RMB7	=	_____
Received MIRRORED BIT 8:	RMB8	=	_____

Miscellaneous Global Settings

Front-panel time-out: (0–30 minutes)	FP_TIMEOUT	=	_____
Group change delay: (0–900 seconds)	TGR	=	_____

* OUT17–OUT32 available only on two I/O board relays.

* INPUT9–INPUT16 available only on two I/O board relays.

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Line Terminal Settings

Relay Identifier: (17 Characters) RELID = _____
 Terminal Identifier: (39 Characters) TRMID = _____

Positive-Seq. Line Impedance Magnitude: (0.25–1275 Ω sec.)	Z1MAG = _____
Positive-Seq. Line Impedance Angle: (40°–90°)	Z1ANG = _____
Zero-Seq. Line Impedance Magnitude: (0.25–1275 Ω sec.)	Z0MAG = _____
Zero-Seq. Line Impedance Angle: (40°–90°)	Z0ANG = _____
Fault Location Enable: (Y,R,N)	LOCAT = _____
Line Length: (0.1–999 unitless)	LL = _____
Current Transformer Ratio: (1–6000)	CTR = _____
Potential Transformer Ratio: (1–10000)	PTR = _____

Enable Zones of Distance Settings

Number Distance Zones:	Mho Phase: (N,1,2,3,4)	PMHOZ = _____
	Mho Ground: (N,1,2,3,4)	GMHOZ = _____
	Quad. Ground: (N,1,2,3,4)	QUADZ = _____

Distance Zones and Overcurrent Levels Direction Settings

Distance Zone 1/Overcurrent Level 1 Direction: (F/R)	DIR1 = _____
Distance Zone 2/Overcurrent Level 2 Direction: (F/R)	DIR2 = _____
Distance Zone 3/Overcurrent Level 3 Direction: (F/R)	DIR3 = _____
Distance Zone 4/Overcurrent Level 4 Direction: (F/R)	DIR4 = _____

Mho Phase Distance Settings

Impedance Reach:	Zone 1: (0.25–320 Ω sec.)	Z1P = _____
	Zone 2: (0.25–320 Ω sec.)	Z2P = _____
	Zone 3: (0.25–320 Ω sec.)	Z3P = _____
	Zone 4: (0.25–320 Ω sec.)	Z4P = _____

Mho Phase Distance Overcurrent Supervision Settings

Phase-to-phase Overcurrent:

Zone 1: (0.2–34 A sec.)	50PP1 = _____
Zone 2: (0.2–34 A sec.)	50PP2 = _____
Zone 3: (0.2–34 A sec.)	50PP3 = _____
Zone 4: (0.2–34 A sec.)	50PP4 = _____

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Mho Ground Distance Settings

Impedance Reach:	Zone 1: (0.25–320 Ω sec.)	Z1MG	=	_____
	Zone 2: (0.25–320 Ω sec.)	Z2MG	=	_____
	Zone 3: (0.25–320 Ω sec.)	Z3MG	=	_____
	Zone 4: (0.25–320 Ω sec.)	Z4MG	=	_____

Quadrilateral Ground Distance Settings

Reactive Reach:	Zone 1: (0.25–320 Ω sec.)	XG1	=	_____
	Zone 2: (0.25–320 Ω sec.)	XG2	=	_____
	Zone 3: (0.25–320 Ω sec.)	XG3	=	_____
	Zone 4: (0.25–320 Ω sec.)	XG4	=	_____
Resistive Reach:	Zone 1: (0.25–250 Ω sec.)	RG1	=	_____
	Zone 2: (0.25–250 Ω sec.)	RG2	=	_____
	Zone 3: (0.25–250 Ω sec.)	RG3	=	_____
	Zone 4: (0.25–250 Ω sec.)	RG4	=	_____

Ground Distance Overcurrent Supervision Settings

Phase Overcurrent Supervision:	Zone 1: (0.1–20 A sec.)	50L1	=	_____
	Zone 2: (0.1–20 A sec.)	50L2	=	_____
	Zone 3: (0.1–20 A sec.)	50L3	=	_____
	Zone 4: (0.1–20 A sec.)	50L4	=	_____
Residual Overcurrent Supervision:	Zone 1: (0.1–20 A sec.)	50G1	=	_____
	Zone 2: (0.1–20 A sec.)	50G2	=	_____
	Zone 3: (0.1–20 A sec.)	50G3	=	_____
	Zone 4: (0.1–20 A sec.)	50G4	=	_____

Zero-Sequence Compensation Factor Settings

Zone 1 Zero-Sequence Comp. Factor 1 Magnitude: (0–4 unitless)	k01M	=	_____
Zone 1 Zero-Sequence Comp. Factor 1 Angle: ($\pm 45^\circ$)	k01A	=	_____
Zones 2, 3, & 4 Zero-Sequence Comp. Factor 2 Mag.: (0–4 unitless)	k0M	=	_____
Zones 2, 3, & 4 Zero-Sequence Comp. Factor 2 Angle: ($\pm 45^\circ$)	k0A	=	_____
Non-Homogeneous Correction Angle: ($\pm 20^\circ$)	T	=	_____

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Out-of-Step Blocking and Tripping Settings

Enable OOS: (Y/N)	EOOS	=	_____
OOSB Enable:	OOSB1	=	_____
Block Zone 1: (Y/N)	OOSB2	=	_____
Block Zone 2: (Y/N)	OOSB3	=	_____
Block Zone 3: (Y/N)	OOSB4	=	_____
Block Zone 4: (Y/N)			
Out-of-Step Block Time Delay (TDPD): (0.5–8000 cycles)	OSBD	=	_____
Enable OOST: (I/O/N)	EOOST	=	_____
Out-of-Step TOWI Time Delay (TDPD): (0.5–8000 cycles)	OSTD	=	_____
Zone 5 Reactive Reach:	X1T5	=	_____
Top: (0 to $\pm 480 \Omega$ sec.)	X1B5	=	_____
Bottom: (0 to $\pm 480 \Omega$ sec.)			
Zone 5 Resistive Reach:	R1R5	=	_____
Right: (0 to $\pm 350 \Omega$ sec.)	R1L5	=	_____
Left: (0 to $\pm 350 \Omega$ sec.)			
Zone 6 Reactive Reach:	X1T6	=	_____
Top: (0 to $\pm 480 \Omega$ sec.)	X1B6	=	_____
Bottom: (0 to $\pm 480 \Omega$ sec.)			
Zone 6 Resistive Reach:	R1R6	=	_____
Right: (0 to $\pm 350 \Omega$ sec.)	R1L6	=	_____
Left: (0 to $\pm 350 \Omega$ sec.)			
Zone 6 Positive-Sequence Overcurrent Supervision: (0.2–20 A sec., I ₁)	50ABC	=	_____
Negative-Sequence Current Unblock Delay (0.5–120 cycles)	UBD	=	_____

Load-Encroachment Settings

Enable Load-Encroachment: (Y/N)	ELE	=	_____
Load Impedance:	ZLF	=	_____
Forward: (0.25–320 Ω sec.)	ZLR	=	_____
Reverse: (0.25–320 Ω sec.)			
Load Angle:	PLAF	=	_____
Positive Forward: (-90° to +90°)	NLAF	=	_____
Negative Forward: (-90° to +90°)	PLAR	=	_____
Positive Reverse: (+90° to +270°)	NLAR	=	_____
Negative Reverse: (+90° to +270°)			

Negative-Sequence Directional Element Settings

Forward Directional Z2 Threshold: ($\pm 320 \Omega$ sec.)	Z2F	=	_____
Forward Directional Current Threshold: (0.05–1 A sec., 3I ₂)	50QF	=	_____
Reverse Directional Z2 Threshold: ($\pm 320 \Omega$ sec.)	Z2R	=	_____
Reverse Directional Current Threshold: (0.05–1 A sec., 3I ₂)	50QR	=	_____
Positive-Sequence Current Restraint Factor: (0.02–0.5 unitless)	a2	=	_____

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Phase Time-Overcurrent Element Settings

Phase Time-Overcurrent Element: Enable: (Y/N)	E51P	=	_____
Pickup: (0.1–3.2 A sec.)	51PP	=	_____
Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)	51PC	=	_____
Time Dial: (US 0.5–15, IEC 0.05–1)	51PTD	=	_____
Reset Delay: (Y/N)	51PRS	=	_____
Torque Control: (ZLIN, ZLOUT, M2P, N)	51PTC	=	_____

Residual Time-Overcurrent Element Settings

Residual Time-Overcurrent Element: Enable: (Y/N/S)	E51N	=	_____
Pickup: (0.1–3.2 A sec., 3I ₀)	51NP	=	_____
Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)	51NC	=	_____
Time Dial: (US 0.5–15, IEC 0.05–1)	51NTD	=	_____
Reset Delay: (Y/N)	51NRS	=	_____
Torque Control: (32QF, 32QR, Z2G, N)	51NTC	=	_____

Residual Overcurrent Element Settings

Enable Number of Residual Instantaneous Overcurrent Levels: (N,1,2,3,4)	E50N	=	_____
Residual Inst. Overcurrent Pickup: Level 1: (0.05–16 A sec., 3I ₀)	50N1	=	_____
Level 2: (0.05–16 A sec., 3I ₀)	50N2	=	_____
Level 3: (0.05–16 A sec., 3I ₀)	50N3	=	_____
Level 4: (0.05–16 A sec., 3I ₀)	50N4	=	_____

Negative-Sequence Time-Overcurrent Element Settings

Negative-Sequence Time-Overcurrent: Enable: (Y/N/S)	E51Q	=	_____
Pickup: (0.1–3.2 A sec., 3I ₂)	51QP	=	_____
Curve Family: (U1,U2,U3,U4,C1,C2,C3,C4)	51QC	=	_____
Time Dial: (US 0.5–15, IEC 0.05–1)	51QTD	=	_____
Reset Delay: (Y/N)	51QRS	=	_____
Torque Control: (32QF, 32QR, M2P, Z2G, N)	51QTC	=	_____

Negative-Sequence Overcurrent Element Settings

Enable Number of Neg.-Sequence Inst. Overcurrent Levels: (N,1,2,3,4)	E50Q	=	_____
Neg.-Seq. Inst. Overcurrent Pickup: Level 1: (0.05–16 A sec., 3I ₂)	50Q1	=	_____
Level 2: (0.05–16 A sec., 3I ₂)	50Q2	=	_____
Level 3: (0.05–16 A sec., 3I ₂)	50Q3	=	_____
Level 4: (0.05–16 A sec., 3I ₂)	50Q4	=	_____

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Voltage Element Settings

Enable Voltage Elements: (Y/N)	EVOLT	=	_____
Zero-Sequence Overvoltage: (0–150 V sec., 3V0)	59N	=	_____
Bus Phase Undervoltage: (0–100 V sec.)	27L	=	_____
Bus Phase Overvoltage: (0–100 V sec.)	59L	=	_____
Positive-Sequence Bus Overvoltage: (0–150 V sec., V1)	59PB	=	_____
Positive-Sequence Bus Overvoltage Time Delay (TDPU): (0–8000 cyc)	59PBD	=	_____
Positive-Sequence Remote Bus Overvoltage: (0–150 V sec., V1)	59PR	=	_____
Current Comp. Remote Overvoltage Time Delay (TDPU): (0–8000 cyc)	59PRD	=	_____
Current Compensated Remote Overvoltage Adjustment: (0–2 unitless)	a1	=	_____

Time Step Backup Time Delay Settings

Zone 2 Phase Long Time Delay (TDPU): (0–2000 cycles)	Z2PD	=	_____
Zone 3 Phase Time Delay (TDPU): (0–2000 cycles)	Z3PD	=	_____
Zone 4 Phase Time Delay (TDPU): (0–2000 cycles)	Z4PD	=	_____
Zone 2 Ground Long Time Delay (TDPU): (0–2000 cycles)	Z2GD	=	_____
Zone 3 Ground Time Delay (TDPU): (0–2000 cycles)	Z3GD	=	_____
Zone 4 Ground Time Delay (TDPU): (0–2000 cycles)	Z4GD	=	_____
Level 1 Residual Time Delay (TDPU): (0–2000 cycles)	67NL1D	=	_____
Level 2 Residual Long Time Delay (TDPU): (0–2000 cycles)	67NL2D	=	_____
Level 3 Residual Time Delay (TDPU): (0–2000 cycles)	67NL3D	=	_____
Level 4 Residual Time Delay (TDPU): (0–2000 cycles)	67NL4D	=	_____
Level 1 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL1D	=	_____
Level 2 Negative-Sequence Long Time Delay (TDPU): (0–2000 cycles)	67QL2D	=	_____
Level 3 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL3D	=	_____
Level 4 Negative-Sequence Time Delay (TDPU): (0–2000 cycles)	67QL4D	=	_____

Permissive Overreaching Scheme Settings

Enable Permissive Overreaching Transfer Trip Scheme: (Y/N)	EPOTT	=	_____
Zone 3 Reverse Block Time Delay (TDDO): (0–2000 cycles)	Z3RBD	=	_____
Echo Block Time Delay (TDDO): (0–2000 cycles)	EBLKD	=	_____
Echo Time Delay Pickup Time Delay (TDPU): (0–2000 cycles)	ETDPU	=	_____
Echo Duration Time Delay (TDDO): (0–2000 cycles)	EDURD	=	_____
Weak-Infeed Enable: (Y/N)	EWFC	=	_____

Directional Comparison Unblocking Scheme Settings

Enable DCUB: (Y/N)	EDCUB	=	_____
Guard Present Security Time Delay (TDDO): (0–2000 cycles)	GARD1D	=	_____
DCUB Disabling Time Delay (TDPU): (0.25–2000 cycles)	UBDURD	=	_____
DCUB Duration Time Delay (TDPU): (0–2000 cycles)	UBEND	=	_____

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Directional Comparison Blocking Scheme Settings

Enable DCB: (Y/N)	EDCB	=	_____
Zone 3 Dropout Extension Time Delay (TDDO): (0–2000 cycles)	Z3XD	=	_____
Block Trip Receive Extension Time Delay (TDDO): (0–2000 cycles)	BTXD	=	_____
Zone 2 Phase Distance Short Delay Time Delay (TDPU): (0–60 cycles)	Z2PSD	=	_____
Zone 2 Ground Distance Short Delay Time Delay (TDPU): (0–60 cycles)	Z2GSD	=	_____
Level 2 Residual Short Delay Time Delay (TDPU): (0–60 cycles)	67N2SD	=	_____
Level 2 Neg.-Seq. Short Delay Time Delay (TDPU): (0–60 cycles)	67Q2SD	=	_____

Zone 1 Extension Settings

Enable Zone 1 Extension: (Y/N)	EZ1EXT	=	_____
Enable Time Delay (TDPU): (0–2000 cycles)	Z1EXTD	=	_____
Multiplier: (1–5 unitless)	Z1EXTM	=	_____

Remote-End-Just-Opened Settings

Enable: (Y/N)	EREJO	=	_____
Pickup Time Delay (TDPU): (0–2000 cycles)	REJOD	=	_____
Overcurrent Element Pickup: (0.1–20 A sec.)	3P50R	=	_____

Switch-On-to-Fault Settings

Enable: (Y/N)	ESOTF	=	_____
Enable Close Logic: (Y/N)	ENCLO	=	_____
Close Enable Time Delay (TDPU): (0–8000 cycles)	CLOEND	=	_____
Enable 52A Logic: (Y/N)	EN52A	=	_____
52A Enable Time Delay (TDPU): (0–8000 cycles)	52AEND	=	_____
Time Duration (TDDO): (0.5–8000 cycles)	SOTFD	=	_____
High-Set Phase Overcurrent Pickup: (0.1–20 A sec.)	50H	=	_____

Loss-of-Potential Settings

Enable Loss-of-Potential: (Y/N)	ELOP	=	_____
Loss-of-Potential Time Delay (TDPU): (1–60 cycles)	LOPD	=	_____
Medium-Set Phase Overcurrent Pickup: (0.1–20 A sec.)	50M	=	_____
Zero-Sequence Voltage LOP Supervision: (0–150 V sec., V0)	59NL	=	_____
Positive-Sequence Voltage LOP Supervision: (0–150 V sec., V1)	59PL	=	_____

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Miscellaneous Scheme Settings

Pole-Discordance Enable: (Y/N)	EPOLD	=	_____
Single-Pole Trip Pole-Discordance Time Delay (TDPU): (0–8000 cycles)	SPPDD	=	_____
Single-Pole Trip Enable: (Y/N/Y1/N1)	ESPT	=	_____
Single-Pole Open Enable: (Y/N)	ESPO	=	_____
Open-Pole Option: (52,27)	OPO	=	_____
Single-Pole Open Time Delay (TDDO): (0–8000 cycles)	SPOD	=	_____
Three-Pole Open Time Delay (TDDO): (0–8000 cycles)	3POD	=	_____
Enable Stub Protection: (Y/N)	ESTUB	=	_____
Stub Protection Time Delay (TDPU): (0–2000 cycles)	50MFD	=	_____
Trip Unlatch Option: (N,1,2,3,4)	TULO	=	_____

Miscellaneous Timers

Minimum Trip Duration Time Delay (TDDO): (0–2000 cycles)	TDURD	=	_____
Trip During Open Pole Time Delay (TDDO): (0–8000 cycles)	TOPD	=	_____
Relay Element X Time Delay Pickup (TDPU): (0–8000 cycles)	TXPU	=	_____
Relay Element X Time Delay Dropout (TDDO): (0–8000 cycles)	TXDO	=	_____
Relay Element Y Time Delay Pickup (TDPU): (0–8000 cycles)	TYPU	=	_____
Relay Element Y Time Delay Dropout (TDDO): (0–8000 cycles)	TYDO	=	_____
Relay Element Z Time Delay Pickup (TDPU): (0–8000 cycles)	TZPU	=	_____
Relay Element Z Time Delay Dropout (TDDO): (0–8000 cycles)	TZDO	=	_____
Instantaneous Trip Time Declaration Delay (TDPU): (0–60 cycles)	ITTD	=	_____

Logic Variables

LOGIC V	=	_____
LOGIC W	=	_____
LOGIC X	=	_____
LOGIC Y	=	_____
LOGIC Z	=	_____

Tripping Logic

MTCS	=	_____
MTU	=	_____
MTO	=	_____

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Event Report Trigger Condition Logic

MER = _____

Output Contact Logic

OUT1 = _____
OUT2 = _____
OUT3 = _____
OUT4 = _____
OUT5 = _____
OUT6 = _____
OUT7 = _____
OUT8 = _____
OUT9 = _____
OUT10 = _____
OUT11 = _____
OUT12 = _____
OUT13 = _____
OUT14 = _____
OUT15 = _____
* OUT17 = _____
* OUT18 = _____
* OUT19 = _____
* OUT20 = _____
* OUT21 = _____

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* OUT22 = _____
* OUT23 = _____
* OUT24 = _____
* OUT25 = _____
* OUT26 = _____
* OUT27 = _____
* OUT28 = _____
* OUT29 = _____
* OUT30 = _____
* OUT31 = _____
* OUT32 = _____
TMB1 = _____
TMB2 = _____
TMB3 = _____
TMB4 = _____
TMB5 = _____
TMB6 = _____
TMB7 = _____
TMB8 = _____

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Global Contact Input Settings

Input Contact 1 Assignment:	IN1	=	_____
Input Contact 2 Assignment:	IN2	=	_____
Input Contact 3 Assignment:	IN3	=	_____
Input Contact 4 Assignment:	IN4	=	_____
Input Contact 5 Assignment:	IN5	=	_____
Input Contact 6 Assignment:	IN6	=	_____
Input Contact 7 Assignment:	IN7	=	_____
Input Contact 8 Assignment:	IN8	=	_____
* Input Contact 9 Assignment:	IN9	=	_____
* Input Contact 10 Assignment:	IN10	=	_____
* Input Contact 11 Assignment:	IN11	=	_____
* Input Contact 12 Assignment:	IN12	=	_____
* Input Contact 13 Assignment:	IN13	=	_____
* Input Contact 14 Assignment:	IN14	=	_____
* Input Contact 15 Assignment:	IN15	=	_____
* Input Contact 16 Assignment:	IN16	=	_____
Received MIRRORED BIT® 1:	RMB1	=	_____
Received MIRRORED BIT 2:	RMB2	=	_____
Received MIRRORED BIT 3:	RMB3	=	_____
Received MIRRORED BIT 4:	RMB4	=	_____
Received MIRRORED BIT 5:	RMB5	=	_____
Received MIRRORED BIT 6:	RMB6	=	_____
Received MIRRORED BIT 7:	RMB7	=	_____
Received MIRRORED BIT 8:	RMB8	=	_____

Miscellaneous Global Settings

Front-panel time-out: (0–30 minutes)	FP_TIMEOUT	=	_____
Group change delay: (0–900 seconds)	TGR	=	_____

* OUT17–OUT32 available only on two I/O board relays.

* INPUT9–INPUT16 available only on two I/O board relays.

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SECTION 6: INSTALLATION

INTRODUCTION

Planning should be the first step you take before installing any new device, and it is equally essential to ensure successful installation and operation of the SEL-321-5 Relay. This section of the SEL-321-5 instruction manual includes information and procedures you should be familiar with to install the SEL-321-5 Relay safely and effectively. Safe and effective installation of the SEL-321-5 Relay requires proper mounting, connection, communications, and setup.

INITIAL CHECKOUT

Perform the following steps to ensure that the SEL-321-5 Relay operates prior to installation:

1. Visually inspect the relay for loose or damaged parts.
2. Connect and apply power to the relay (see the “PWR SUP” field on the rear-panel nameplate for power requirements). If you do not have the proper voltage source available, use a power supply, such as the SEL-LPS, to power the unit.
3. Verify that the front-panel LEDs and LCD back-light come on when power is applied.
4. After a couple of seconds, the EN LED should light and “EN” should be visible in the LCD display. The ALARM contact should also operate (open). Momentarily press the TARGET RESET button and verify that all LEDs operate. (**Note:** If the LCD display is not readable, use a small slotted-tip screwdriver to adjust it via the hole near the EN LED).
5. Connect a terminal (or computer equipped with terminal emulation software) to the front-panel connector Port 3 of the SEL-321-5 Relay by using an SEL-C234A cable or equivalent (see **Communication Cables** in this section).
6. Set the computer terminal or emulation software to operate at: 2400 baud, 8 data bits, 1 stop bit, no parity
7. Press <ENTER> and verify that a “=” prompt is returned.
8. Type **ACCESS<ENTER>** to change to Access Level 1. If you enabled password protection, enter the factory-set password by typing **OTTER<ENTER>** at the password prompt. You should now have a “=>” (Level 1) prompt
9. Type **STATUS<ENTER>** and verify that a status report appears on your terminal. Refer to the **STATUS** command in **Section 3: Communications** for more detailed information. This step completes initial checkout of the SEL-321-5 Relay.

MOUNTING AND CONNECTIONS

This subsection provides details about the physical mounting and connection requirements for the SEL-321-5 Relay.

Mounting

The relay is designed to be permanently mounted in a dry, indoor location. The relay may be mounted either horizontally or vertically by its front flanges in a 19-inch relay rack. It may also be mounted semi-flush in a switchboard panel. Use four #10 screws for mounting. See Figure 6.2 through Figure 6.10 for front- and rear-panel drawings, mounting dimensions, and drilling details.

Frame Ground Connection

You must connect the grounding terminal (#124) labeled “GND” on the rear panel to a frame ground for proper safety and performance. Use 12 AWG (or heavier) wire, less than 2m (6 feet) long for this. This terminal connects directly to the internal chassis ground of the instrument.

Power Connections

The terminals labeled “POWER” on the rear panel must be connected to a power source that matches the power supply (PWR SUP) characteristics specified on the rear-panel nameplate of your SEL-321-5 Relay. Control power passes through these terminals to the fuse(s) and a toggle switch, if installed. These terminals are isolated from the chassis ground. If you provide a dc power source, you must connect the source with the proper polarity as indicated by the “+” and “-” symbols on the power terminals. The SEL-321-5 Relay internal power supply has low power consumption and a wide input voltage tolerance. See ***General Specifications*** in ***Section 2: Specifications*** for complete power supply information.

Secondary Circuit Connections

The SEL-321-5 Relay presents a very low burden to the secondary potential and current circuits. It requires three phase, four-wire (wye) potentials (VA, VB, VC, and N) and three currents (IA, IB, IC) from the power system transformer secondaries. See Figure 6.13. Check the specified rotation and nominal voltage, current, and frequency on the rear-panel nameplate to ensure proper application prior to connection. To verify these connections, trigger an event report by using the **TRIGGER** command (see ***Section 3: Communications***). Analyze it by using the SEL Direction and Polarity Check Form included at the end of this section.

Control Circuit Connections

Refer to Figure 6.14 and Figure 6.15.

Control Inputs

Relays come standard with control inputs that operate at the same voltage level as the relay power source. Check the control voltage, labeled “LOGIC INPUT” on the rear-panel nameplate, before making any connections. The control inputs are optically isolated “dry” circuits and are not polarity sensitive. To assert the IN1 input, for example, you must apply control voltage to the terminals assigned the IN1 input. Each input is individually isolated, and a terminal pair is

brought out for each input. There are no internal connections between control inputs. To assign the functions of the control inputs, see **Contact Input Assignments** in **Section 2: Specifications** and **SET G** in **Section 3: Communications** for more details. To verify operation of the inputs, use the **TARGET** command (see **Section 3: Communications**). Several control (or contact) input configurations are available; contact your local representative or the factory for information.

Control Outputs

The standard control outputs are “dry” relay contacts rated for tripping duty. The optional interrupting-duty control outputs are polarity-dependent and are capable of interrupting high-current, inductive loads. A metal-oxide varistor (MOV) protects each contact. Each output is individually isolated, and a terminal pair is brought out for each output (**Note:** some I/O boards share a common connection with adjacent contacts). There are no internal connections between control outputs (except as noted previously). To assign the functions of the control outputs, see **Trip Logic** in **Section 2: Specifications** and **SET L** in **Section 3: Communications** for more details. To verify operation of the outputs, use the **PULSE** command (see **Section 3: Communications**).

Alarm Contact Connection

The SEL-321-5 Relay includes an alarm output contact labeled “ALARM” on the rear panel. At the factory, the alarm contact is configured to be closed for an alarm condition, and open for normal operation. This is a “Form B” contact because it is closed when there is no power. To invert the alarm output to close under normal conditions (“Form-A”), change the soldered jumper associated with the alarm relay on the interface board where the alarm relay is located. See **I/O Connections** later in this section for details.

Note: If the ALARM contact has a “+” symbol, it is polarity-dependent and must be connected accordingly.

The alarm contact asserts when: power is disconnected from the SEL-321-5 Relay, the power supply fails, or self-test diagnostics detect a failure. Self-test diagnostic failures include memory failures, power supply failures, and invalid settings failures. See **Self-Tests** in **Section 2: Specifications** and **STATUS** in **Section 3: Communications** for a discussion on these failures and the alarm contact response to them. Also, the alarm contact is pulsed when Breaker or Level 2 access is established or when a setting change is accepted.

IRIG-B Input Connection

The SEL-321-5 Relay accepts a demodulated IRIG-B signal through a rear-panel 9-pin, subminiature “D” connector labeled “DEMODULATED IRIG-B.” This allows synchronization with an external time source. See **Communications Ports Specifications** in **Section 2: Specifications** for connector pinout and additional details.

The IRIG-B signal includes code for time-of-day and day-of-year. It does not include a code to identify the year. To ensure the device calendar is set to the proper year, set the date by using the **DATE** command (see **Section 3: Communications**). The relay stores the year for the set date with the relay settings in nonvolatile memory, so once the date is properly set, the relay will maintain the proper year even if relay power is cycled off and on. The relay does not maintain the time, month or day when power is off. If no external IRIG-B input signal is applied, the relay will start its clock/calendar at 0:00:00 and 1/1/YY when turned on.

Where distance between the SEL-321-5 Relay and the IRIG-B sending device exceeds the cable length recommended for conventional EIA-232 metallic conductor cables, you can use modems to provide isolation and to establish communications to remote locations. Unfortunately, conventional short-haul, fiber-optic, and telephone modems do not support IRIG-B signal transmission, so their use requires that you use some other method to synchronize the time in the SEL-321-5 Relay. Special fiber-optic modems (like the SEL-2810) are available, however, that include a channel for the IRIG-B time code; these modems enable you to synchronize more precisely with devices (such as the SEL-2020) capable of sending IRIG-B time code, even with a fiber-optic communication link.

The actual IRIG-B input circuit is a 330 Ω resistor in series with an optocoupler input diode. The input diode forward voltage drop is about 1.5 V. Driver circuits should put approximately 10 mA through the circuit when “on” (this would be accomplished by a 0–5 Vdc signal capable of supplying at least 10 mA when at 5 V). Ensure that the two connector pins are connected with proper polarity.

The IRIG-B serial data format consists of a one-second frame containing 100 pulses that are divided into fields. The relay decodes the second, minute, hour, and day fields and sets its internal time clock accordingly.

When IRIG-B data acquisition is activated, either manually (with the **IRIG** command), or automatically, two consecutive frames are taken. The first frame is updated by one second and then compared with the second frame. If they do not agree, the relay considers the data erroneous and discards it.

The relay reads the time code automatically about once every minute. The relay stops IRIG-B data acquisition 10 minutes before midnight on New Year’s Eve every year so the relay clock may implement the year change without interference from the IRIG-B input. Ten minutes later, the relay restarts IRIG-B data acquisition.

Communication Circuit Connections

The SEL-321-5 Relay is equipped with two rear-panel serial communication ports, labeled “SERIAL PORT 1” and “SERIAL PORT 2,” and one front-panel serial communications port, labeled “SERIAL PORT 3.” The data connection for each SEL-321-5 serial communications port uses EIA-232 standard signal levels in a 9-pin, subminiature “D” connector (see Figure 6.1 for pin number convention and **Communications Ports Specifications** in **Section 2: Specifications** for pin assignments). EIA-232 interfaces are supported by almost all modern relays, meters, computer, and communications devices. See Figure 6.11 and Figure 6.12.

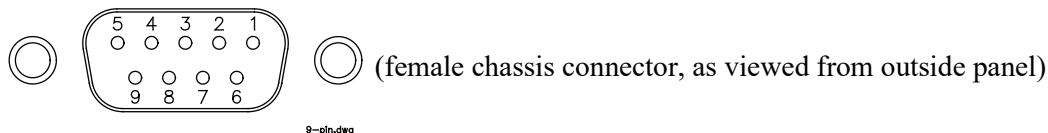


Figure 6.1: 9-Pin Connector Pin Number Convention



WARNING

Do not rely upon pins 5 and 9 for safety grounding, because their current carrying capacity is less than control power short circuit and protection levels.

Pins 5 and 9 connect to frame (chassis) ground via the main board ground plane. The communication circuits are protected internally by low-energy, low-voltage MOVs and passive RC filters.

You should keep the length of the communication cables as short as possible to minimize communication circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions. See the next subsection, **Communication Cables**, for additional details and restrictions.

Communication Cables

Several standard SEL communication cables are available for use with the SEL-321-5 Relay. See below for some representative pinouts. Using an improper cable can cause numerous problems, so you must be sure to specify the proper cable for the application. To help in this regard, cable selector software is now available. Contact SEL for more information or if you have any questions about cables and cable connections.

Never use standard null-modem cables with the SEL-321-5 Relay. Using any non-SEL cable can cause severe power and ground problems on the SEL-321-5 Relay communication ports.

The following list provides additional rules and practices you should follow to ensure successful communication using EIA-232 serial communication devices and cables:

- You should keep the length of the communication cables as short as possible to minimize communication circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions.
- EIA-232 communication cable lengths should never exceed 50 feet, and you should always use shielded cables for communication circuit lengths greater than 10 feet.
- Modems are required for communications over long distances and to provide isolation from ground potential differences between device locations.
- Route communication cables well away from power and control circuits. Switching spikes and surges in power and control circuits can cause noise in the communications circuits if not adequately separated.
- Lower baud rate communication is less susceptible to interference and will transmit greater distances over the same medium than with higher baud rates. You should use the lowest baud rate that provides adequate data transfer speed.

EIA-232 Cables

SEL-C234A Cable

<u>SEL-321-5 Relay</u>		<u>*DTE Device</u>
9-Pin Male “D” Subconnector		9-Pin Female “D” Subconnector
RXD 2	—————	3 TXD
TXD 3	—————	2 RXD
GND 5	—————	5 GND
CTS 8	—————	8 CTS
		7 RTS
		1 DCD
		4 DTR
		6 DSR

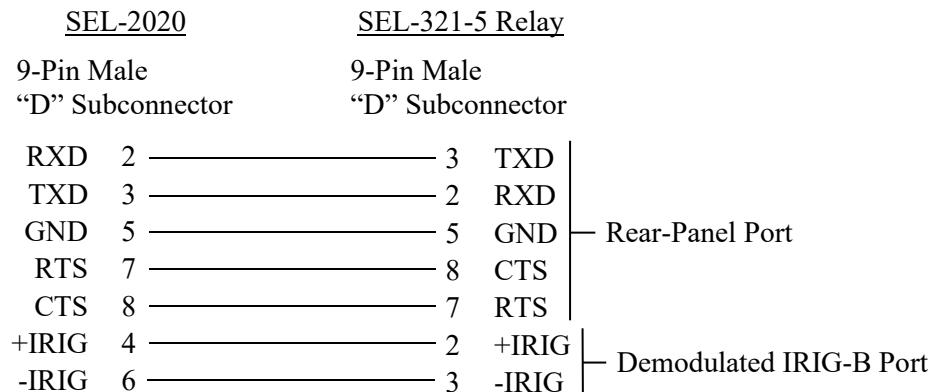
SEL-C222 Cable

<u>SEL-321-5 Relay</u>		<u>**DCE Device</u>
9-Pin Male “D” Subconnector		25-Pin Male “D” Subconnector
GND 5	—————	7 GND
TXD 3	—————	2 TXD (IN)
RTS 7	—————	20 DTR (IN)
RXD 2	—————	3 RXD (OUT)
CTS 8	—————	8 CD (OUT)
GND 9	—————	1 GND

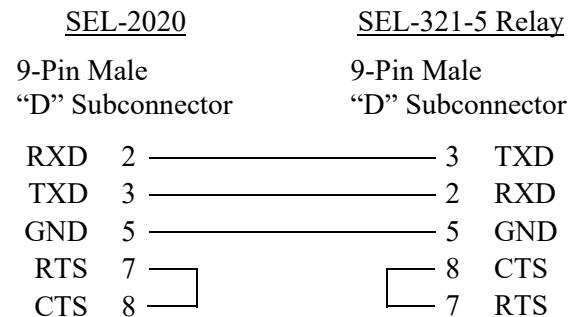
SEL-231 Cable

<u>SEL-PRTU</u>		<u>SEL-321-5 Relay</u>
9-Pin Male Round Conxall		9-Pin Male “D” Subconnector
GND 1	—————	5 GND
TXD 2	—————	2 RXD
RXD 4	—————	3 TXD
CTS 5	—————	7 RTS
+12 7	—————	8 CTS
GND 9	—————	9 GND

SEL-239 Cable
Data and IRIG-B



SEL-272A Cable
Data Only



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

** DCE = Data Communications Equipment (Modem, etc.)

COMMUNICATIONS

This subsection describes how you can optimize the communications interface between the SEL-321-5 Relay and other devices it will communicate with.

Modems

If electrical interference is a problem, consider using point-to-point fiber-optic modems to provide electrical isolation and noise immunity. We recommend the SEL-2800/2810 Fiber-Optic Transceivers for these applications. The connection between the SEL-321-5 Relay and the modem is EIA-232. The connection between the remote modem and the remote device is also EIA-232. Optical fibers connect the two modems.

For sites where the main issue is cable length, you can use short-haul modems connected by wire. This alternative is a compromise between the low cost and short cable for direct EIA-232 connections and the isolation and noise immunity of higher-cost fiber-optic links.

You must provide power to any modem that you install between the SEL-321-5 Relay and another device. You can use the SEL-321-5 Relay to power some types of modems connected to its rear-panel ports. The SEL-321-5 will support modems that accept +5 Vdc power. The total current drawn by all of the external modems powered by one SEL-321-5 should not exceed 0.5 A. Some modems power themselves from the control and data lines. These modems do not require connection to the +5 Vdc power.

Note: The three rear-panel ports provide +5 Vdc at Pin 1 of their 9-pin connectors. These are directly tied to the main board power supply. Use care when connecting these pins. Misapplication may result in main board damage.

Telephone Line Communications

A telephone dial-up link is one option for offsite communications with an SEL-321-5 Relay. Use a modem to convert from the audio telephone line to an EIA-232 interface on the SEL-321-5 Relay.

You should use telephone line protection equipment where the line enters the building, to ensure personnel safety and reduce damage to equipment from ground potential rise and other hazardous conditions. Connect the line protection equipment to the modem following standard commercial telephone wiring standards.

Data Flow Control

All SEL devices, including the SEL-321-5 Relay, support XON/XOFF software data flow control. Set RTS/CTS = N to connect an SEL-321-5 Relay to any SEL device. See **SET P** in **Section 3: Communications** for details.

The SEL-321-5 Relay also supports RTS/CTS hardware data flow control on Port 1 and Port 2. You should select the RTS/CTS option only if the connected device uses RTS/CTS, and does not use XON/XOFF flow control. Consult the instruction manual or contact the device vendor to determine the proper flow control technique for each non-SEL device. If you select RTS/CTS hardware data flow control, make sure that the cable you are using to connect the device to the SEL-321-5 Relay has conductors for RTS/CTS.

Baud Rate

The factory-default baud rate for the SEL-321-5 Relay ports is 2400 baud. You can change the baud rate, and other port communication parameters, using the **SET P** command (see **Section 3: Communications**). Available baud rates are 300, 1200, 2400, 4800, 9600 and 19200.

To change the communication baud rate, you should change the baud rate on the SEL-321-5 Relay first, then change the baud rate setting on the communicating device.

Passwords

Factory-set passwords are:

Level 1 = OTTER (all caps)

Level B = EDITH (all caps)

Level 2 = TAIL (all caps)

You can set your own passwords with the **PASSWORD** command (see *Section 3: Communications*), or you can disable the password protection with jumper selection (see *Main Board Jumpers* below).

JUMPER SETTINGS

This subsection describes the hardware jumper selections available on the SEL-321-5 Relay, and the recommended procedures for making the jumper setting changes.

Main Board Jumpers

Set the main board jumpers to meet your requirements. See Table 6.1 for jumper functions and positions. See *Appendix B* for jumper locations on the main board.

Table 6.1: Main Board Jumper Positions

Function	Install Jumpers At:
<u>Password Protection Disabled</u> <u>Password Protection Enabled</u> (default)	P7: J105 shorting block installed P7: J105 shorting block removed
OPEN/CLOSE Command Enable (default) OPEN/CLOSE Command Disable	P7: J106 shorting block installed P7: J106 shorting block removed
Note: Unused (spare) jumpers may be placed on P7 locations labeled “GND.” P7: J101 through P7: J204 do not provide any function.	

I/O Connections

Your SEL-321-5 Relay is equipped with one or two I/O boards.

Configure the Output Contact Form

The SEL-321-5 Relay I/O boards are shipped from the factory with form A output contacts (except for the alarm contact). You may reconfigure the contacts by desoldering and then resoldering the 20 AWG jumper wire for each contact. See *Appendix J* for information on jumper locations and positions required to configure the contacts.

Open the SEL-321-5 Relay to Access Internal Jumpers

If you have decided that the SEL-321-5 Relay default configuration does not meet your needs, perform the following steps to gain access to internal jumpers:

1. De-energize the SEL-321-5 Relay.



Never work on the relay with the front or top cover removed, when the relay is energized.

2. Remove the screws attaching the front panel and top cover and remove the front panel and top cover. (**Note:** The top cover does not need to be removed to access the main board jumpers.) Be careful of the cables attaching the front-panel board to the main board.



The relay contains devices sensitive to electrostatic discharge (ESD). When working on the relay with front or top cover removed, work surfaces and personnel must be properly grounded or equipment damage may result.

3. If an I/O board requires changes, disconnect as many cables as necessary so that the I/O board can be removed. Release the I/O board by pulling out the white release clamps at the corners and then slide the board forward and out.

Set Jumpers

See **Appendix B** for main board jumper locations. Configure the following main board jumpers according to the selections you have made:

- OPEN/CLOSE Command Enable/Disable jumper.
- Password Enable/Disable jumper.

See **Appendix J** for I/O board jumper locations and positions. While the I/O board is removed, configure the following jumpers according to the selections you have made:

- Select output contact form: A or B (**Note:** most boards have a jumper for each output).

Reassemble the SEL-321-5 Relay

After configuring jumpers, reassemble the SEL-321-5 Relay as follows:

1. If you removed an I/O board, replace it.
2. Reconnect any cables that were disconnected between the I/O board and the other board(s).
3. Replace the top cover and top-cover screws and tighten them securely.
4. Replace the front panel and front-panel screws and tighten them securely. Once again, be careful of the cables attaching the front-panel board to the main board. Ensure that they are fully engaged and that they do not get pinched during reassembly.
5. Re-energize the relay and ensure that it powers up as expected.

INSTALLATION

Before you install the SEL-321-5 Relay, you should perform the initial checkout procedure found earlier in this section, and set the configuration jumpers according to your installation requirements per the instructions outlined earlier in this section. Install the SEL-321-5 Relay according to the following step-by-step instructions:

1. Mount the SEL-321-5 Relay in the desired panel location. Mounting information, including chassis, cutout and drilling dimensions are shown in Figure 6.10.
2. Connect the devices you desire to the SEL-321-5 Relay rear-panel DB-9 communication ports by using SEL cables, or their equivalents. Cable information is located earlier in this section.
3. Connect power and ground, alarm, IRIG-B, and other cabling on the rear panel.
4. Connect a terminal (or computer equipped with terminal emulation software) to the front-panel connector Port 3 of the SEL-321-5 Relay by using an SEL-C234A cable or equivalent.
5. Set the computer terminal or emulation software to operate at: 2400 baud, 8 data bits, 1 stop bit, no parity
6. Press <ENTER> and verify that a “=” prompt is returned.
7. Type **ACCESS<ENTER>** to change to Access Level 1. If you enabled password protection, enter the factory-set password by typing **OTTER<ENTER>** at the password prompt. You should now have a “=>” (Level 1) prompt
8. Type **STATUS<ENTER>** and verify that a status report appears on your terminal. Confirm that IRIG-B, PORT, and I/O board connections/configurations match your expectations. Change the SEL-321-5 Relay settings as desired/required to suit the application (as outlined in other sections of this manual) and verify that their operation matches your expectations.
9. After you have installed the SEL-321-5 Relay, perform the checkout procedures in **Section 7: Maintenance and Testing**. You may follow the suggestions there, or combine them with your normal practice. Never implement recommendations prohibited by the rules of your normal practice.
10. When local checkout is complete, check communications with the SEL-321-5 Relay via the remote interface (if applicable). Make sure the automatic port is properly assigned and that the desired time-out intervals are selected for each port. Lastly, be sure to record password settings. This step completes installation of the SEL-321-5 Relay.

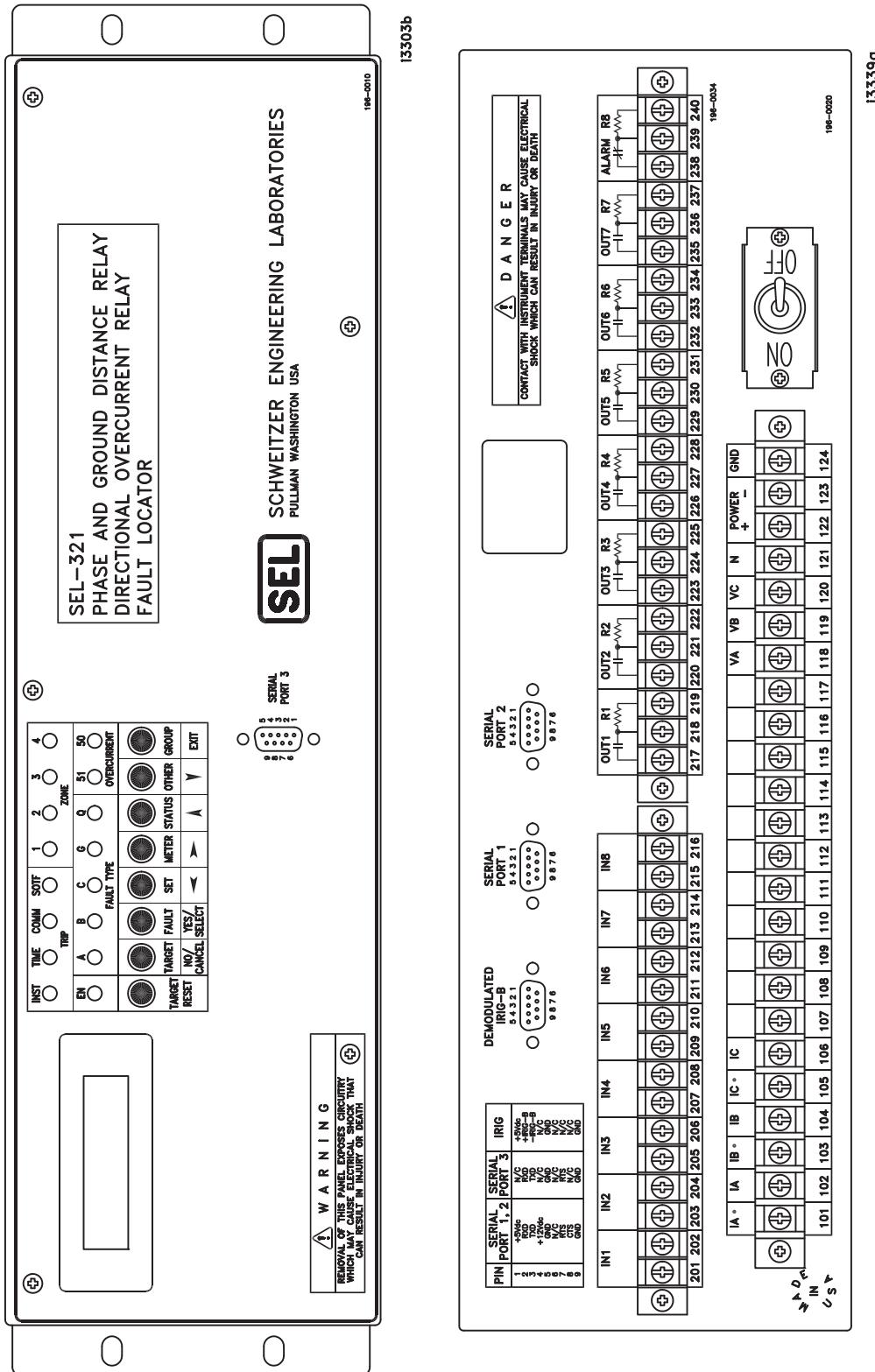


Figure 6.2: SEL-321-5 Relay Horizontal Front- and Rear-Panel Drawings (One I/O Board Conventional Terminal Block Version; 8 Fast High-Current Interrupting Isolated Outputs Shown—Other Options Are Available)

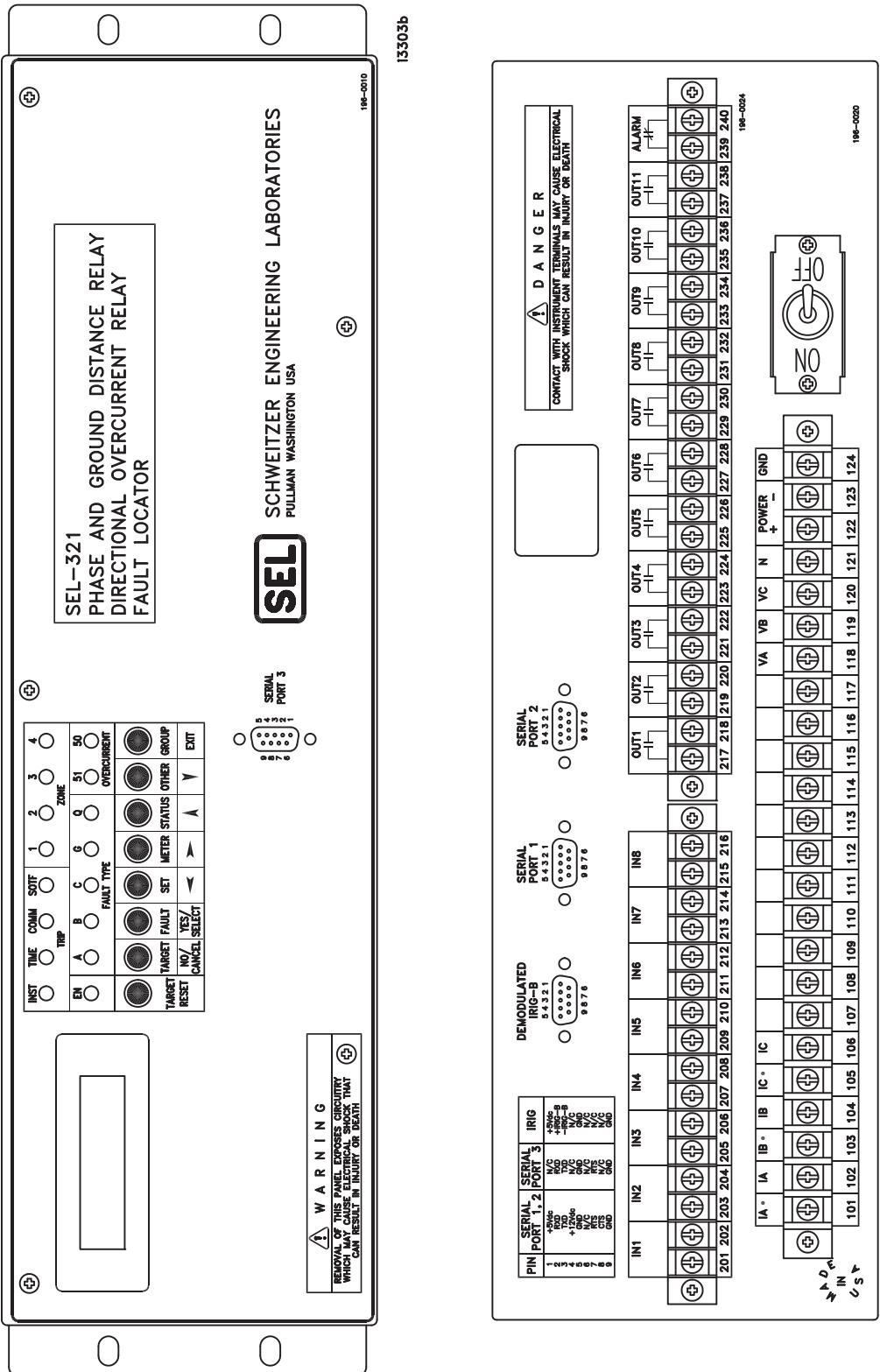


Figure 6.3: SEL-321-5 Relay Horizontal Front- and Rear-Panel Drawings (One I/O Board Conventional Terminal Block Version; 12 Isolated Outputs Shown—Other Options Are Available)

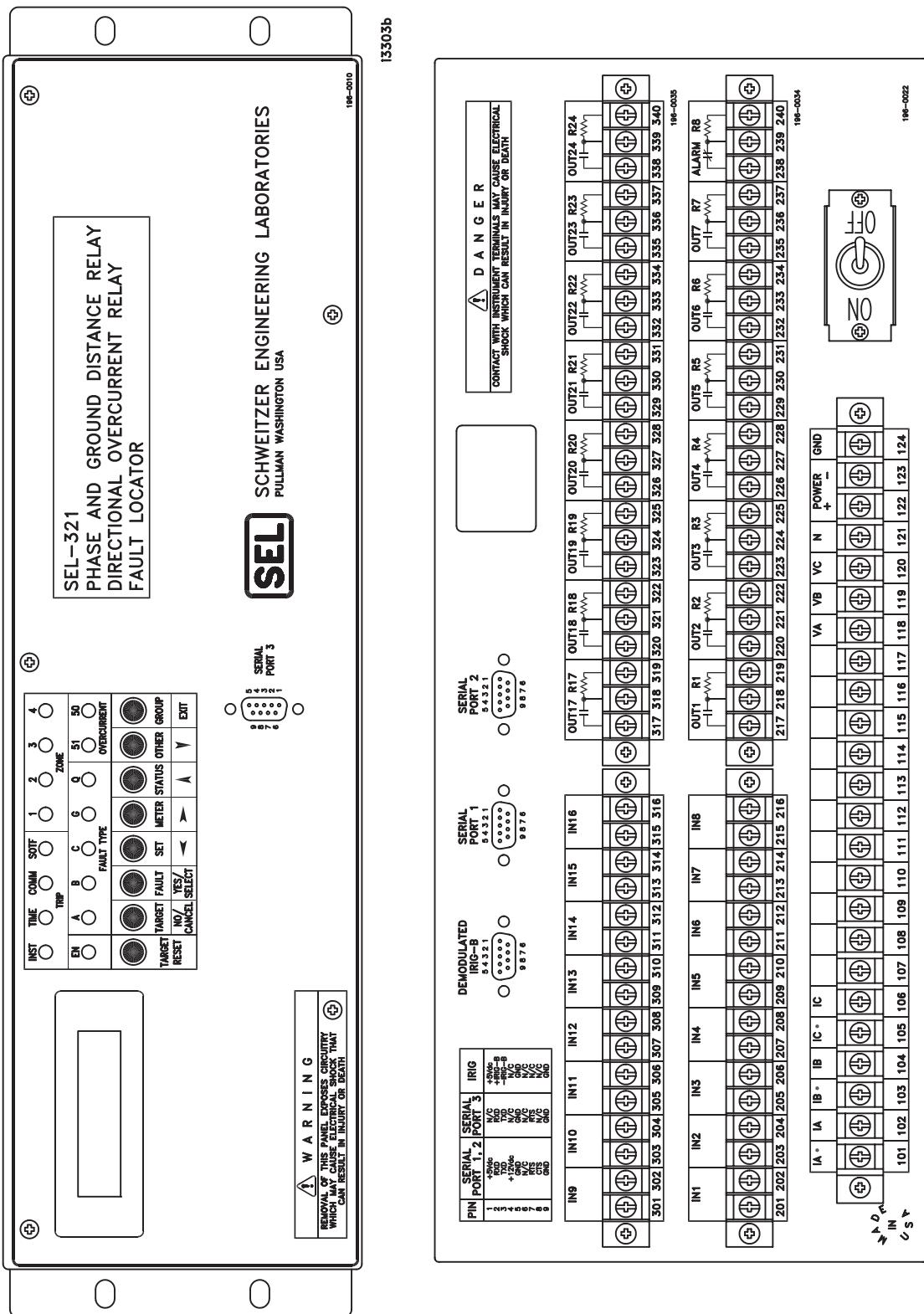


Figure 6.4: SEL-321-5 Relay Horizontal Front- and Rear-Panel Drawings (Two I/O Board Conventional Terminal Block Version; 8 Fast High-Current Interrupting Isolated Outputs Per Board Shown—Other Options Are Available)

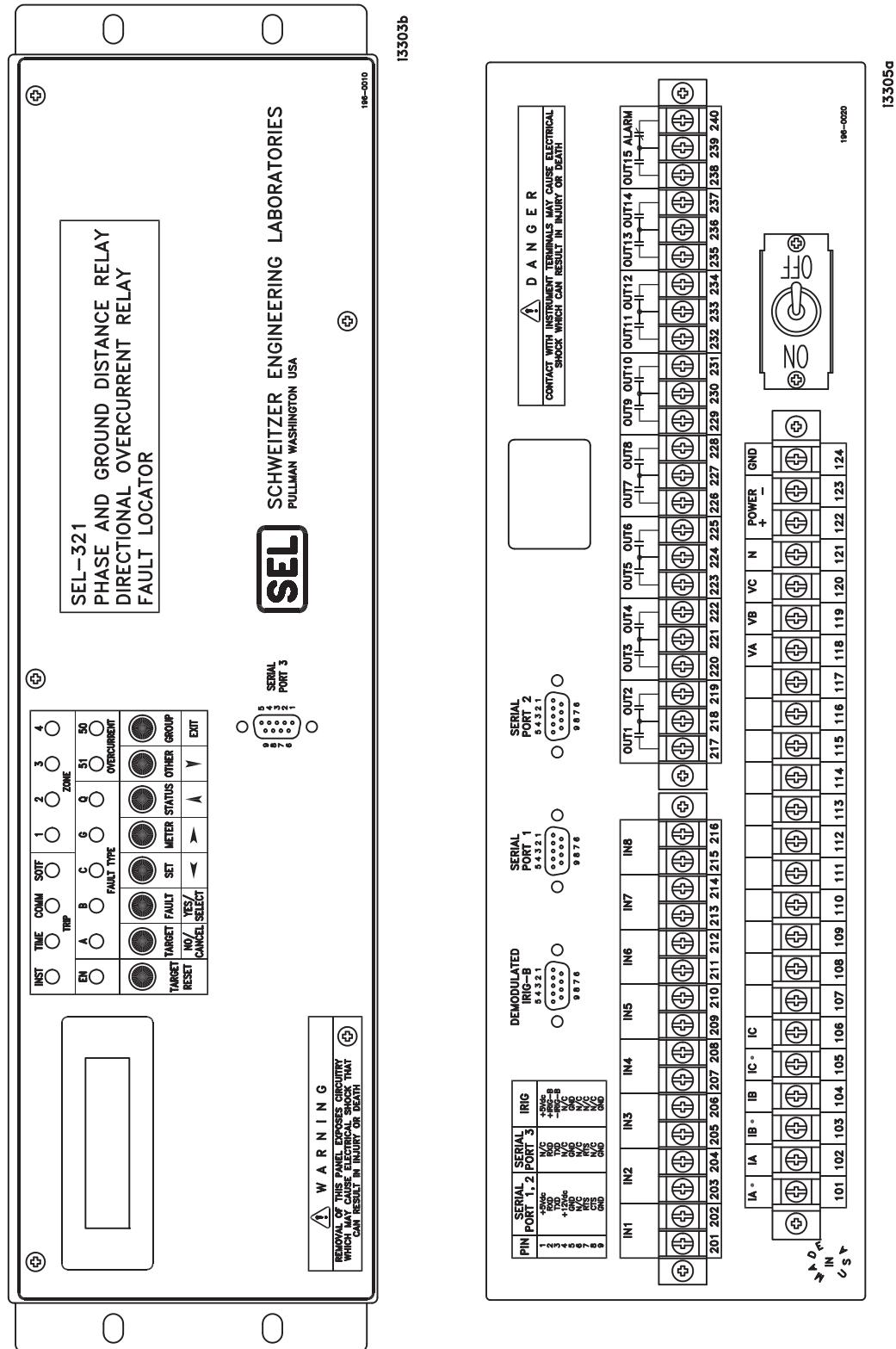
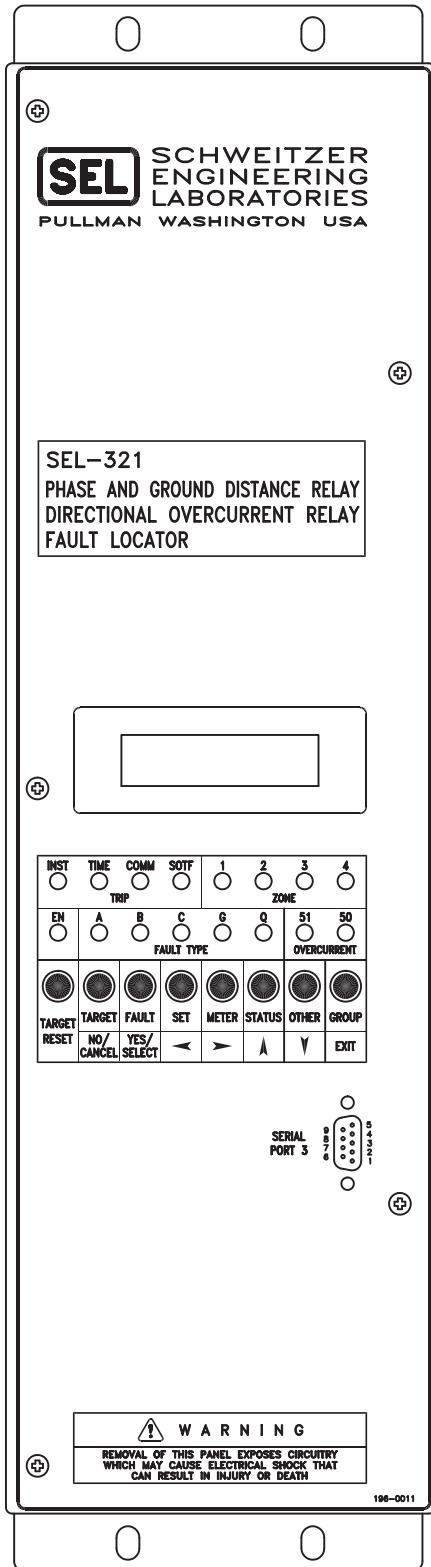
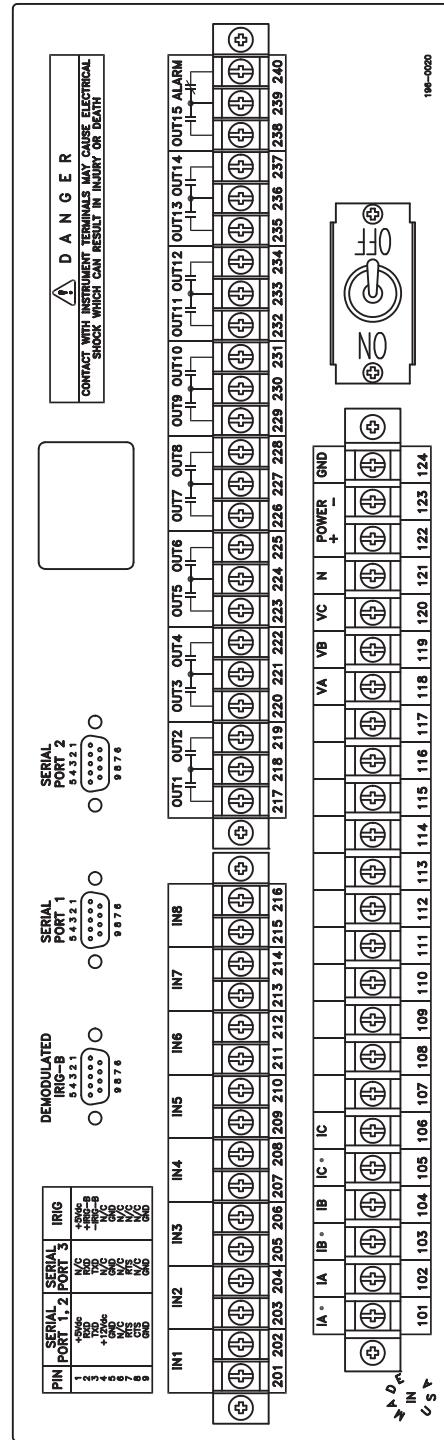


Figure 6.5: SEL-321-5 Relay Horizontal Front- and Rear-Panel Drawings (One I/O Board Conventional Terminal Block Version; 16 Outputs With Shared Return Terminals Shown—Other Options Are Available)



I3304a



I3305a

Figure 6.6: SEL-321-5 Relay Vertical Front- and Rear-Panel Drawings (One I/O Board Conventional Terminal Block Version; 16 Outputs With Shared Return Terminals Shown—Other Options Are Available)

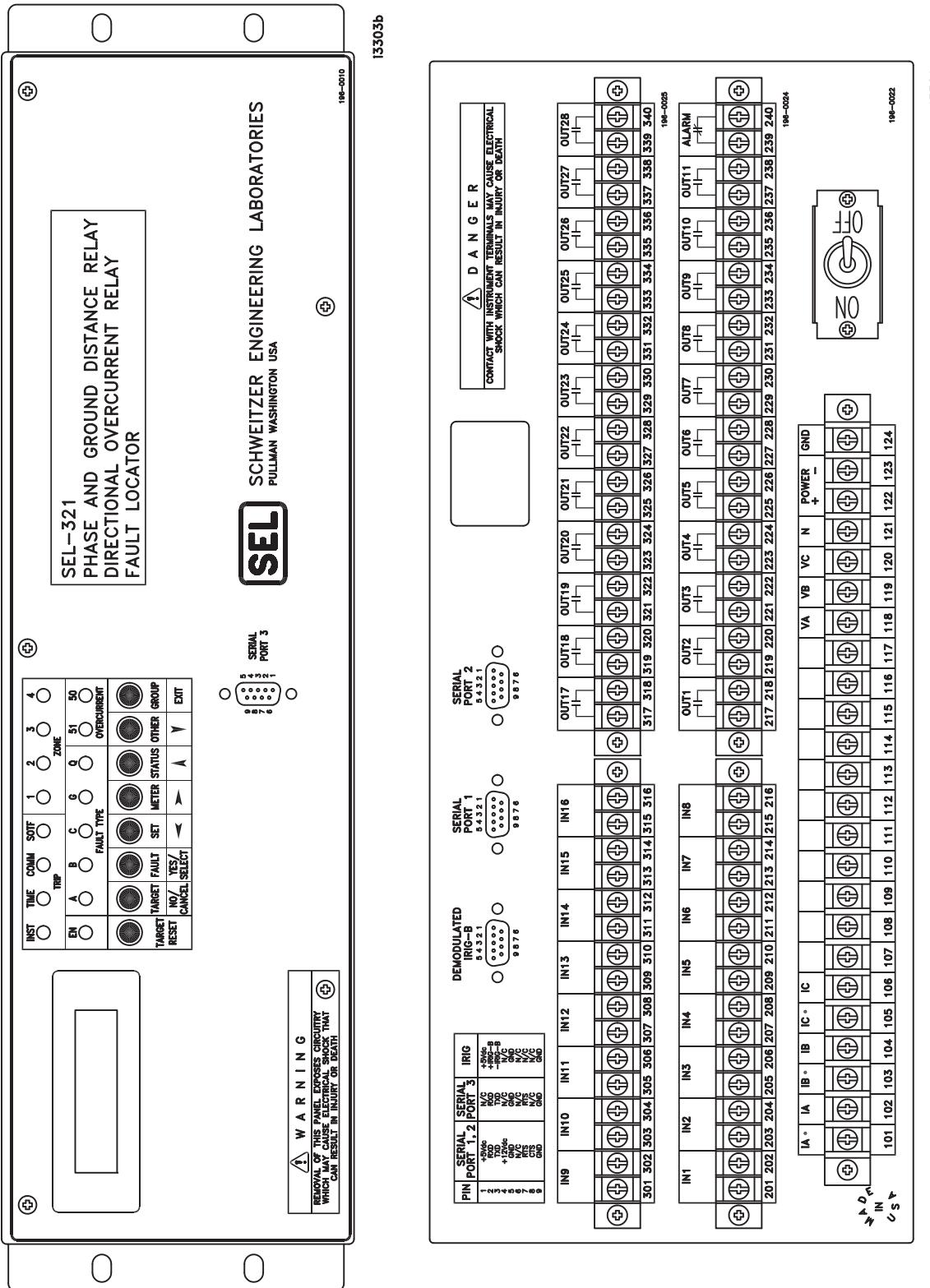


Figure 6.7: SEL-321-5 Relay Horizontal Front- and Rear-Panel Drawings (Two I/O Board Conventional Terminal Block Version; 12 Isolated Outputs Per Board Shown—Other Options Are Available)

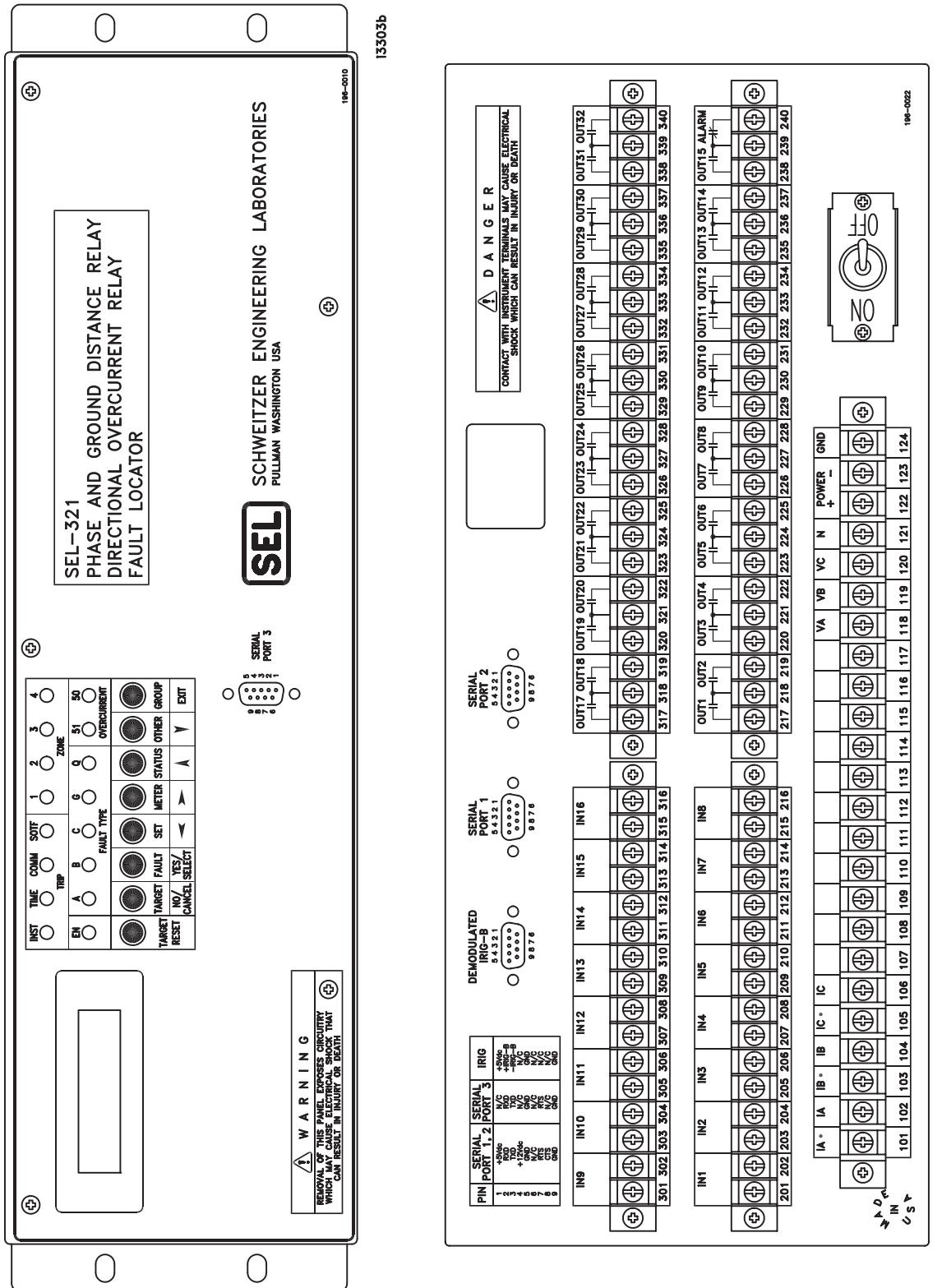
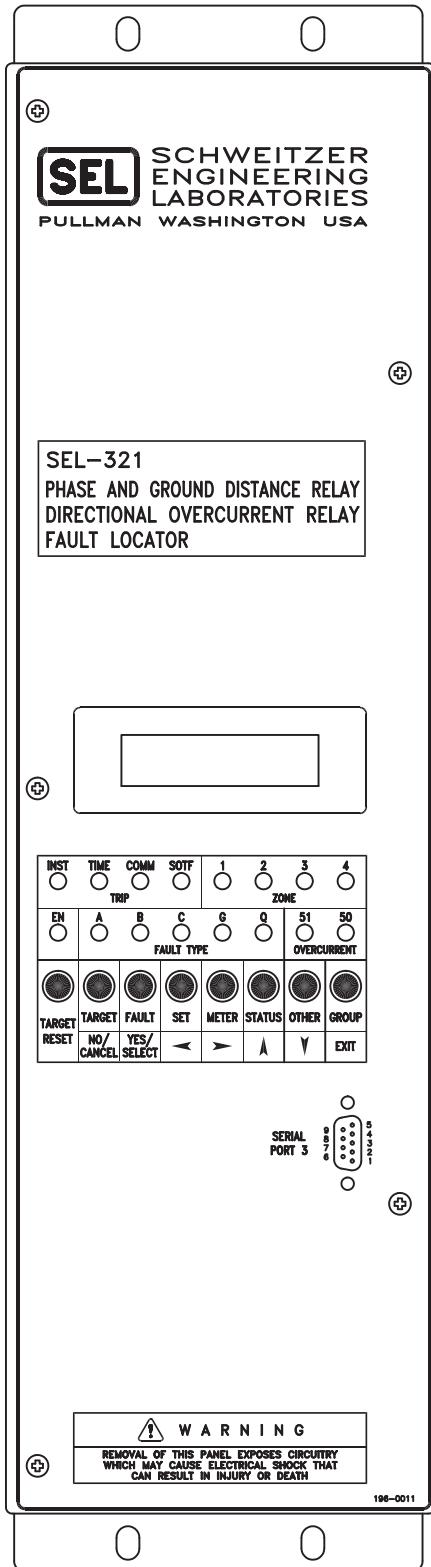
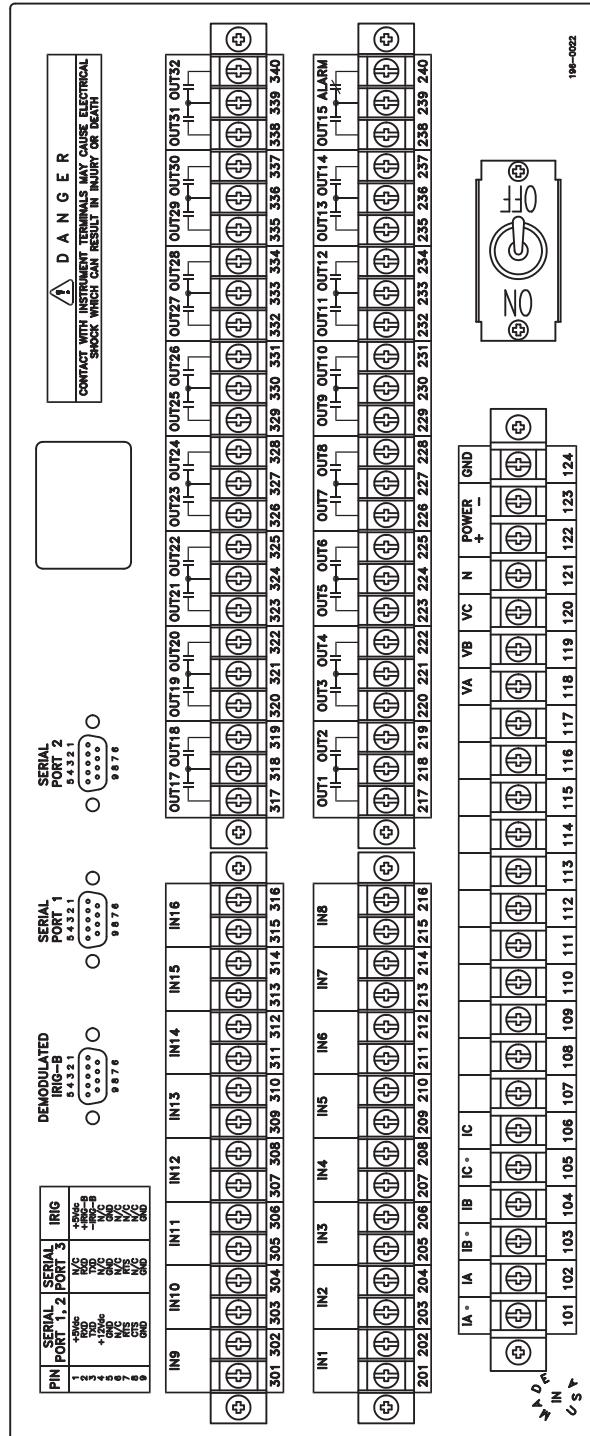


Figure 6.8: SEL-321-5 Relay Horizontal Front- and Rear-Panel Drawings (Two I/O Board Conventional Terminal Block Version; 16 Outputs With Shared Return Terminals Per Board Shown—Other Options Are Available)

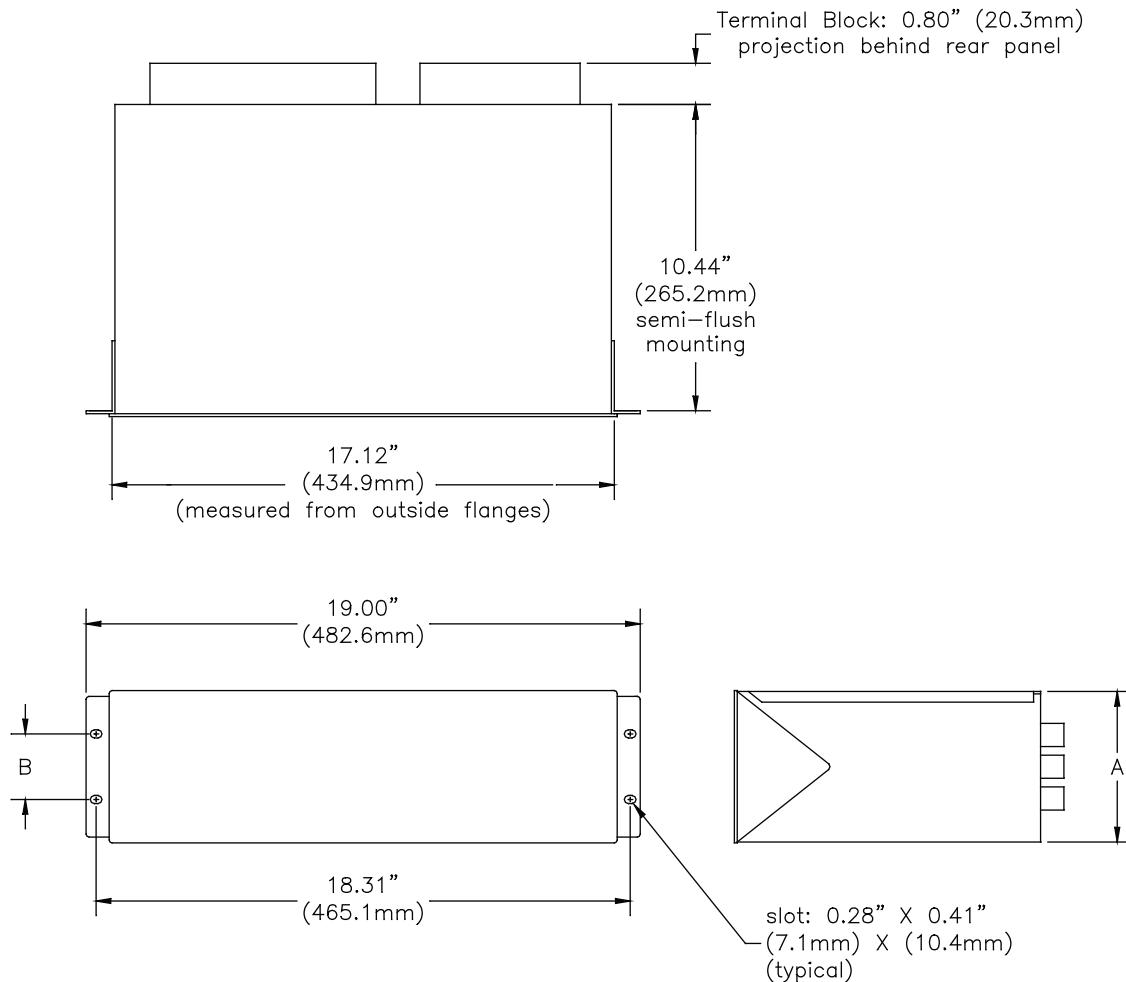


13304a



13388a

Figure 6.9: SEL-321-5 Relay Vertical Front- and Rear-Panel Drawings (Two I/O Board Conventional Terminal Block Version; 16 Outputs With Shared Return Terminals Per Board Shown—Other Options Are Available)



DIMENSION	ONE I/O BOARD (3U)	TWO I/O BOARDS (4U)
A	5.22" (132.6mm)	6.97" (177.0mm)
B	2.25" (57.2mm)	4.00" (101.6mm)

NOTE:

1. ALL TOLERANCES ARE $\pm 0.020"$ (0.51mm)
2. TO DETERMINE THE CUTOUT DIMENSIONS
CONSIDER BOTH SEL'S SPECIFIED TOLERANCE
AND THE CUSTOMER'S ALLOWED TOLERANCE.
3. DRAWING NOT TO SCALE

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DATE: 12 AUG 98

Figure 6.10: Relay Dimensions and Drill Plan (Conventional Terminal Block Version)

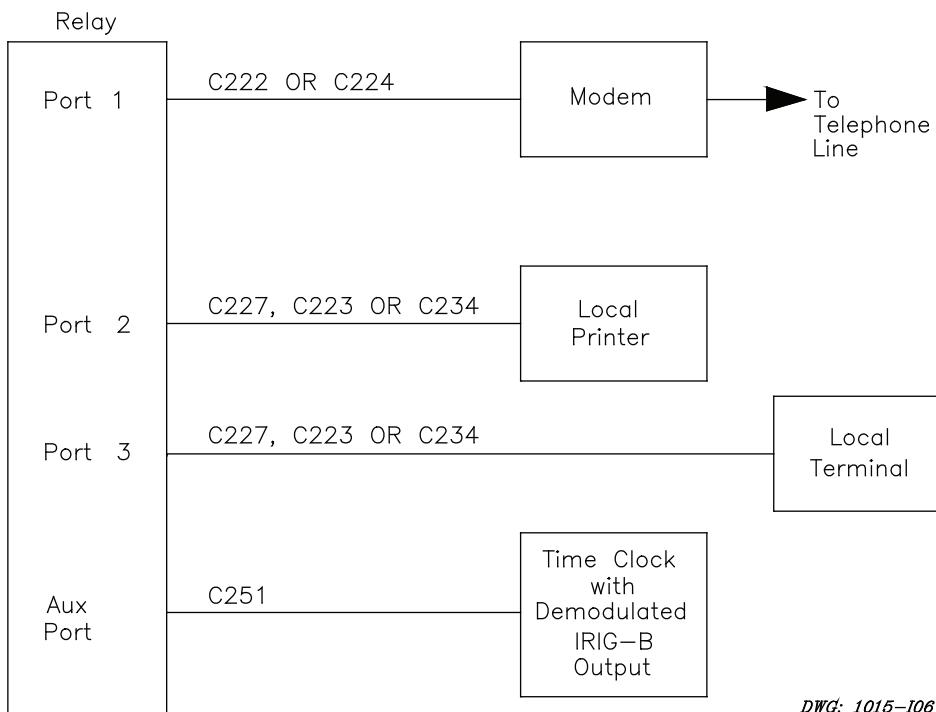


Figure 6.11: Communications and Clock Connections—One Unit at One Location

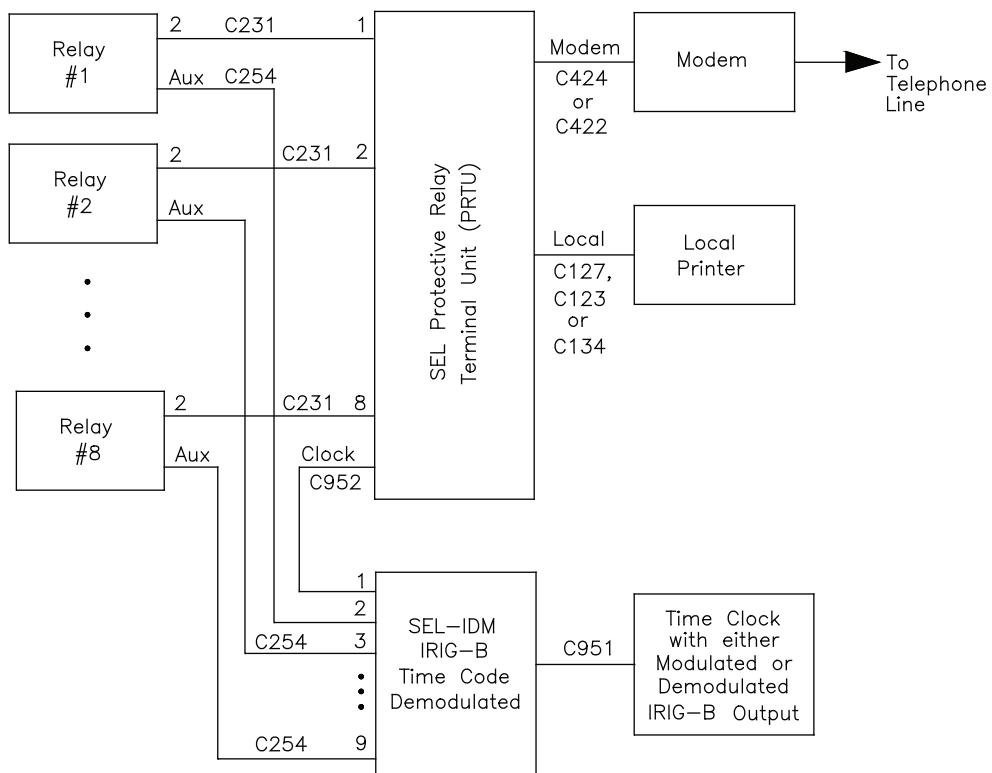


Figure 6.12: Communications and Clock Connections—Multiple Units at One Location

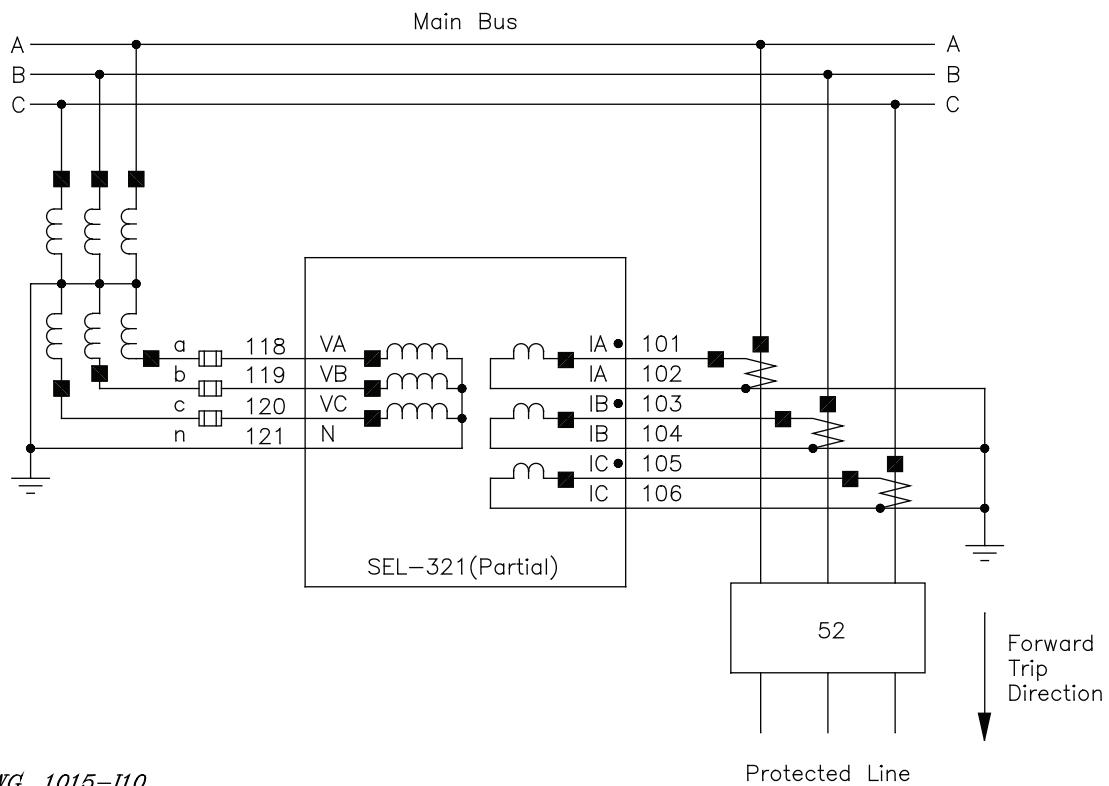


Figure 6.13: SEL-321-5 Relay External AC Current and Voltage Connections

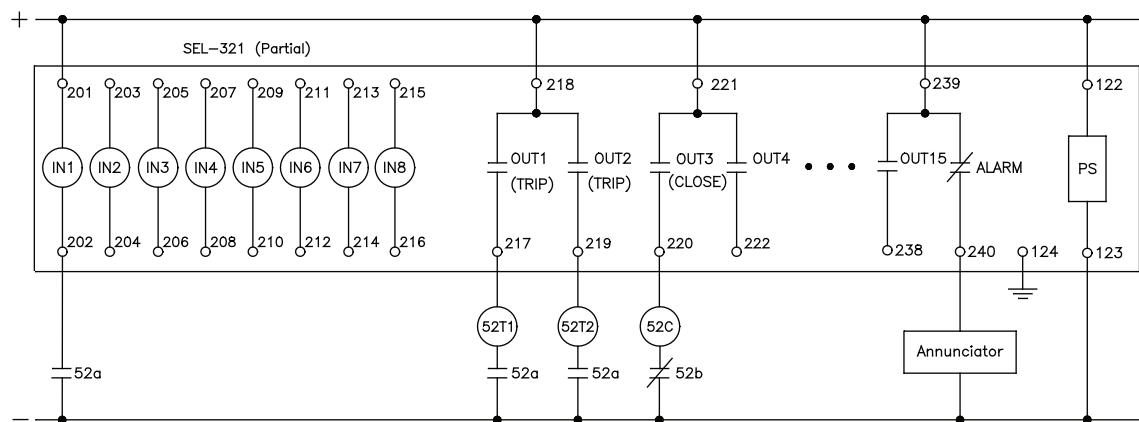
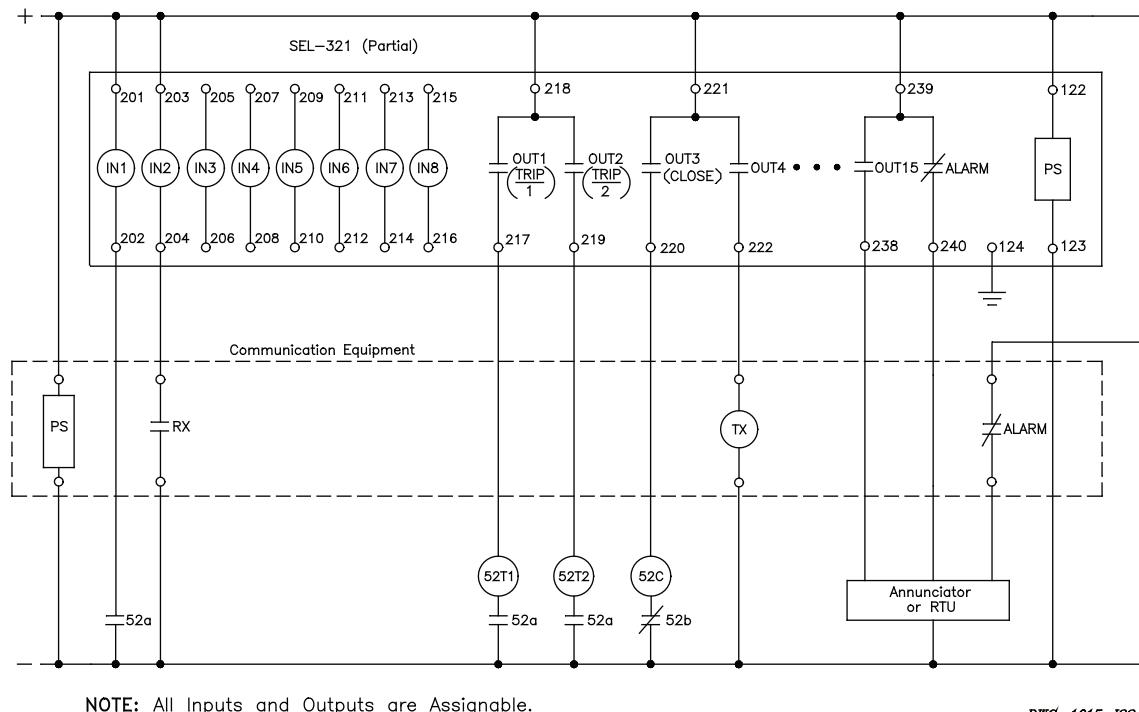


Figure 6.14: SEL-321-5 Relay Typical External DC Connection Diagram (One I/O Board Version; 16 Outputs With Shared Return Terminals Shown—Other Options Are Available)



NOTE: All Inputs and Outputs are Assignable.

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**Figure 6.15: SEL-321-5 Relay External DC Connections to Communications Equipment
(One I/O Board Version; 16 Outputs With Shared Return Terminals Shown—
Other Options Are Available)**

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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

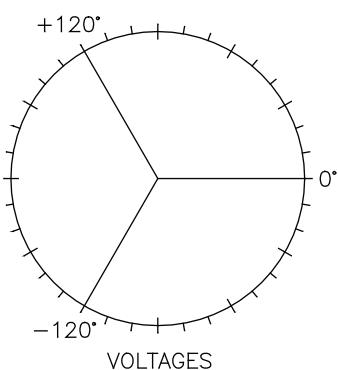
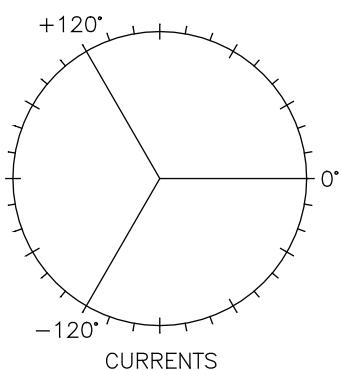
SEL READINGS: _____ MW (+)(-) _____ MVAR (+)(-)

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 $\sqrt{x^2 + y^2}$						
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 1

ROW 2

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



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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

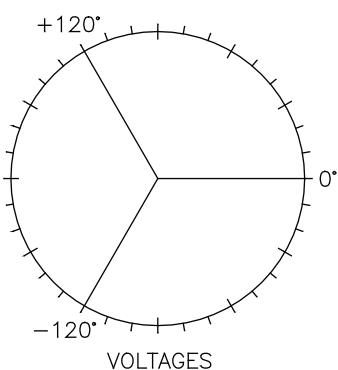
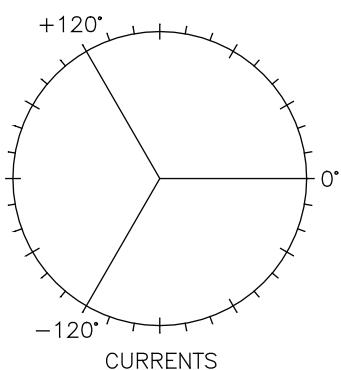
SEL READINGS: _____ MW (+)(-) _____ MVAR (+)(-)

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 $\sqrt{x^2 + y^2}$						
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 1

ROW 2

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



DWG: A7-0446

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SECTION 7: MAINTENANCE AND TESTING

INTRODUCTION

This section contains the following items:

- Initial Checkout Procedure
- SEL Relay Testing Philosophy
- Test Methods and Tools
- Test Procedures for overcurrent, directional, and distance elements
- Relay Test and Operation Troubleshooting Guides
- Firmware Upgrade Installation Procedures

INITIAL CHECKOUT

The initial checkout procedure should familiarize you with the relay. Study **Section 2: Specifications, Description of Commands** in **Section 3: Communications**, **Section 4: Event Reporting**, and **Section 5: Applications** for a complete understanding of the relay capabilities.

Equipment Required

The following equipment is necessary for initial checkout.

1. Source of control power.
2. Source of three-phase voltages and at least two currents.
3. Ohmmeter or contact opening/closing sensing device.

Checkout Procedure

Step 1. Purpose: Be sure you received the relay in satisfactory condition.

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

Step 2. Purpose: Refer to the Relay Part Number and Hardware Identification Sticker on the relay rear panel to verify the power supply voltage, dc control voltage, and nominal ac signal magnitudes appropriate for the relay under test.

Method: Refer to the information sticker on the rear panel of the relay. Figure 7.1 provides an example. Information on this sticker is important to note before applying power to the relay or starting tests.

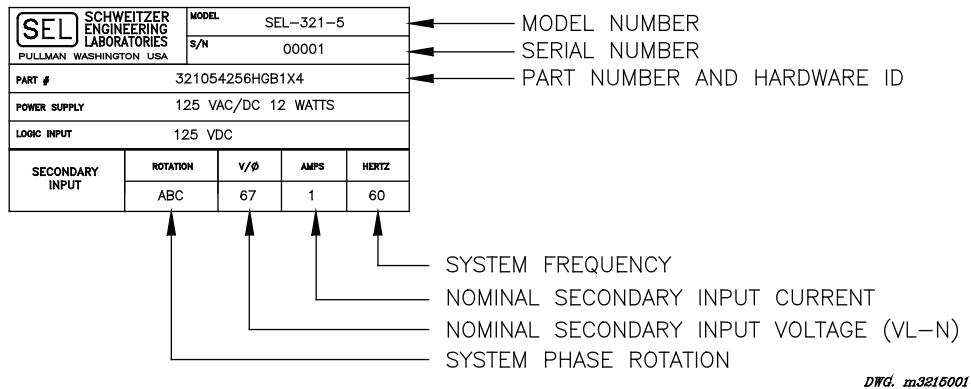


Figure 7.1: Relay Part Number and Hardware Identification Sticker

The relay described by the sticker shown in Figure 7.1 is an SEL-321-5 Relay, serial number 00001. The part number describes the relay configuration in a concise manner. Some critical aspects of this part number are called out under the Power Supply, Logic Input, and Secondary Input sections of the sticker.

The Power Supply specification shown in Figure 7.1 indicates that this relay is equipped with a power supply that accepts 125 Vac or dc. Other power supply options include 24 Vdc, 48 Vdc, and 250 Vac/dc. Refer to the sticker attached to your relay to determine the magnitude of voltage you should apply to the relay power supply input terminals. The voltage source should be capable of providing 12 watts continuously at the rated voltage.

The Logic Input specification indicates that the relay logic inputs are rated to accept 125 Vdc. Other options include 24 Vdc, 48 Vdc, and 250 Vdc. To assert a relay logic input, apply dc voltage to the relay input terminals. Refer to the sticker attached to your relay to determine the magnitude of voltage you should apply to the relay logic inputs. Approximately four mA of current flow when rated voltage is applied to a relay logic input.

The Rotation specification indicates the expected power system phase rotation. Figure 7.1 indicates that this relay is configured to accept ABC rotation. This is also referred to as 123 or positive phase rotation by some utilities. Under nominal conditions on a system with ABC rotation, B-phase voltage lags A-phase voltage by 120°, and C-phase voltage lags B-phase voltage by 120°.

The V/Ø specification indicates the nominal ac voltage that the relay is designed to measure. This voltage is specified from line-to-neutral and assumes a standard 4-wire wye ac voltage connection. Figure 7.1 indicates that this relay is configured to accept 67 Vac, line-to-neutral. The relay measures other ac voltage magnitudes accurately, as defined in **Section 2: Specifications**.

The A specification indicates the nominal ac current that the relay is designed to measure. Figure 7.1 indicates that this relay is configured to accept 1 A ac, per phase. The relay measures other ac current magnitudes accurately, as defined in **Section 2: Specifications**.

The Hertz specification indicates the relay is designed to measure ac voltage and current signals at the nominal system frequency. The relay is designed to make accurate voltage and current measurements during frequency excursions, as defined in **Section 2: Specifications**.

- Step 3.** Purpose: Connect power supply voltage to the relay.

Method: If the relay is equipped with a rear-panel power switch, move the switch to the ‘OFF’ position. Connect a frame ground to terminal marked GND on the rear panel and connect a voltage source to the terminals marked + and -. Polarity is unimportant. Relays equipped with 125 or 250 V power supplies may be powered from a 115 Vac wall receptacle for testing. In the final installation, we recommend that the relay receive control power from the station dc battery. This helps prevent loss of relay event reports stored in volatile memory if station ac service is lost.

- Step 4.** Purpose: Apply power supply voltage to the relay and access the relay via the LCD front panel.

Method: Turn on the voltage source connected to the relay power supply inputs. If the relay is equipped with a power switch, move the relay power switch to the ‘ON’ position. If you are using a battery simulator as the relay power supply voltage source, be sure the simulator voltage level is stabilized before turning the relay on.

The relay front-panel Enable target (EN) should illuminate. EN should appear in the relay LCD screen.

The relay output labeled ALARM is typically configured as a normally closed (form “b”) contact and closes to indicate loss of dc power to the relay, failure of a relay self-test, and several other functions. With power applied to the relay and the relay turned on, the ALARM contacts open.

If the Enable LED does not illuminate or EN does not appear on the relay LCD screen, turn off the power and refer to Relay Troubleshooting later in this section.

- Step 5.** Purpose: Perform a front-panel LED test and check LCD screen contrast.

Method: Press the **TARGET RESET** button to perform an LED lamp test. During the lamp test, the relay illuminates all 16 front-panel LEDs for approximately one second. The relay also turns on the LCD backlighting. If the LCD contrast is poor, refer to the Relay Troubleshooting Table in this section for steps to adjust the contrast.

- Step 6.** Purpose: Verify the relay self-test status.

Method: Press the front-panel **STATUS** button. The message **STATUS: OK** should appear on the relay LCD screen. Use the Up and Down arrow buttons to view the results of specific relay self-tests. Press the front-panel **CANCEL** or **EXIT** button to exit the STATUS display.

Step 7. Purpose: Connect voltage and current sources to the relay.

Method: Turn off the relay. If three voltage sources and three current sources are available, connect the sources to the relay as shown in Figure 7.3. If three voltage sources and two current sources are available, connect them as shown in Figure 7.5. Apply 67 V per phase (line-to-neutral) in positive-sequence rotation. Apply 2.0 A per phase, in phase with the applied phase voltages.

Step 8. Purpose: Verify correct voltage and current connections and levels.

Method: Turn on the relay. Press the front-panel **METER** button. Use the arrow keys to examine the **METER** data. The relay displays the measurements of the voltages and currents applied in Step 7. With applied voltages of 67 V per phase and a potential transformer ratio of 2000:1, the displayed line-to-neutral voltages should be 134 kV. With applied currents of 2.0 A per phase and a current transformer ratio of 200:1, the displayed line-to-neutral currents should be 400 A. All line-to-line quantities should be balanced, differing from the line-to-neutral measurements by a factor of 1.73. Real power P should be approximately 160.1 MW; reactive power Q should be approximately 0 MVAR.

If you inadvertently switched a pair of voltages or currents, the MW reading should be approximately zero. It is important to remember this when commissioning the relay using system voltages and currents.

If you wish to verify the relay voltage and current connections in a more detailed manner, use the SEL Direction and Polarity Check Form provided in **Section 6: Installation**.

Step 9. Purpose: Use the front-panel setting feature to adjust a relay setting.

Method: The following steps are required to change a relay setting from the SEL-321-5 Relay front panel:

1. Enter Access Level 2 by using the appropriate password.
2. Execute the **SET** command.
3. Select the setting to change.
4. Make and accept the setting change.

With EN displayed on the relay LCD screen, press the front-panel button labeled **OTHER**. With 2AC shown on the screen, press **SELECT**. This instructs the relay to execute the **2ACCESS** command.

To enter Access Level 2, you must enter the correct password. The relay is equipped with an Access Level 2 password of TAIL. The relay displays a list of characters to build the password from. Use the Up or Down arrow button to choose the list of characters containing T. Use the Left and Right arrow buttons to underline the T. Press **SELECT** to enter T as the first letter of the Level 2 password.

Next, use the Up or Down arrow button to choose the list of characters containing A, I, and L. Underline each character in turn and press the **SELECT** button to enter each character into the Level 2 password.

When the upper line of the display reads:

PASSWORD: TAIL

press the **EXIT** button to enter Access Level 2. The relay briefly displays the note **Level 2**, then resumes the **EN** display.

Press the button labeled **SET**. The display shows:

SET GROUP

Press **SELECT**. Use the Down arrow button to enter the number 1, then press **SELECT** again.

Note: The SEL-321-5 Relay includes six setting groups. While you are testing this relay, it is important to change settings in the group that is active. If you change settings in an inactive setting group, the relay performance will not change. The relay is shipped with Setting Group 1 active. You may change the active group by executing the **GROUP** command from the relay front panel or from a terminal connected to a relay serial port. You must enter the Breaker Access Level or Access Level 2 to change the active group.

Press the Down arrow button repeatedly, until the upper line of the display reads:

Misc Scheme Logic

Press **SELECT**. Press the Down arrow button repeatedly until the lower line of the display reads:

TULO = 3

Press **SELECT**. Press the Up arrow button until the lower line of the display reads:

TULO = 1 *

Press **SELECT**. Press **EXIT**. Press **YES** to save the new settings.

Step 10. Purpose: Test the fault locator.

Method: Test the fault locator by using the voltages and currents in Table 7.1. These voltages and currents were obtained for various locations and fault types assuming a radial line with a source impedance of 0.2 times the total 100-mile line impedance.

Note: To simplify this step, apply dc voltage to the IN1 input. The relay recognizes the asserted input when applied dc voltage is approximately equal to the Logic Input voltage rating shown on the relay identification sticker. Input IN1 is programmed to monitor the breaker auxiliary contact, 52A. Energize the IN1 input for the duration of this step to block the Switch-On-Fault logic from operating. If dc voltage source is not available, set ESOTF = N in

the relay settings.

Run ground fault tests by using the test source connections shown in Figure 7.3, Figure 7.4, or Figure 7.6. Run phase-to-phase fault tests by using the test source connections shown in Figure 7.3, Figure 7.4, or Figure 7.7.

Table 7.1: Fault Locator Test Values

Location	Type	VA	VB	VC	IA	IB	IC	Units
75 miles	AG	52.89 0.00	69.97 -124.30	70.34 124.10	5.24 -82.40	0.00 0.00	0.00 0.00	V or A Degrees
	BC	67.00 0.00	56.75 -126.20	56.75 126.20	0.00 0.00	7.83 -174.00	7.83 6.00	V or A Degrees
85 miles	AG	54.24 0.00	69.67 -123.90	70.00 123.70	4.74 -82.40	0.00 0.00	0.00 0.00	V or A Degrees
	BC	67.00 0.00	57.69 -125.50	57.69 125.50	0.00 0.00	7.08 -174.00	7.08 6.00	V or A Degrees

Faults at 75 miles are within Zone 1, since the Zone 1 reach setting is 80% of the 100-mile line positive-sequence impedance (see Z1P, Z1MG, and XG1 in the settings). Faults at 85 miles are beyond Zone 1, but within Zone 2.

Faults listed in Table 7.1 cause certain combinations of output contacts to close and front-panel LEDs to illuminate. You may use the front-panel LCD functions to examine the short form fault data following each test. Table 7.2 shows the expected results.

Table 7.2: Output Contact and Target LED Results

Location	Type	Output Relays	Target LEDs
75 miles	AG	OUT1, OUT2, OUT4	INST, Zone 1, A, G
75 miles	BC	OUT1, OUT2, OUT4	INST, Zone 1, B, C
85 miles	AG	OUT1, OUT2, OUT4	TIME, Zone 2, A, G
85 miles	BC	OUT1, OUT2, OUT4	TIME, Zone 2, B, C

Output Contact Explanation

The OUT1 and OUT2 are set to close for three-pole trips. The relay is set to trip instantaneously for Zone 1 faults, with a short time delay for Zone 2 faults, and by operation of the residual and negative-sequence time-overcurrent elements. OUT4 is set to close for assertion of the KEY element. The KEY element is used in Permissive Overreaching Transfer Tripping protection schemes to send the permissive signal to the remote end. The SEL-321-5 Relay asserts the KEY element when overreaching Zone 2 elements pick up, if other conditions permit.

Target LED Explanation

The INST target illuminates when the relay trips for a protection element that has been asserted for a time less than the relay ITTD setting.

The TIME target illuminates when the relay trips for a protection element that has been asserted for a time greater than the relay ITTD setting.

The Zone targets indicate the zone of the element that caused the trip. The A, B, C, and G targets indicate the phase involvement. The Q target indicates that a negative-sequence overcurrent element was asserted at the time of trip.

The 50 and 51 targets indicate trips based upon overcurrent element operation. The 50 indicates instantaneous and definite-time delayed overcurrent element operations. The 51 indicates time-overcurrent element operations.

The COMM and SOTF targets indicate when the trip occurred as part of a Communications-based operation or a Switch-On-To-Fault operation, respectively.

Section 2: Specifications includes detailed information regarding operation of the relay targets.

Front-Panel LCD Explanation

The relay generates an event report for each fault. To see the summary event report for the last fault, press the **FAULT** button on the relay front panel and use the Up, Down, Left, and Right arrow buttons to review the information presented there.

If a new fault occurs while you are reviewing the fault data, press the **EXIT** button, then the **FAULT** button to review the new data.

You may review the long form event report for each fault using a terminal connected to one of the relay serial ports. Each event report is an eleven-cycle record of the currents, voltages, relay element states, and logic input and contact output states. The relay saves the 12 newest reports. See **Section 3: Communications** and **Section 4: Event Reporting** for further details on the retrieval and analysis of event reports saved by this relay.

TESTING PHILOSOPHY

Protective relay testing may be divided into three categories: acceptance, commissioning, and maintenance testing. The categories are differentiated by when they take place in the life cycle of the relay, as well as in the test complexity.

The paragraphs below describe when each type of test is performed, the goals of testing at that time, and the relay functions that you need to test at each point. While this information is intended as a guideline for testing SEL relays, each utility must determine its own testing practices.

Acceptance Testing

When: When qualifying a relay model to be used on the utility system.

Goal:

- a) Ensure relay meets published critical performance specifications such as operating speed and element accuracy.
- b) Ensure that the relay meets the requirements of the intended application.
- c) Gain familiarity with relay settings and capabilities.

What to test: All protection elements and logic functions critical to the intended application.

SEL performs detailed acceptance testing on all new relay models and versions. We are certain the relays we ship meet their published specifications. It is important for you to perform acceptance testing on a relay if you are unfamiliar with its operating theory, protection scheme logic, or settings. This helps ensure the accuracy and correctness of the relay settings when you issue them.

Commissioning Testing

- When: When installing a new protection system.
- Goal:
- Ensure that all system ac and dc connections are correct.
 - Ensure that the relay functions as intended using your settings.
 - Ensure that all auxiliary equipment operates as intended.
- What to test: All connected or monitored inputs and outputs; polarity and phase rotation of ac current and voltage connections; simple check of protection elements.

SEL performs a complete functional check and calibration of each relay before it is shipped. This helps ensure that you receive a relay that operates correctly and accurately. Commissioning tests should verify that the relay is properly connected to the power system and all auxiliary equipment. Verify permissive trip or blocking signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs and monitoring outputs. Use an ac connection check to verify that the relay voltage and current inputs are of the proper magnitude and phase rotation.

Brief fault tests ensure that the relay settings are correct. A Zone 1 AB fault, Zone 2 CG fault, and Zone 3 three-phase fault can verify distance and directional elements, time delays, and the relay trip and output functions. It is not necessary to test every relay element, timer, and function in these tests.

Maintenance Testing

- When: At regularly scheduled intervals, or when there is an indication of a problem with the relay or system.
- Goal:
- Ensure that the relay is measuring ac quantities accurately.
 - Ensure that scheme logic and protection elements are functioning correctly.
 - Ensure that auxiliary equipment is functioning correctly.
- What to test: Anything not shown to have operated during an actual fault within the past maintenance interval.

SEL relays use extensive self-testing capabilities and feature detailed metering and event reporting functions that lower the utility dependence on routine maintenance testing.

Use the SEL relay reporting functions as maintenance tools. Periodically verify that the relay is making correct and accurate current and voltage measurements by comparing the relay METER output to other meter readings on that line. Review relay event reports in detail after each fault. Using the event report voltage, current, and relay element data, you can determine that the relay protection elements are operating properly. Using the event report input and output data you can determine that the relay is asserting outputs at the correct instants and that auxiliary equipment is operating properly. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

The basis of this testing philosophy is simple: If the relay is correctly set and connected, is measuring properly, and no self-test has failed, there is no reason to test it further.

Each time a fault occurs, the protection system is tested. Use event report data to point out areas requiring attention. Slow breaker auxiliary contact operations, increasing or varying breaker operating time, fluctuations in total communications channel delay can all be detected through detailed analysis of relay event reports.

Because SEL relays are microprocessor-based, their operating characteristics do not change over time. Time-current operating times and distance element characteristics are affected only by the relay settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

At SEL, we recommend that maintenance tests on SEL relays be limited under the guidelines provided above. The time saved may be spent analyzing event data and thoroughly testing those systems that require more attention.

TESTING METHODS AND TOOLS

Test Aids Provided by the Relay

The following features assist you during relay testing.

METER Command	The METER command shows the voltages and currents presented to the relay in primary values. The relay calculates Megawatts (MW) and Megavars (MVAR) from these voltages and currents. These quantities are useful for comparing relay calibration against other meters of known accuracy.
Event Reporting	The relay generates an 11-cycle event report in response to faults or disturbances. Each event report contains voltage and current information, relay element states, and I/O contact information in quarter-cycle or sixteenth-cycle resolution. If you question the relay response or your test method, use the event report for more information.
	Each event report is date- and time-tagged relative to the triggering instant. If the time-out of a protective element results in a TRIP, the relay records a second event report. Thus, the relay may generate two event reports for a long duration fault: the first when the instantaneous element asserts, the second when the TRIP occurs.
Programmable Logic	Where Time Delayed Pickup (TDPU) timers are concerned, the time tag in the event reports may be used to determine the validity of a TDPU timer setting. Simply subtract the latest event report time tag from the previous event report time tag. Section 2: Specifications has further details concerning event report generation.

TARGET 44 Command	The TARGET 44 command shows the state of the eight relay logic inputs in a relay with one I/O board. This allows you to monitor the input states while asserting the inputs to verify correct wiring and correct operation of the inputs.
----------------------	--

For more information on these commands, see *Section 3: Communications*.

Test Methods

There are two means of determining the pickup and dropout of relay elements: front-panel LCD indication and output contact closure.

Testing Via Front-Panel LCD/LED Indication

To use the relay LCD/LED front panel to display the state of elements, press the front-panel **TARGET** button. Use the Up or Down arrow button to select the TAR number, or row, that contains the element under test. Press **SELECT**. The relay displays the elements that are presently asserted in that row. The LCD display updates about twice per second.

The relay also illuminates front-panel LEDs corresponding to asserted elements in the selected row. The front-panel LEDs are updated every eighth of a cycle. They may flicker to indicate an element that is on a pickup threshold.

For example, TAR row 7 indicates the state of several overcurrent elements. Press the front-panel **TARGET** button, use the Up arrow button to select TAR 7, then press **SELECT**. The relay LCD screen displays the names of the elements that are asserted. With no current applied, the LCD display is blank and the lower row of LEDs is dark. As you apply current to the relay, the various elements assert and their names appear in the LCD display screen. LEDs corresponding to asserted elements illuminate. You may wish to use this function to assist in element pickup tests.

Testing Via Output Contact Assertion

To test via output contact assertion, use the **SET L** command to set one programmable output contact to assert when the element under test picks up.

As an example, you could set the OUT7 output to follow the state of the M3P element. When the relay is set in this manner, you can monitor Output 7 on the relay rear panel to determine when the Zone 3 phase distance element asserts.

For a normally open (form “a”) contact, when the condition asserts, the output contact closes. When the condition deasserts, the output contact opens.

For a normally closed (form “b”) contact, when the condition asserts, the output contact opens. When the condition deasserts, the output contact closes.

Programmable output contacts can be specified at the factory as either form “a” or “b.”

Using contact operation as an indicator, you can measure element operating characteristics, stop timers, etc.

Tests in this section use the output contact method and assume that a normally open (form “a”) output contact is used to indicate the functions under test.

Using a Breaker Simulator

If the relay setting EN52A = Y, the relay Switch-On-Fault (SOTF) logic operates based on the state of the relay 52A input. When EN52A = Y, we recommend testing the relay with a latching relay to simulate line breaker auxiliary contact action. This ensures proper assertion and deassertion of the 52A input on the back panel. If you do not have a means of simulating breaker status, disable 52A-based SOTF protection by:

- Setting EN52A = N,
- Setting the MTO logic equation to N/A,
- Disabling Switch-On-Fault protection by setting ESOTF = N.

Low-Level Test Interface

The SEL-321-5 Relay has a low-level test interface between the calibrated input module and the separately-calibrated processing module. You may test the relay in either of two ways: conventionally, by applying ac current signals to the relay inputs or by applying low magnitude ac voltage signals to the low-level test interface. Access the test interface by removing the relay front panel.

Figure 7.2 shows the low-level interface connections. This drawing also appears on the inside of the relay front panel. Remove the ribbon cable between the two modules to access the outputs of the input module and the inputs to the processing module (relay main board).

You can test the relay processing module by using signals from the SEL-RTS Low-Level Relay Test System. Never apply voltage signals greater than 9 V peak-peak to the low-level test interface. Figure 7.2 shows the signal scaling factors.



The relay contains devices sensitive to electrostatic discharge (ESD). When working on the relay with front or top cover removed, work surfaces and personnel must be properly grounded or equipment damage may result.

You can test the input module two different ways:

1. Measure the outputs from the input module with an accurate voltmeter (measure signal pin to GND pin), and compare the readings to accurate instruments in the relay input circuits, or
2. Replace the ribbon cable, press the front-panel <METER> button, and compare the relay readings to other accurate instruments in the relay input circuits.

LOW-LEVEL TEST INTERFACE

**REMOVE RIBBON
CABLE FOR TESTING**

INPUT MODULE OUTPUT (J2) : 100 mV AT NOMINAL CURRENT (1 A OR 5 A)

1313.7 mV AT NOMINAL VOLTAGE (67 V_{IN})

PROCESSING MODULE INPUT (J13) : 9 V p-p MAXIMUM

U.S. Patent 5,479,315

SEL-321 157-0020

Figure 7.2: Low-Level Test Interface

TEST SETUP

Test Source Connections

Each relay element test requires that ac voltage and/or current signals be applied to the relay. The figures and text below describe the test source connections required for relay protection element tests.

Three Voltage Source and Three Current Source Connections

Figure 7.3 shows connections to use when three voltage sources and three current sources are available. Any protective element may be tested and any fault type simulated using these connections.

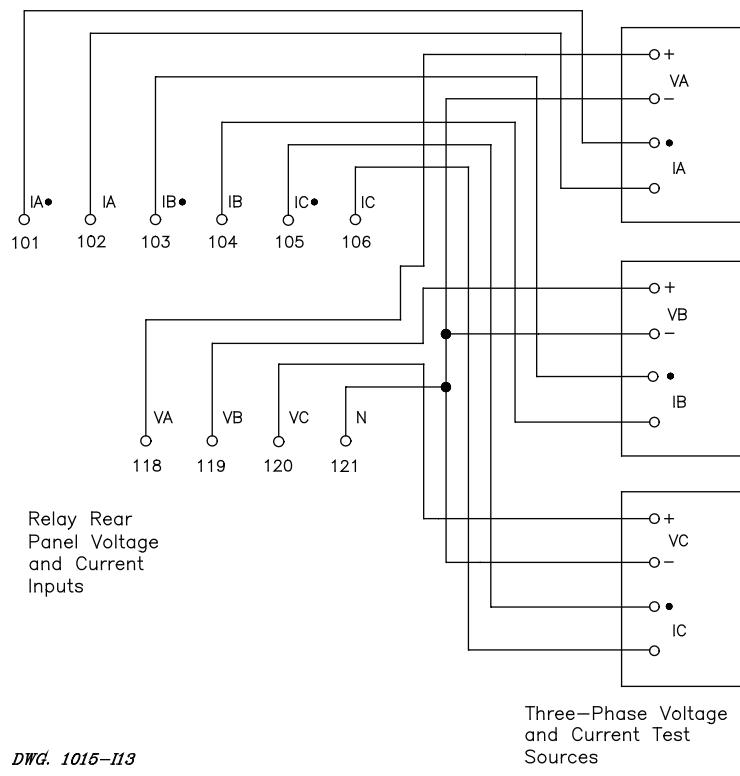


Figure 7.3: Three Voltage Source and Three Current Source Test Connections

Three Voltage Source and Two Current Source Connections

Figure 7.4 and Figure 7.5 show connections to use when three voltage sources and two current sources are available. Phase-to-phase, phase-ground, and two-phase-ground faults may be simulated using the connections shown in Figure 7.4. Three-phase faults may be simulated using the connections shown in Figure 7.5.

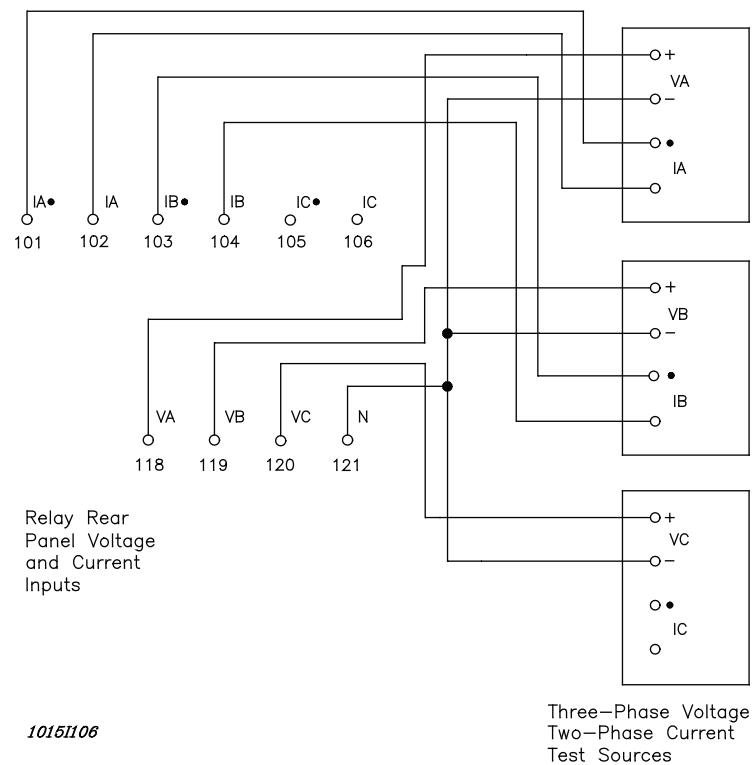


Figure 7.4: Phase-to-Phase, Phase-to-Ground, and Two-Phase-to-Ground Fault Test Connections Using Two Current Sources

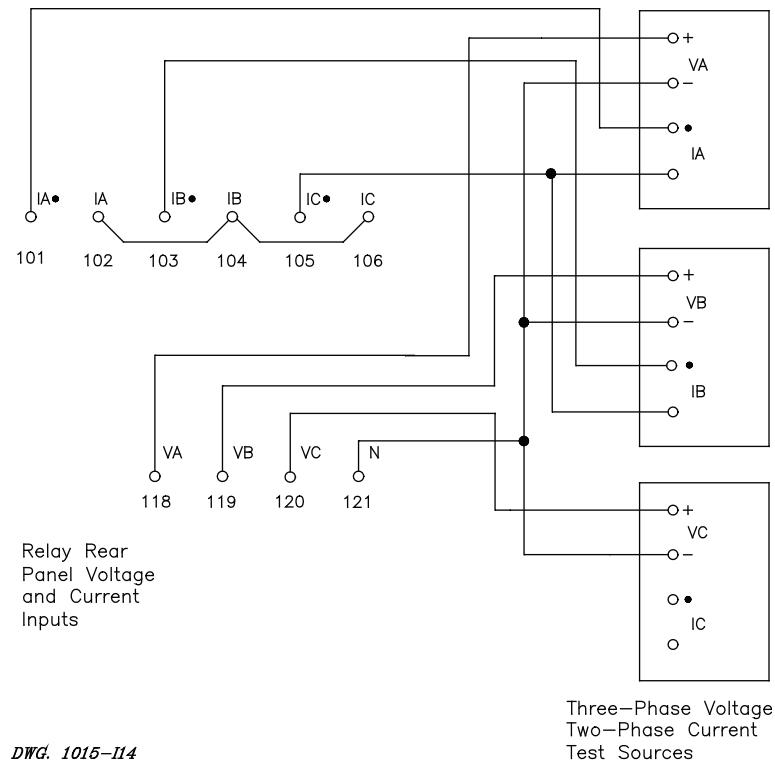


Figure 7.5: Three-Phase Fault and METER Test Connections Using Two Current Sources

Three Voltage Source and One Current Source Connections

Figure 7.6 and Figure 7.7 show connections to use when three voltage sources and a single current source are available. Phase-ground faults may be simulated using the connections shown in Figure 7.6. Phase-to-phase faults may be simulated using the connections shown in Figure 7.7.

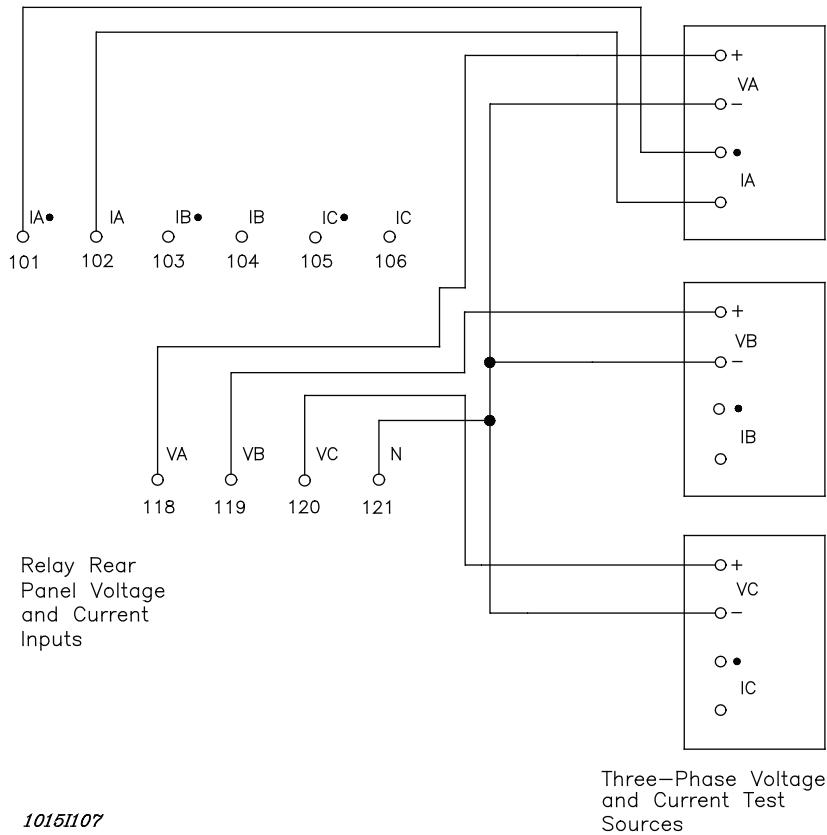


Figure 7.6: Phase-to-Ground Fault Test Connections Using a Single Current Source

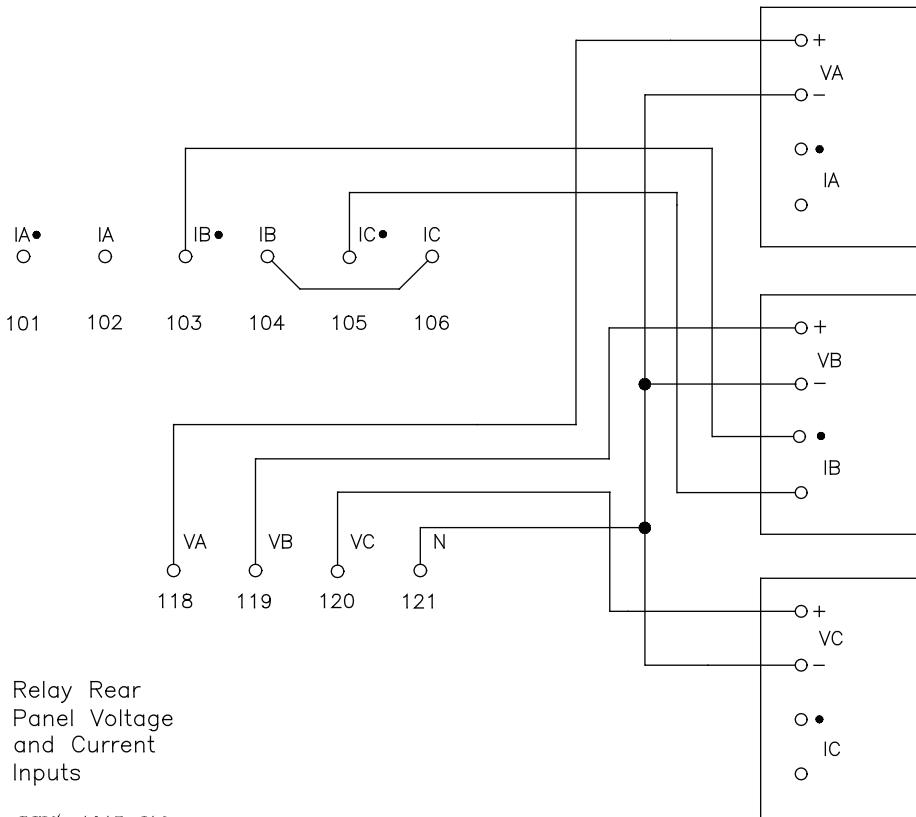


Figure 7.7: Phase-to-Phase Fault Test Connections Using a Single Current Source

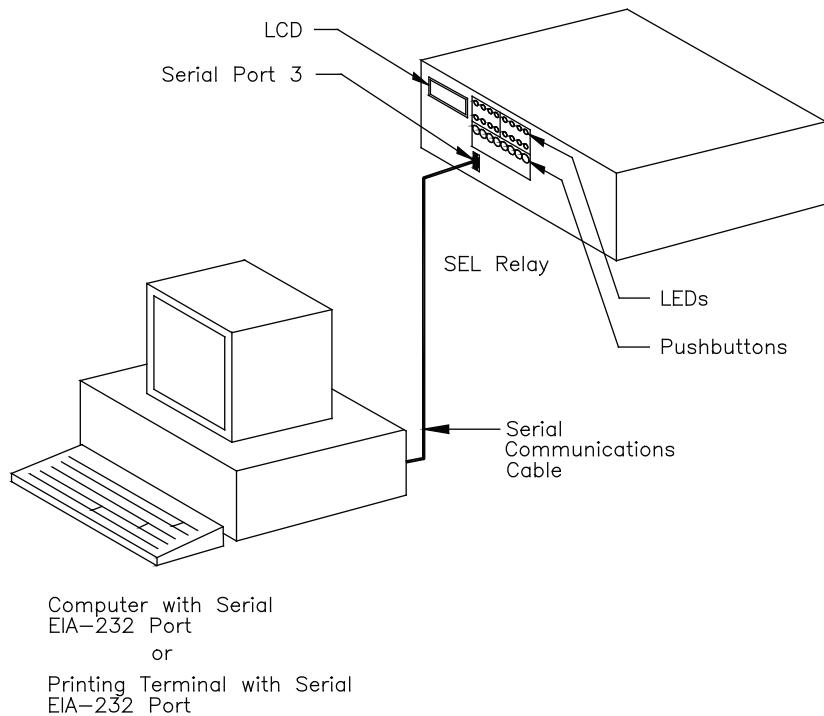
Serial Communication Equipment Connections

A terminal or PC with communications software is necessary to make SELOGIC® control equations setting changes and examine relay event reports. We recommend using a terminal during relay testing. Figure 7.8 shows typical connections between a computer and the SEL-321-5 Relay Port 3. Complete details regarding serial communications with the relay may be found in **Section 3: Communications**.



WARNING

Use only serial communications cables manufactured by SEL or built to SEL specifications with the SEL-321-5 Relay. Damage to the relay or your communication equipment may result from the use of incorrect communication connections.



Please refer to Section 6:
INSTALLATION for cable pinout listing.
Communication cable may be connected to
Port 1, 2 or 3. Verify baud rate settings
to ensure proper communications.

DWG. 1016-II9

Figure 7.8: Communications Connections Between the SEL-321-5 Relay and a Terminal

TEST PROCEDURES

This section includes outline test procedures for overcurrent, directional, phase distance, and ground distance elements included in the SEL-321-5 Relay. The procedures are general, so that they may be applied to any specific element or zone.

Overcurrent Elements

The SEL-321-5 Relay includes phase, residual, negative-sequence, and positive-sequence overcurrent elements. The type of overcurrent element under test determines the test connections required. Some elements are supervised by directional elements or distance elements.

The steps necessary to perform an overcurrent element test are shown below.

- Step 1.** Select element under test. Briefly review the specifications for the element under test. If the element under test is supervised by other conditions, be sure that you understand the inputs necessary to satisfy the supervisory conditions, and the overcurrent condition.
- Step 2.** Verify the element setting by executing the **SHOWSET** command via a terminal connected to a relay serial port, or by examining the relay settings via the front-panel LCD display by using the Access Level 2 **SET** command.
- Step 3.** Select the method used to indicate assertion of the element under test. Typically, this is accomplished by monitoring an output contact programmed to indicate only the condition under test.
- Step 4.** Make test source connections. If an unsupervised, single-phase overcurrent element, such as the 50H element, is being tested, a single current source is all that is required to perform the test. If a directionally supervised negative-sequence overcurrent element is to be tested, voltage sources are also required to satisfy the directional supervision conditions.
Make test source connections based upon the requirements of the test and the availability of sources. Figure 7.3 through Figure 7.7 illustrate the various source connections you may use.
- Step 5.** Determine the signals required to operate the element. For unsupervised elements, simply use the equations shown on the following page. Fulfilling the requirements of the supervisory conditions may be more complicated. Refer to the test procedures appropriate to the supervising element for details.
- Step 6.** Apply the test signals.
- Step 7.** Monitor the output contact assigned to indicate the state of the element under test to ensure that the element asserts. Review the event reports to ensure that supervisory conditions and the element under test asserted appropriately.

Calculating Overcurrent Element Test Quantities

The SEL-321-5 Relay is equipped with several different types of overcurrent elements. Each has a specific purpose and a slightly different method of testing. The types of overcurrent elements, the signals they operate from, and the elements of that type are listed below.

<u>Element Type</u>	<u>Operates Based Upon the Magnitude of:</u>	<u>Relay Elements</u>
Phase	A-phase, or B-phase or C-phase current. Test by using single-phase current.	50H, 50M, 50L1, 50L2, 50L3, 50L4
Three-Phase	A-phase, B-phase, and C-phase current. Test by using three-phase current.	3P50R

<u>Element Type</u>	<u>Operates Based Upon the Magnitude of:</u>	<u>Relay Elements</u>
Phase-to-Phase	Vector difference between two phase currents. Test by using one or two phase currents.	50PP1, 50PP2, 50PP3, 50PP4
Residual	Residual current: $I_R = I_A + I_B + I_C$. Test by using single-phase current.	50G1, 50G2, 50G3, 50G4, 50N1, 50N2, 50N3, 50N4
Negative-Sequence	$3 \cdot I_2 = (I_A + a^2 \cdot I_B + a \cdot I_C)$. Test by using single-phase current.	50Q1, 50Q2, 50Q3, 50Q4, 50QF, 50QR
Positive-Sequence	$I_1 = 1/3 (I_A + a \cdot I_B + a^2 \cdot I_C)$. Test by using three-phase or single-phase current.	50ABC

Overcurrent Element Test Examples

Examples below illustrate the test methods used for several elements.

Single-Phase Overcurrent Element: 50H

Note: The steps taken in the example test for the 50H nondirectional phase overcurrent element may be applied to test the 50M, 50L1, 50L2, 50L3, and 50L4 nondirectional phase overcurrent element as well as the residual and negative-sequence overcurrent elements 50G1, 50G2, 50G3, 50G4, 50N1, 50N2, 50N3, 50N4, 50Q1, 50Q2, 50Q3, 50Q4, 50QF, and 50QR.

- Step 1.** Execute the **SHOWSET** command and verify the relay setting for the 50H overcurrent element. The example relay settings set the 50H element to pick up at 11.25 A, secondary.
- Step 2.** Select an output contact to indicate operation of the 50H overcurrent element. In this example we use the OUT8 output.

From Access Level 2, execute the **SET L n** command to configure output OUT8 to close for assertion of the 50H overcurrent element.

```
=>>SET L 1 OUT8 <ENTER>
SELogic group 1
OUT8 =NA
? 50H <ENTER>
OUT9 =NA
? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. You must type **<ENTER>** a second time to review the full group of logic settings. At the prompt, type **Y <ENTER>** to accept those settings.

Connect output OUT8 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

- Step 3.** Connect a single current source to a phase current input of the relay. Refer to the current connections shown in Figure 7.6 as an example.
- Step 4.** Because the 50H overcurrent element operates based upon the magnitude of any single-phase current, the 50H element asserts when any phase current exceeds 11.25 A.
- Step 5.** Turn on the current test source and slowly increase the magnitude of current applied until the 50H element asserts, causing OUT8 to close. This should occur when current applied is approximately 11.25 A.
- Note:** As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

Phase-to-Phase Overcurrent Element: 50PP2

- The SEL-321-5 Relay uses the 50PP overcurrent elements to supervise operation of the phase mho distance elements. If a phase distance element zone is not enabled by the PMHOZ setting, the 50PP element setting is not displayed and the element cannot pick up.
- The steps taken in the example test for the 50PP2 overcurrent element may be applied to test the 50PP1, 50PP3, and 50PP4 phase-to-phase overcurrent elements.

- Step 1.** Execute the **SHOWSET** command and verify the relay setting for the 50PP2 overcurrent element. The example relay settings set the 50PP2 element to pick up at 2.22 A, secondary.
- Step 2.** Select an output contact to indicate operation of the 50PP2 overcurrent element. In this example we use the OUT8 output.

From Access Level 2, execute the **SET L n** command to configure Output 8 to close for assertion of the 50PP2 overcurrent element.

```
=>>SET L 1 OUT8 <ENTER>
SELogic group 1

OUT8 =NA

? 50PP2 <ENTER>
OUT9 =NA

? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. Type **Y <ENTER>** to accept those settings.

Connect output OUT8 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

- Step 3.** Connect a single current source to two relay phase current inputs. Refer to the current connections shown in Figure 7.7 as an example.

You may wish to use the connections shown in Figure 7.3 or Figure 7.4 (modified to use I_B and I_C). If you use either of these alternative connections, set the magnitude of I_C equal to the magnitude of I_B and set the phase angle of I_C equal to the phase angle of $(I_B + 180^\circ)$.

- Step 4.** The 50PP overcurrent elements operate based upon the magnitude of the vector difference between any two-phase currents. Using the current connections shown in Figure 7.7, the magnitude of I_{BC} is twice the magnitude of the applied current. This is illustrated by the following equations.

$$\begin{aligned} I_{TEST} &= I_B = -I_C \\ I_{BC} &= I_B - I_C \\ I_{BC} &= 2 \cdot I_B \\ I_{BC} &= 2 \cdot I_{TEST} \end{aligned} \quad \text{Equation 7.1}$$

With a 50PP2 setting of 2.22 A, 50PP2 picks up when I_{TEST} is greater than 1.11 A.

- Step 5.** Turn on the current test source and slowly increase the magnitude of current applied until the 50PP2 element asserts, causing OUT8 to close. This should occur when current applied is approximately 1.11 A.

- Note:** As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

Negative-Sequence Directional Element

The SEL-321-5 Relay includes a directional element that operates based upon the calculated magnitude and angle of negative-sequence impedance applied to the relay. There are two methods of testing the element. The first, using a single voltage and current, and the second using three voltages and one current. Examples of both methods are provided below following an explanation of the equations that define the element.

Negative-Sequence Directional Element Based Upon Negative-Sequence Impedance

The SEL-321-5 Relay calculates the magnitude and angle of negative-sequence voltage and current applied to the relay. From that information, the relay calculates the magnitude of negative-sequence impedance that lies collinear to the line positive-sequence impedance. The equation defining that function is shown below:

$$Z_{2c} = \frac{\operatorname{Re}[V_2 \cdot (1 \angle Z1ANG^\circ \cdot I_2)^*]}{|I_2|^2} \quad \text{Equation 7.2}$$

Where: Re indicates the real part of the term in brackets, for instance $\operatorname{Re}[A + jB] = A$
 $*$ indicates the complex conjugate of the expression in parentheses, $(A + jB)^* = (A - jB)$.

The result of Equation 7.2 is an impedance magnitude value that varies with the magnitude and angle of applied current. An example illustrates this operation.

Consider the result of applying the following voltage and current signals to Equation 7.2:

$$\angle Z1ANG = 90^\circ$$

$$V_2 = 10 \angle 180^\circ V, \text{ secondary}$$

$$I_2 = 2 \angle -90^\circ A, \text{ secondary}$$

$$Z2c = \frac{\operatorname{Re}[10 \angle 180^\circ \cdot (1 \angle 90^\circ \cdot 2 \angle -90^\circ)^*]}{|2|^2}$$

$$Z2c = \frac{-20 \Omega}{4}$$

$$Z2c = -5 \Omega$$

Coincidentally, these voltage and current signals could represent a forward single line-ground fault on a system with a 90° impedance angle. Normally, a forward fault results in a negative $Z2c$ value.

Here is an example for a reverse single line-ground fault.

$$\angle Z1ANG = 90^\circ$$

$$V_2 = 10 \angle 180^\circ V, \text{ secondary}$$

$$I_2 = 2 \angle 90^\circ A, \text{ secondary}$$

$$Z2c = \frac{\operatorname{Re}[10 \angle 180^\circ \cdot (1 \angle 90^\circ \cdot 2 \angle +90^\circ)^*]}{|2|^2}$$

$$Z2c = \frac{20 \Omega}{4}$$

$$Z2c = 5 \Omega$$

Notice that the result of Equation 7.2 is positive for a reverse fault and negative for a forward fault. This result is consistent with actual behavior on the power system.

The relay determines fault direction by comparing the result of Equation 7.2 to forward and reverse impedance thresholds that are dependent upon the $Z2F$ and $Z2R$ relay settings and the magnitude of negative-sequence voltage divided by the magnitude of negative-sequence current.

When $Z2c$ is less than the forward $Z2$ threshold, $Z2FT$, the fault is in the forward direction, so the relay sets the 32QF element, if other supervisory conditions permit. When $Z2c$ is greater than the reverse $Z2$ threshold, $Z2RT$, the fault is in the reverse direction, so the relay sets the 32QR element, if other supervisory conditions permit.

The forward directional threshold is calculated using Equation 7.3 when $Z2F$ is negative or Equation 7.4 when $Z2F$ is positive.

When $Z2F \leq 0$:

$$Z2FT = 0.75 \cdot Z2F - 0.25 \cdot Z2m \quad \text{Equation 7.3}$$

When $Z2F > 0$:

$$Z2FT = 1.25 \cdot Z2F - 0.25 \cdot Z2m \quad \text{Equation 7.4}$$

Where:

$$Z2m = \frac{|V_2|}{|I_2|}$$

The reverse directional threshold is calculated using Equation 7.5 when Z2R is positive or Equation 7.6 when Z2R is negative.

When $Z2R \geq 0$:

$$Z2RT = 0.75 \cdot Z2R + 0.25 \cdot Z2m \quad \text{Equation 7.5}$$

When $Z2R < 0$:

$$Z2RT = 1.25 \cdot Z2R + 0.25 \cdot Z2m \quad \text{Equation 7.6}$$

The threshold equations have a unique property. When $Z2m = |Z2R|$, $Z2RT = Z2R$ and when $Z2m = |Z2F|$, $Z2FT = Z2F$. This property is used to simplify the test procedures outlined on the following pages.

It is possible to create test conditions for a Z2c that lies between the forward and reverse thresholds. In this case the relay does not set the 32QR or the 32QF element. While these conditions can be contrived in the lab, correct Z2F and Z2R settings prevent this from occurring for real power system faults.

Settings for both Z2F and Z2R may be either positive or negative, depending upon the constraints of the relay application. **Section 5: Applications** of this instruction manual provides guidelines for the selection of Z2F and Z2R settings.

Negative-Sequence Directional Element Supervisory Conditions

There are a number of supervisory conditions that must be fulfilled before the relay asserts the 32QF or 32QR elements. These supervisory conditions are described below:

Magnitude of $3I_2$

The SEL-321-5 Relay uses the 50QF and 50QR negative-sequence overcurrent elements to supervise operation of the directional element. If the magnitude of applied $3I_2$ is not greater than the 50QF setting, the 32QF element does not assert to indicate direction. If the magnitude of $3I_2$ applied is not greater than the 50QR setting, the 32QR element does not assert.

Magnitude Comparison of Positive-Sequence Current to Negative-Sequence Current

The relay multiplies the measured positive-sequence current (I_1) magnitude by the a2 setting, then compares the result to the measured magnitude of negative-sequence current (I_2). The magnitude of I_2 must be greater than the magnitude of I_1 multiplied by a2 for the directional element (32QF or 32QR) to operate.

Loss-of-Potential Supervision

If ELOP = Y, the relay supervises the directional logic by using the Internal Loss-of-Potential condition (ILOP). If ELOP = Y, the relay sets the 32QF element when a loss-of-potential is detected, regardless of other signals applied to the relay. If you test the directional logic by using single voltage and current sources, set ELOP = N to simplify the test.

Single-Pole Open Supervision

The relay cannot issue an appropriate directional decision in single-pole trip applications if one or more breaker poles is open when line-side voltage transformers are applied. The relay asserts the 32QF element any time a Single-Pole Open condition is detected. To simplify directional element tests, apply dc voltage to any inputs assigned to perform the 52 auxiliary functions, or disable the Single-Pole Open logic by setting ESPO = N.

Negative-Sequence Directional Element Test Using Single Voltage and Current Sources

Step 1. Execute the **SHOWSET** command and verify the following relay settings: Z1MAG, Z1ANG, Z2F, 50QF, Z2R, 50QR, and a2. The example relay settings use the following settings: Z1MAG = 7.8 Ω, Z1ANG = 83.97°, Z2F = 0.77 Ω; 50QF = 0.5 A secondary; Z2R = 5.45 Ω; 50QR = 0.5 A secondary; a2 = 0.07.

Execute the **SET** command and change the example ELOP setting from Y to N.

Step 2. Select output contacts to indicate operation of the 32QF and 32QR elements. In this example we use the OUT7 and OUT8 outputs.

From Access Level 2, execute the **SET L n** command to configure Output 7 and Output 8 to close for assertion of the 32QF and 32QR elements, respectively.

```
=>>SET L 1 OUT7 <ENTER>
SELogic group 1
OUT7 =NA

? 32QF <ENTER>
OUT8 =50PP2
? 32QR <ENTER>
OUT9 =NA
? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. At the prompt, type **Y <ENTER>** to accept those settings.

Connect outputs OUT7 and OUT8 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

Step 3. Connect the voltage source to the A-phase-to-neutral relay voltage input. Connect the current source to the A-phase relay current input. Refer to the A-phase voltage and current connections shown in Figure 7.6 as an example. The B-phase and C-phase voltage connections are not required for this test.

Step 4. As described above, the relay 32Q element operates based upon the magnitude and angle of negative-sequence voltages and currents. You can calculate the magnitude

and angle of V_2 and I_2 , given the magnitude and angle of each of the phase quantities by using the equations below.

$$\begin{aligned}V_2 &= \frac{1}{3} \cdot (V_A + a^2 \cdot V_B + a \cdot V_C) \\I_2 &= \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C)\end{aligned}$$

Using single-phase signals simplifies the V_2 and I_2 calculations.

$$\begin{aligned}V_B &= V_C = 0V \\I_B &= I_C = 0A \\V_2 &= \frac{1}{3} \cdot (V_A) \\I_2 &= \frac{1}{3} \cdot (I_A)\end{aligned}$$

Assume that you apply a test voltage $V_A = 18.0 \angle 180^\circ$ V secondary.

$$\begin{aligned}V_2 &= \frac{1}{3} \cdot (18.0 \angle 180^\circ) V \\V_2 &= 6.0 \angle 180^\circ V\end{aligned}$$

Determine the test angle of A-phase current from the Z1ANG relay setting. Equation 7.2 yields a positive result when I_2 lags V_2 by the angle of $Z1ANG^\circ$. Equation 7.2 yields a negative result when I_2 leads V_2 by $(180^\circ - Z1ANG^\circ)$.

We are testing for positive values of $Z2c$, so I_2 should lag V_2 by $Z1ANG$.

Assuming that $V_A = 18.0 \angle 180^\circ$ V, the angle of I_A for this test should be 96° .

Determine the magnitude of A-phase current where $Z2$ equals $Z2R$ or $Z2F$ using Equation 7.7:

$$|I_A| = 3 \cdot (|V_2| / |Z_2|) \quad \text{Equation 7.7}$$

For $Z2R = 5.45 \Omega$:

$$\begin{aligned}|I_A| &= 3 \cdot (6.0V / 5.45\Omega) \\|I_A| &= 3.3A\end{aligned}$$

Calculate $Z2m$:

$$\begin{aligned}Z2m &= \frac{|V_2|}{|I_2|} \\Z2m &= \frac{6.0V}{1.1A} \\Z2m &= 5.45\Omega\end{aligned}$$

Because $Z2R$ is positive, use Equation 7.5 to calculate $Z2RT$.

$$\begin{aligned}Z2RT &= 0.75 \cdot Z2R + 0.25 \cdot Z2m \\Z2RT &= 0.75 \cdot (5.45) + 0.25 \cdot (5.45) \\Z2RT &= 5.45\Omega\end{aligned}$$

The 32QR element asserts when $Z2c$ applied is greater than $Z2RT$. As the magnitude of I_A is increased, the magnitudes of $Z2c$ and $Z2m$ decrease. For magnitudes of I_A less than 3.3 A, 32QR asserts, given the other test quantities. For I_A magnitudes greater than 3.3 A, $Z2c$ is less than $Z2RT$, so 32QR deasserts.

For Z2F = 0.77 Ω:

$$\begin{aligned}|I_A| &= 3 \cdot (6.0V / 0.77\Omega) \\ |I_A| &= 23.4A\end{aligned}$$

Calculate Z2m:

$$\begin{aligned}Z2m &= \frac{|V_2|}{|I_2|} \\ Z2m &= \frac{6.0V}{7.8A} \\ Z2m &= 0.77\Omega\end{aligned}$$

Because Z2F is positive, use Equation 7.4 to calculate Z2FT.

$$\begin{aligned}Z2FT &= 1.25 \cdot Z2F - 0.25 \cdot Z2m \\ Z2FT &= 1.25 \cdot (0.77) - 0.25 \cdot (0.77) \\ Z2FT &= 0.77\Omega\end{aligned}$$

The 32QF element asserts when Z2c is less than Z2FT. As the magnitude of I_A is increased, the magnitudes of Z2c and Z2m decrease. For magnitudes of I_A less than 23.4 A, 32QF should not assert, given the other test quantities. For I_A magnitudes greater than 23.4 A, Z2c applied is less than Z2FT, so 32QF asserts.

Step 5. Turn on the voltage source.

Apply $V_A = 18.0 V \angle 180^\circ$, $I_A = 0.0 A \angle 96^\circ$.

Slowly increase the magnitude of I_A , without varying the phase angle.

The relay 32QR element asserts, closing OUT8 when $|I_A| = 0.5 A$. This indicates that Z2c applied is greater than Z2RT, 3I₂ is greater than 50QR, and I₂ is greater than $a_2 \cdot I_1$, where a_2 is the relay setting.

Continue to increase the magnitude of I_A . 32QR deasserts when $|I_A| = 3.3 A$, indicating that Z2c is now less than Z2RT. 32QF asserts, closing OUT7 when $|I_A| = 23.4 A$, indicating that Z2c is less than Z2FT.

Verify the performance described above by calculating Z2c using Equation 7.2 and the test quantities listed above.

For $V_A = 18.0V \angle 180^\circ$, $I_A = 3.3A \angle 96^\circ$:

$$\begin{aligned}V_2 &= 6.0 \angle 180^\circ \\ I_2 &= 1.10 \\ 1 \angle Z1ANG^\circ &= 1 \angle 83.97^\circ\end{aligned}$$

$$Z_{2c} = \frac{\text{Re}[V_2(1\angle Z1ANG^\circ I_2)^*]}{|I_2|^2}$$

$$Z_{2c} = \frac{\text{Re}[6\angle 180^\circ \cdot (1\angle 83.97^\circ \cdot 1.10\angle 96^\circ)^*]}{|1.10|^2}$$

$$Z_{2c} = \frac{6.6\Omega}{1.21}$$

$Z_{2c} = 5.45\Omega = Z_{2RT}$ when $Z_{2m} = 5.45\Omega$

For $V_A = 18.0V\angle 180^\circ$, $I_A = 23.4A\angle 96^\circ$, and using the equation above:

$$V_2 = 6.0V\angle 180^\circ$$

$$I_2 = 7.80$$

$$1\angle Z1ANG^\circ = 1\angle 83.97^\circ$$

$$Z_{2c} = \frac{\text{Re}[6\angle 180^\circ \cdot (1\angle 83.97^\circ \cdot 7.80\angle 96^\circ)^*]}{|7.80|^2}$$

$$Z_{2c} = \frac{46.8\Omega}{60.84}$$

$Z_{2c} = 0.77\Omega = Z_{2FT}$ when $Z_{2m} = 0.77\Omega$

Note: As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

Negative-Sequence Directional Element Test Using Three Voltage Sources and One Current Source

Step 1. Execute the **SHOWSET** command and verify the following relay settings: Z1MAG, Z1ANG, Z2F, 50QF, Z2R, 50QR, and a2. The example relay settings use the following settings: Z1MAG = 7.8 Ω; Z1ANG = 83.97°; Z2F = 0.77 Ω; 50QF = 0.5 A secondary; Z2R = 5.45 Ω; 50QR = 0.5 A secondary; a2 = 0.07.

Execute the **SET** command and change the example ELOP setting from Y to N.

Step 2. Select output contacts to indicate operation of the 32QF and 32QR elements. In this example we use the OUT7 and OUT8 outputs.

From Access Level 2, execute the **SET L n** command to configure Output 7 and Output 8 to close for assertion of the 32QF and 32QR elements, respectively.

```
=>>SET L 1 OUT7 <ENTER>
SELogic group 1
OUT7 =NA

? 32QF <ENTER>
OUT8 =50PP2

? 32QR <ENTER>
OUT9 =NA

? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. Type **Y <ENTER>** to accept those settings.

Connect outputs OUT7 and OUT8 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

Step 3. Connect the three voltage sources and one current source to the relay as shown in Figure 7.6.

Step 4. As described above, the relay 32Q element operates based upon the magnitude and angle of negative-sequence voltages and currents. You can calculate the magnitude and angle of V_2 and I_2 , given the magnitude and angle of each of the phase quantities using the equations below.

$$\begin{aligned}V_2 &= \frac{1}{3} (V_A + a^2 \cdot V_B + a \cdot V_C) \\I_2 &= \frac{1}{3} (I_A + a^2 \cdot I_B + a \cdot I_C)\end{aligned}$$

Using a single-phase current source simplifies the I_2 calculation.

$$\begin{aligned}I_B &= I_C = 0A \\I_2 &= \frac{1}{3} (I_A)\end{aligned}$$

Assume that you apply the following test voltages:

$$\begin{aligned}V_A &= 49.0V \angle 0^\circ \\V_B &= 67.0V \angle -120^\circ \\V_C &= 67.0V \angle 120^\circ\end{aligned}$$

$$V_2 = \frac{1}{3}(49.0 \angle 0^\circ + 1 \angle 240^\circ \cdot 67 \angle -120^\circ + 1 \angle 120^\circ \cdot 67 \angle 120^\circ)V$$

$$\begin{aligned}V_2 &= \frac{1}{3}(49.0 \angle 0^\circ + 67 \angle 120^\circ + 67 \angle -120^\circ)V \\V_2 &= 6.0 \angle 180^\circ V\end{aligned}$$

Determine the test angle of A-phase current from the Z1ANG relay setting. For Equation 7.2 to yield a positive result, I_A , hence I_2 , should lag V_2 by the angle of Z1ANG. For Equation 7.2 to yield a negative result, I_A should lead V_2 by $(180^\circ - \angle Z1ANG^\circ)$.

When you apply the voltage signals shown above, V_2 is 180° out of phase from V_A . Take this into account, and calculate the angle of I_A with respect to the angle of V_A . Equation 7.2 yields a positive result when I_A leads V_A by $(180^\circ - \angle Z1ANG^\circ)$. Equation 7.2 yields a negative result when I_A lags V_A by $\angle Z1ANG^\circ$.

We are testing for positive values of Z2c, so I_A should lead V_A by $(180^\circ - \angle Z1ANG^\circ)$. Assuming that $V_A = 49.0 \angle 0^\circ V$, the angle of I_A for this test should be 96° .

Calculate the magnitude of A-phase current where Z2c equals Z2RT or Z2FT using Equation 7.7:

$$|I_A| = 3 \cdot (|V_2| / |Z_2|)$$

For Z2R = 5.45 Ω:

$$\begin{aligned}|I_A| &= 3 \cdot (6.0V / 5.45\Omega) \\ |I_A| &= 3.3A\end{aligned}$$

Calculate Z2m:

$$\begin{aligned}Z2m &= \frac{|V_2|}{|I_2|} \\ Z2m &= \frac{6.0V}{1.1A} \\ Z2m &= 5.45\Omega\end{aligned}$$

Because Z2R is positive, use Equation 7.5 to calculate Z2RT.

$$\begin{aligned}Z2RT &= 0.75 \cdot Z2R + 0.25 \cdot Z2m \\ Z2RT &= 0.75 \cdot (5.45) + 0.25 \cdot (5.45) \\ Z2RT &= 5.45\Omega\end{aligned}$$

The 32QR element asserts when Z2c applied is greater than Z2RT. As the magnitude of I_A is increased, the magnitudes of Z2c and Z2m decrease. For magnitudes of I_A less than 3.3 A, 32QR asserts, given the other test quantities. For I_A magnitudes greater than 3.3 A, Z2c is less than Z2RT, so 32QR deasserts.

For Z2F = 0.77 Ω:

$$\begin{aligned}|I_A| &= 3 \cdot (6.0V / 0.77\Omega) \\ |I_A| &= 23.4A\end{aligned}$$

Calculate Z2m:

$$\begin{aligned}Z2m &= \frac{|V_2|}{|I_2|} \\ Z2m &= \frac{6.0V}{7.8A} \\ Z2m &= 0.77\Omega\end{aligned}$$

Because Z2F is positive, use Equation 7.4 to calculate Z2FT.

$$\begin{aligned}Z2FT &= 1.25 \cdot Z2F - 0.25 \cdot Z2m \\ Z2FT &= 1.25 \cdot (0.77) - 0.25 \cdot (0.77) \\ Z2FT &= 0.77\Omega\end{aligned}$$

The 32QF element asserts when Z2c is less than Z2FT. As the magnitude of I_A is increased, the magnitudes of Z2c and Z2m decrease. For magnitudes of I_A less than 23.4 A, 32QF should not assert, given the other test quantities. For I_A magnitudes greater than 23.4 A, Z2c applied is less than Z2FT, so 32QF asserts.

Step 5. Turn on the voltage sources.

Apply:

$$\begin{aligned}V_A &= 49.0V \angle 0^\circ \\V_B &= 67.0V \angle -120^\circ \\V_C &= 67.0V \angle 120^\circ \\I_A &= 0.0A \angle 96^\circ\end{aligned}$$

Slowly increase the magnitude of I_A , without varying the phase angle.

The relay 32QR element asserts, closing OUT8 when $|I_A| = 0.5$ A. This indicates that $Z2c$ applied is greater than $Z2RT$, $3I_2$ is greater than $50QR$, and I_2 is greater than $a2 \cdot I_1$, where $a2$ is the relay setting.

Continue to increase the magnitude of I_A . 32QR deasserts when $|I_A| = 3.3$ A, indicating that $Z2c$ is now less than $Z2RT$. 32QF asserts, closing OUT7 when $|I_A| = 23.4$ A, indicating that $Z2c$ is less than $Z2FT$.

Verify that the relay operated properly by calculating $Z2c$ using Equation 7.2 and the test quantities listed below.

For:

$$\begin{aligned}I_A &= 3.30A \angle 96^\circ \\V_A &= 49.0V \angle 0^\circ \\V_B &= 67.0V \angle -120^\circ \\V_C &= 67.0V \angle 120^\circ\end{aligned}$$

$$\begin{aligned}V_2 &= 6.0V \angle 180^\circ \\I_2 &= 1.10 \\1 \angle Z1ANG^\circ &= 1 \angle 83.97^\circ\end{aligned}$$

$$\begin{aligned}Z2c &= \frac{\text{Re}[V_2 \cdot (1 \angle Z1ANG^\circ \cdot I_2)^*]}{|I_2|^2} \\Z2c &= \frac{\text{Re}[6 \angle 180^\circ \cdot (1 \angle 83.97^\circ \cdot 1.10 \angle 96^\circ)^*]}{|1.10|^2}\end{aligned}$$

$$Z2c = \frac{6.6\Omega}{1.21}$$

$$Z2c = 5.45\Omega = Z2RT \text{ when } Z2m = 5.45\Omega$$

For:

$$\begin{aligned}I_A &= 23.4A \angle 96^\circ \\V_A &= 49.0V \angle 0^\circ \\V_B &= 67.0V \angle -120^\circ \\V_C &= 67.0V \angle 120^\circ\end{aligned}$$

$$\begin{aligned}V_2 &= 6.0V \angle 180^\circ \\I_2 &= 7.80 \\1 \angle Z1ANG^\circ &= 1 \angle 83.97^\circ\end{aligned}$$

$$Z_{2c} = \frac{\text{Re}[6\angle 180^\circ \cdot (1\angle 83.97^\circ \cdot 7.80\angle 96^\circ) *]}{|7.80|^2}$$

$$Z_{2c} = \frac{46.8\Omega}{60.84}$$

$$Z_{2c} = 0.77\Omega = Z_{2F} \text{ when } Z_{2m} = 0.77\Omega$$

Note: As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

Phase Mho Distance Elements

The SEL-321-5 Relay includes up to four zones of mho phase distance protection. Enable the number of phase distance zones you would like to apply using the PMHOZ setting. You may set the phase distance elements to reach in the forward or reverse direction. The reach and direction of each zone is independent from the other zones. When a zone of phase distance protection is set to reach in one direction, the ground distance elements associated with that zone must be set to reach in the same direction. Reach is set in secondary Ω . The phase distance element maximum reach angle is always equal to the angle of Z1ANG.

Each zone has an instantaneous indication. For example, the M3P element asserts without intentional time delay for A-B, B-C, or C-A faults within the Zone 3 characteristic. Zones 2, 3, and 4 also include time delayed indication through elements M2PT, M3PT, and M4PT. In addition, the relay provides an instantaneous indication for each individual phase-to-phase distance element. For example, the MAB1, MAB2, MAB3, and MAB4 elements provide instantaneous indication of A-B phase faults in each zone.

For general testing, use the instantaneous and time delayed elements that respond to any phase-to-phase fault within a given zone such as M1P, M2P, etc. You can record more detailed and specific test results using the instantaneous element associated with the faulted phase pair and zone under test.

Phase Distance Element Supervisory Conditions

There are a number of supervisory conditions that must be fulfilled before the relay allows a phase distance element to pick up. These supervisory conditions are described below.

Phase-to-Phase Nondirectional Overcurrent Element, 50PPn

Each phase-to-phase distance element is supervised by a nondirectional phase-to-phase overcurrent element. For example, the relay cannot assert the Zone 3 A-B phase-to-phase distance element if the vector difference between A-phase current and B-phase current is less than the 50PP3 setting.

Negative-Sequence Directional Element

The phase distance protection function is supervised by the negative-sequence directional element to provide improved directional security. Forward-reaching phase distance elements may not assert unless the 32QF element is asserted. Reverse-reaching phase distance elements may not

assert unless the 32QR element is asserted. The relay operates properly for three-phase faults where no negative-sequence current is present using alternative logic to detect three-phase faults.

Loss-of-Potential Logic

If ELOP = Y, the relay supervises the phase distance element logic by using the Internal Loss-of-Potential condition (ILOP). When ELOP = Y, the relay disables the phase distance elements when a loss-of-potential is detected, regardless of other signals applied to the relay. If you test the phase distance elements by using low voltage signals, set ELOP = N to simplify the test.

Single-Pole Open Logic

In single-pole trip applications, the relay cannot properly polarize or operate the phase distance elements associated with an open breaker pole. The relay Single-Pole Open logic disables the two phase-to-phase distance elements associated with an open breaker pole. For instance, if Pole A is open, the relay may not operate the A-B or C-A phase-to-phase distance elements. To simplify distance element tests, apply control voltage to any inputs assigned to perform the 52 auxiliary functions, or disable the Single-Pole Open logic by setting ESPO = N.

Load-Encroachment Logic

The relay includes Load-Encroachment logic to help prevent the relay phase distance elements from operating improperly under heavy load conditions. Forward and reverse load regions are defined using impedance and angle settings. The relay calculates the positive-sequence impedance. If the calculated impedance falls within the set load area, the phase distance elements are blocked from operating. This may result in a phase distance element characteristic that appears to have a bow-tie shaped section missing near the area of the resistive axis. Double-check the relay Load-Encroachment logic settings if your test results appear incorrect near the resistive axis.

Out-of-Step Blocking Logic

The relay includes Out-of-Step Tripping and Blocking logic that operates based on the Zone 5 and Zone 6 positive-sequence impedance zones and several timers. If you suspect that the Out-of-Step logic is blocking operation of a phase distance element under test, check the relay settings associated with the Out-of-Step function and review the relay event report.

Phase Distance Element Test Using Three Voltage Sources and One Current Source

Note: This test refers directly to the Zone 2 phase distance element, but may be applied to any other forward-reaching phase-to-phase distance element zone. To test reverse-reaching zones, simply add 180° to the calculated test current phase angle. Verify correct operation of the 32QR element for the test voltage and current signals by using Equation 7.2 in the Negative-Sequence Directional Element Test Procedure.

Step 1. Execute the **SHOWSET** command and verify the following relay settings: Z1MAG, Z1ANG, PMHOZ, DIR2, Z2P, 50PP2, Z2F, and 50QF. The example relay settings use the following settings: Z1MAG = 7.8; Z1ANG = 83.97°; PMHOZ = 3; DIR2 = F; Z2P = 9.36 Ω; 50PP2 = 2.22; Z2F = 0.77 Ω; 50QF = 0.5 A secondary.

Execute the **SET** command and change the example ELOP setting from Y to N. This prevents the relay Loss-of-Potential logic from blocking operation of the relay distance elements.

- Step 2.** Select an output contact to indicate operation of the M2P element. In this example we use the OUT7 output.

From Access Level 2, execute the **SET L n** command to configure Output 7 to close for assertion of the M2P element.

```
=>>SET L 1 OUT7 <ENTER>
SELogic group 1
OUT7 =NA

? M2P <ENTER>
OUT8 =32QR

? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. Type **Y <ENTER>** to accept those settings.

Connect output OUT7 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

- Step 3.** Connect the voltage sources to the relay A-phase, B-phase, and C-phase voltage inputs. Connect the current source to the relay B-phase and C-phase current inputs. Refer to the voltage and current connections shown in Figure 7.7 as an example.

- Step 4.** Select the magnitude of the test signals, I_{BC} , V_B , and V_C .

Table 7.3 summarizes the test quantities for the Zone 2 B-C phase distance element based upon the example relay settings.

Table 7.3: Test Quantities for Zone 2 Phase Distance Element

Test Voltages	Test Current
$V_A = 67 \angle 0^\circ V$	$I_{TEST} = 2.5 \angle -173.97^\circ A$
$V_B = 46.8 \angle -150^\circ V$	
$V_C = 46.8 \angle 150^\circ V$	

The following text describes a hand calculation method you may use to calculate relay distance element voltage and current test signals. If you do not wish to review this information, go to Step 5.

You may want to use the Basic program ONEBUS to calculate distance element test quantities. A listing of this program is provided in Appendix D.

The relay phase distance elements operate based upon the magnitude of applied phase-to-phase impedance. The impedance calculation is also supervised by the functions described. To effectively test the distance elements, select voltage and

current test signals that fulfill the impedance and supervisory requirements of the relay settings, but are within the ability of the voltage and current test sources to produce accurately.

The Zone 2 phase distance element is forward-reaching in the example relay settings. Thus, it is supervised by the forward directional element 32QF, as well as the 50PP2 phase-to-phase overcurrent elements. For the distance element to assert, the applied phase-to-phase current must exceed the 50PP2 setting and applied $3I_2$ must exceed the 50QF setting.

The 50PP overcurrent elements operate based upon the magnitude of the vector difference between any two phase currents. Using the current connections shown in Figure 7.7, the magnitude of I_{BC} is twice the magnitude of the applied current. This is illustrated by the following equations.

$$\begin{aligned} I_{TEST} &= I_B = -I_C \\ I_{BC} &= I_B - I_C \\ I_{BC} &= 2 \cdot I_B \\ I_{BC} &= 2 \cdot I_{TEST} \end{aligned}$$

With a 50PP2 setting of 2.22 A, 50PP2 picks up when I_{TEST} is greater than 1.11 A.

The 50QF negative-sequence overcurrent element operates based upon the magnitude of $3I_2$ applied. Using the current connections shown in Figure 7.7, we can calculate the magnitude of $3I_2$ applied based upon the magnitude of I_{TEST} .

$$\begin{aligned} I_2 &= \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C) \\ 3 \cdot I_2 &= (I_A + a^2 \cdot I_B + a \cdot I_C) \\ I_A &= 0 \text{ and } I_C = -I_B, \text{ so:} \\ 3 \cdot I_2 &= (a^2 \cdot I_B - a \cdot I_B) \\ 3 \cdot I_2 &= I_B \cdot (a^2 - a) \\ 3 \cdot I_2 &= I_B \cdot (1.732 \angle -90^\circ) \end{aligned}$$

Because the 50QF element operates based upon magnitude only, the equation above is simplified.

$$|3 \cdot I_2| = |I_{TEST}| \cdot 1.732$$

With a 50QF setting of 0.5 A, 50QF picks up when I_{TEST} is greater than 0.288 A.

In this example, select $|I_{TEST}| = 2.5$ A, thus $I_{BC} = 5.0$ A and $3I_2 = 4.33$ A. This selection fulfills the supervisory overcurrent conditions described above.

The reach of the distance element under test is defined by the element setting. In this case $Z2P = 9.36$ secondary Ω .

Calculate the magnitude of V_{BC} by using Equation 7.8.

$$\begin{aligned}|V_{BC}| &= |I_{BC}| \cdot |Z_{BC}| \\|V_{BC}| &= |5.0| \cdot |9.36| \\|V_{BC}| &= 46.8V \text{ secondary}\end{aligned}\quad \text{Equation 7.8}$$

Refer to Figure 7.9 and use the equations below to calculate the magnitude and angle of V_B and V_C based upon the magnitude of V_{BC} calculated above.

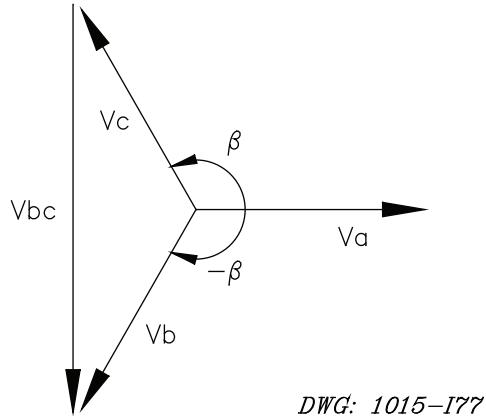


Figure 7.9: Phase Distance Element Test Voltage Signals

When the magnitude of V_{BC} calculated above lies between 67 and 35 V, use $\beta = 150^\circ$ and $|V_B| = |V_C| = |V_{BC}|$.

When the magnitude of V_{BC} calculated above is greater than 67 V, use $|V_B| = |V_C| = 67$ V. Calculate the angle β by using Equation 7.9.

When the magnitude of V_{BC} calculated above is less than 35 V, use $|V_B| = |V_C| = 35$ V. Calculate the angle β by using Equation 7.9.

$$\beta = 180^\circ - \arcsin[|V_{BC}| / (2 \cdot |V_C|)] \text{deg} \quad \text{Equation 7.9}$$

Select $V_A = 67.0 \angle 0^\circ$ V. For the Zone 2 B-C element test, based upon the example settings, the magnitude of V_{BC} equals 46.8 V. From the equations above, select the following test voltage magnitudes and angles.

$$\begin{aligned}V_A &= 67.0 \angle 0^\circ \text{V} \\V_B &= 46.8 \angle -150^\circ \text{V} \\V_C &= 46.8 \angle 150^\circ \text{V}\end{aligned}$$

The phase distance element maximum reach is measured when faulted phase-to-phase current lags faulted phase-to-phase voltage by the distance element maximum torque angle. In the SEL-321-5 Relay, the phase distance element maximum torque angle is defined by the angle of the relay Z1ANG setting.

For the example relay settings, I_{BC} should lag V_{BC} by 83.97° . Based upon the test voltages selected above, V_{BC} lags V_A by 90° , so I_{BC} should lag V_A by 173.97° .

As stated above, the phase distance elements are supervised by the negative-sequence directional element. It is important to check the negative-sequence quantities applied

and verify that the 32QF element should assert allowing the forward-reaching distance element to operate. We can calculate the magnitude and angle of negative-sequence voltage and current applied for the test quantities listed above. We can then calculate the negative-sequence impedance, Z2c, applied using Equation 7.2 and compare Z2c to the Z2FT threshold, which is a function of the Z2F setting and Z2m.

$$V_2 = \frac{1}{3} \cdot (V_A + a^2 \cdot V_B + a \cdot V_C)$$

$$I_2 = \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C)$$

$$Z2c = \frac{\operatorname{Re}[V_2 \cdot (1\angle Z1ANG^\circ \cdot I_2)^*]}{|I_2|^2}$$

$$Z2m = \frac{|V_2|}{|I_2|}$$

$$Z2FT = 1.25 \cdot Z2F - 0.25 \cdot Z2m$$

Taking the test signals from Table 7.3.

$$V_A = 67.0V \angle 0^\circ$$

$$V_B = 46.8V \angle -150^\circ$$

$$V_C = 46.8V \angle 150^\circ$$

$$V_2 = \frac{1}{3} \cdot (67.0 \angle 0^\circ + 1\angle 240^\circ \cdot 46.8 \angle -150^\circ + 1\angle 120^\circ \cdot 46.8 \angle 150^\circ) V$$

$$V_2 = 22.3 \angle 0^\circ V$$

Due to the test connections used, $I_B = -I_C = I_{TEST}$.

$$I_A = 0.0A \angle 0^\circ$$

$$I_B = 2.5A \angle -173.97^\circ$$

$$I_C = 2.5A \angle 6.03^\circ$$

$$I_2 = \frac{1}{3} \cdot (0.0 \angle 0^\circ + 1\angle 240^\circ \cdot 2.5 \angle -173.97^\circ + 1\angle 120^\circ \cdot 2.5 \angle 6.03^\circ) A$$

$$I_2 = 1.44 \angle 96.03^\circ A$$

Using Equation 7.2 to calculate Z2c, the result is:

$$Z2c = -15.47\Omega$$

$$Z2m = 15.47\Omega$$

$$Z2FT = 1.25 \cdot (0.77) - 0.25 \cdot (15.47)$$

$$Z2FT = -2.91\Omega$$

The Z2FT threshold is -2.91Ω . Z2c applied (-15.47Ω) is less than the Z2FT threshold based upon the Z2F setting (0.77Ω) and Z2m (15.47Ω), therefore, the 32QF element asserts when these signals are applied. If Z2c applied is greater than the Z2FT threshold, select new test current and voltages by using the steps outlined above.

- Step 5.** Turn on the voltage sources. Apply V_A , V_B , and V_C at the magnitudes and angles listed in Table 7.3. Turn on the current test source. Set the current angle to -174° .

Slowly increase the magnitude of current applied until the M2P element asserts, causing OUT7 to close. This should occur when current applied is approximately 2.5 A.

With these signals applied, the relay measures B-C phase impedance defined by the equation:

$$Z_{BC} = \frac{V_{BC}}{2 \cdot I_{TEST}} \Omega, \text{ sec}$$
Equation 7.10

You may wish to test the distance element characteristic at impedance angles other than the line positive-sequence impedance angle. To do this, you must adjust the magnitude and angle of I_{TEST} from the values shown in Table 7.3. As an example, calculate the current signal necessary to test the distance element at an angle of 38.97°.

First, the new desired impedance angle (38.97°) is 45° less than the original test impedance angle (83.97°). Add 45° to the angle of I_{TEST1} .

$$\begin{aligned}\angle I_{TEST2} &= \angle I_{TEST1} + 45^\circ \\ \angle I_{TEST2} &= -173.97^\circ + 45^\circ \\ \angle I_{TEST2} &= -128.97^\circ\end{aligned}$$

Calculate the magnitude of I_{TEST2} by using Equation 7.11.

$$|I_{TEST2}| = \frac{|I_{TEST1}|}{\cos(\text{Line Impedance Angle} - \text{New Test Impedance Angle})} \text{A, sec}$$

$$\begin{aligned}|I_{TEST2}| &= \frac{2.5}{\cos(83.97^\circ - 38.97^\circ)} \text{A} \\ |I_{TEST2}| &= \frac{2.5}{\cos(45^\circ)} \text{A} \\ |I_{TEST2}| &= 3.54 \text{A}\end{aligned}$$
Equation 7.11

Note: As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

Ground Mho Distance Elements

The SEL-321-5 Relay includes up to four zones of mho ground distance protection. Enable the number of ground distance zones you would like to apply using the GMHOZ setting. You may set the ground distance elements to reach in the forward or reverse direction. The reach and direction of each zone is independent from the other zones. When a zone of phase distance protection is set to reach in one direction, the ground distance elements associated with that zone must be set to reach in the same direction. Reach is set in secondary Ω . The angle of maximum reach of the ground distance elements is defined by the Z1ANG setting and the zero-sequence current compensation factor for the zone under test.

Each zone has an instantaneous indication. For example, the Z3G element asserts without intentional time delay for A-G, B-G, and C-G faults within the Zone 3 mho or quadrilateral

characteristic. Zones 2, 3, and 4 also include time delayed indication through elements Z2GT, Z3GT, and Z4GT. In addition, each individual phase-ground distance element provides an instantaneous indication for each zone. For example, the MAG1, MAG2, MAG3, and MAG4 elements provide instantaneous indication of A-G ground faults in each zone.

For general testing, use the instantaneous and time delayed elements that respond to any phase-ground fault within a given zone such as Z1G, Z2G, etc. You can record more detailed and specific test results using the instantaneous element associated with the faulted phase and zone under test.

There are a number of supervisory conditions that must be fulfilled before the relay allows a ground distance element to pick up. These supervisory conditions are described below.

Ground Distance Element Supervisory Conditions

Note: Unless otherwise indicated, all of the supervisory conditions listed below apply to the ground mho and ground quadrilateral distance elements.

Phase and Ground Nondirectional Overcurrent Elements, 50Ln and 50Gn

Each zone ground distance element is supervised by two nondirectional overcurrent elements, 50Gn and 50Ln, where n indicates the zone associated with the overcurrent element. For example, the relay may assert the Zone 3 A-ground distance element only if the A-phase current is greater than the 50L3 setting and the residual current is greater than the 50G3 setting.

Negative-Sequence Directional Element

The ground distance protection function is supervised by the negative-sequence directional element to provide improved directional security. Forward-reaching distance elements may not assert unless the 32QF element is asserted. Reverse-reaching distance elements may not assert unless the 32QR element is asserted.

Loss-of-Potential Logic

If ELOP = Y, the relay supervises the ground distance element logic by using the Internal Loss-of-Potential condition (ILOP). When ELOP = Y, the relay disables the ground distance elements when a loss-of-potential is detected, regardless of other signals applied to the relay. If you test the ground distance elements by using low voltage signals, set ELOP = N to simplify the test.

Single-Pole Open Logic

In single-pole trip applications, the relay cannot properly polarize or operate the ground distance elements associated with an open breaker pole. The relay Single-Pole Open logic disables the ground distance element associated with an open breaker pole. For instance, if Pole A is open, the relay cannot operate the A-G ground mho distance elements. If any single-pole is open, the relay disables all ground quadrilateral distance elements. To simplify distance element tests, apply control voltage to any inputs assigned to perform the 52 auxiliary functions, or disable the Single-Pole Open logic by setting ESPO = N.

Three-Pole Open Logic

If significant pole-scatter occurs when a circuit breaker closes, sensitive ground distance elements may operate undesirably due to the unbalanced signals applied. The SEL-321-5 Relay disables the ground distance elements during Three-Pole Open conditions and for a short, settable time after the breaker closes. The time is set by the 3POD time delay settings. To simplify distance element tests, apply control voltage to any inputs assigned to perform the 52 auxiliary functions.

Ground Distance Element Disable Inputs

The SEL-321-5 Relay is equipped with ground distance element disabling inputs, PARA, PARB, and PARC. When a relay input assigned to one of these functions is asserted, the relay disables the ground distance elements associated with that phase. For instance, if Input 4 is assigned to PARA, each time Input 4 is asserted, all of the A-ground distance elements are disabled.

Ground Mho Distance Element Test Using Three Voltage Sources and One Current Source

Note: This test refers directly to the Zone 2 ground mho distance element, but may be applied to any other forward-reaching ground mho distance element zone. To test reverse-reaching zones, simply add 180° to the calculated test current phase angle. Verify correct operation of the 32QR element for the test voltage and current signals by using Equation 7.2 in the Negative-Sequence Directional Element Test Procedure.

Step 1. Execute the **SHOWSET** command and verify the following relay settings: Z1MAG, Z1ANG, GMHOZ, DIR2, Z2MG, 50L2, 50G2, k0M, k0A, Z2F, and 50QF. The example relay settings use the following settings: Z1MAG = 7.8; Z1ANG = 83.97°; GMHOZ = 3; DIR2 = F; Z2MG = 9.36 Ω; 50L2 = 0.90; 50G2 = 0.60; k0M = 0.726; k0A = -3.69; Z2F = 0.77 Ω; 50QF = 0.5 A secondary.

Execute the **SET** command and change the following settings. Change QUADZ to N and ELOP from Y to N. Changing the QUADZ setting prevents the relay ground quadrilateral distance elements from interfering with the test. Changing the ELOP setting prevents the Loss-of-Potential logic from blocking operation of the relay distance elements if the test signals fulfill Loss-of-Potential conditions.

Step 2. Select an output contact to indicate operation of the Z2G element. In this example we use the OUT7 output.

From Access Level 2, execute the **SET L n** command to configure Output 7 to close for assertion of the Z2G element.

```
=>>SET L 1 OUT7 <ENTER>
SELogic group 1
OUT7 =NA
? Z2G <ENTER>
OUT8 =32QR
? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. Type **Y <ENTER>** to accept those settings.

Connect output OUT7 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

Step 3. Connect the voltage sources to the A-phase, B-phase, and C-phase-to-neutral relay voltage inputs. Connect the current source to the A-phase relay current input. Refer to the voltage and current connections shown in Figure 7.6 as an example.

Step 4. Select the magnitude of the test signals, I_A and V_A .

Table 7.4 summarizes the test quantities for the Zone 2 A-G ground distance element based upon the example relay settings.

Table 7.4: Test Quantities for Zone 2 Ground Mho Distance Element

Test Voltages	Test Current
$V_A = 40.4 \angle 0^\circ V$	$I_{TEST} = 2.5 \angle -82.42^\circ A$
$V_B = 67.0 \angle -120^\circ V$	
$V_C = 67.0 \angle 120^\circ V$	

The following text describes a hand calculation method you may use to calculate relay distance element voltage and current test signals. If you do not wish to review this information, go to Step 5.

You may want to use the Basic program ONEBUS to calculate distance element test quantities. A listing of this program is provided in *Appendix D*.

The relay ground distance elements operate based upon the magnitude of applied phase-ground impedance. The impedance calculation is supervised by the functions described. To effectively test the distance elements, select test signals that fulfill the impedance and supervisory requirements of the relay, but are within the ability of the test sources to produce accurately.

The Zone 2 ground distance element is forward-reaching in the example relay settings. Thus, it is supervised by the forward directional element 32QF, as well as the 50L2 and 50G2 phase and residual overcurrent elements. Applied phase current must exceed the 50L2 setting, applied residual current must exceed the 50G2 setting, and applied $3I_2$ must exceed the 50QF setting.

The 50L overcurrent elements operate based upon the magnitude of the phase current. Using the current connections shown in Figure 7.6, the magnitude of I_A is equal to the magnitude of the applied test current. With a 50L2 setting of 0.90 A, 50L2 picks up when I_{TEST} is greater than 0.90 A.

The 50G overcurrent elements operate based upon the magnitude of the residual current. Using the current connections shown in Figure 7.6, the magnitude of I_R is equal to the magnitude of the applied test current, I_A . With a 50G2 setting of 0.60 A, 50G2 picks up when I_{TEST} is greater than 0.60 A.

The 50QF negative-sequence overcurrent element operates based upon the magnitude of $3I_2$ applied. Using the current connections shown in Figure 7.6, we can calculate the magnitude of $3I_2$ applied based upon the magnitude of I_{TEST} .

$$\begin{aligned}I_2 &= \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C) \\3 \cdot I_2 &= (I_A + a^2 \cdot I_B + a \cdot I_C) \\I_A &= I_{TEST} \text{ and } I_B = I_C = 0, \text{ so:} \\3 \cdot I_2 &= I_{TEST}\end{aligned}$$

With a 50QF setting of 0.5 A, 50QF picks up when I_{TEST} is greater than 0.5 A.

Select the magnitude of I_A greater than the 50L2, 50G2, and 50QF settings, but less than the maximum current output capability of the current test source.

In this example, select $|I_{TEST}| = 2.5$ A. This selection fulfills the supervisory overcurrent conditions described above.

The reach of the distance element under test in secondary Ω is defined by the element setting. In this case $Z_{2MG} = 9.36 \Omega$. The impedance measured by the relay for a ground fault is determined by the faulted phase voltage, faulted phase current, and the residual current multiplied by the zero-sequence current compensation factor, $k0$. The SEL-321-5 Relay uses $k0M$ and $k0A$ settings to define the zero-sequence current compensation factor for Zone 1 ground distance elements. The $k0M$ and $k0A$ settings to define $k0$ for the remaining zones. The impedance measured by the relay ground mho distance element for a Zone 2 fault is defined by the following equation:

$$Z_{AG} = \frac{V_A}{I_A + k0 \cdot I_R} \quad \text{Equation 7.12}$$

Where: $k0 = k0M \angle k0A^\circ$

For a fault on a radial system and when testing a ground distance element using a single current source, $I_A = I_R$. In this case, Equation 7.12 can be simplified:

$$Z_{AG} = \frac{V_A}{I_A \cdot (1 + k0)} \quad \text{Equation 7.13}$$

If we multiply both sides of Equation 7.13 by the quantity $(1 + k0)$, the result is the impedance applied by the A-phase test signals, V_A and I_A .

$$Z_{AG} \cdot (1 + k0) = \frac{V_A}{I_A} \quad \text{Equation 7.14}$$

Since we are testing the Zone 2 mho ground distance element, the intended value of $Z_{AG} = Z_{2MG} = 9.36 \Omega$. The angle of Z_{2MG} is equal to the angle of positive-sequence impedance, $Z1ANG$.

Because the element under test is not a Zone 1 element, the $k0$ value is defined by the relay settings $k0M$ and $k0A$. When you test the relay Zone 1 ground elements, use $k01M$ and $k01A$ to define the magnitude and angle of $k0$.

Calculate the value of $Z_{AG} \cdot (1 + k0)$ based upon the information above.

$$Z_{AG} \cdot (1 + k0) = Z_{TEST} = Z_{2MG} \cdot (1 + k0M \angle k0A) \quad \text{Equation 7.15}$$

$$\begin{aligned}Z_{\text{TEST}} &= 9.36 \angle 83.97^\circ (1 + 0.726 \angle -3.69^\circ) \\Z_{\text{TEST}} &= 9.36 \angle 83.97^\circ (1.725 \angle -1.55^\circ) \\Z_{\text{TEST}} &= 16.15 \angle 82.42^\circ\end{aligned}$$

I_A must lag V_A by the angle of Z_{TEST} to check the maximum reach of the element under test. With V_A applied at an angle of 0° , the angle of I_A is:

$$I_A = 2.5 \angle -82.42^\circ$$

Calculate the magnitude of V_A by using Equation 7.16

$$\begin{aligned}V_A &= I_A \cdot Z_{\text{TEST}} \\V_A &= 2.5 \angle -82.42^\circ \cdot 16.15 \angle 82.42^\circ \\V_A &= 40.4 \angle 0.0^\circ \text{V secondary}\end{aligned}\quad \text{Equation 7.16}$$

Select $V_B = 67 \angle -120^\circ$ volts and $V_C = 67 \angle 120^\circ$ volts.

The ground distance elements are supervised by the negative-sequence directional element. It is important to check the negative-sequence quantities applied and verify that the 32QF element should assert allowing the forward-reaching distance element to operate. Calculate the magnitude and angle of negative-sequence voltage and current applied for the test quantities listed above. Then calculate the negative-sequence impedance, Z_{2c} , applied using Equation 7.2 and compare Z_{2c} to the Z_{2FT} threshold, which is a function of the Z_{2F} setting and Z_{2m} .

$$\begin{aligned}V_2 &= \frac{1}{3} \cdot (V_A + a^2 \cdot V_B + a \cdot V_C) \\I_2 &= \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C)\end{aligned}$$

$$Z_{2c} = \frac{\operatorname{Re}[V_2 \cdot (1 \angle Z1ANG^\circ \cdot I_2)^*]}{|I_2|^2}$$

$$Z_{2m} = \frac{|V_2|}{|I_2|}$$

$$Z_{2FT} = 1.25 \cdot Z_{2F} - 0.25 \cdot Z_{2m}$$

Taking the test signals from Table 7.4.

$$\begin{aligned}V_A &= 40.4 \text{V} \angle 0^\circ \\V_B &= 67.0 \text{V} \angle -120^\circ \\V_C &= 67.0 \text{V} \angle 120^\circ\end{aligned}$$

$$\begin{aligned}V_2 &= \frac{1}{3} \cdot (40.4 \angle 0^\circ + 1 \angle 240^\circ \cdot 67.0 \angle -120^\circ + 1 \angle 120^\circ \cdot 67.0 \angle 120^\circ) \text{V} \\V_2 &= 8.88 \angle 180^\circ \text{V}\end{aligned}$$

$$\begin{aligned}I_A &= 2.5 \angle -82.42^\circ \\I_B &= 0.0 \angle 0.0^\circ \\I_C &= 0.0 \angle 0.0^\circ\end{aligned}$$

$$I_2 = \frac{1}{3} \cdot (2.5 \angle -82.42^\circ) A$$

$$I_2 = 0.83 \angle -82.42^\circ A$$

Using Equation 7.2 to calculate Z2, the result is:

$$Z2c = -10.66\Omega$$

$$Z2m = 15.47\Omega$$

$$Z2FT = 1.25 \cdot (0.77) - 0.25 \cdot (15.47)$$

$$Z2FT = -2.91\Omega$$

The relay example Z2F setting is 0.77Ω . $Z2c$ applied (-10.66Ω) is less than the $Z2FT$ threshold (-2.91Ω), therefore, the 32QF element asserts when these signals are applied. If $Z2c$ applied is greater than the $Z2FT$ threshold, select new test current and voltages by using the steps outlined above.

- Step 5.** Turn on the voltage sources. Apply V_A , V_B , and V_C at the magnitudes and angles listed in Table 7.4. Turn on the current test source. Set the current angle to -82° . Slowly increase the magnitude of current applied until the $Z2G$ element asserts, causing OUT7 to close. This occurs when current applied is approximately 2.5 A.

You may wish to test the distance element characteristic at impedance angles other than the line positive-sequence impedance angle. To do this, you must adjust the magnitude and angle of I_{TEST} from the values shown in Table 7.4. As an example, calculate the current signal necessary to test the distance element at an angle of 38.97° .

First, the new desired impedance angle (38.97°) is 45° less than the original test impedance angle (83.97°). Add 45° to the angle of I_{TEST1} .

$$\angle I_{TEST2} = \angle I_{TEST1} + 45^\circ$$

$$\angle I_{TEST2} = -173.97^\circ + 45^\circ$$

$$\angle I_{TEST2} = -128.97^\circ$$

Calculate the magnitude of I_{TEST2} by using Equation 7.11.

$$|I_{TEST2}| = \frac{|I_{TEST1}|}{\cos(\text{Line Impedance Angle} - \text{New Test Impedance Angle})} A, \text{ sec}$$

$$|I_{TEST2}| = \frac{2.5}{\cos(83.97^\circ - 38.97^\circ)} A$$

$$|I_{TEST2}| = \frac{2.5}{\cos(45^\circ)} A$$

$$|I_{TEST2}| = 3.54 A$$

- Note:** As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

Ground Quadrilateral Distance Element Reactive Reach Test Using Three Voltage Sources and One Current Source

Note: This test refers directly to the Zone 2 ground quadrilateral distance element, but may be applied to any other forward-reaching ground quadrilateral distance element zone. To test reverse-reaching zones, simply add 180° to the calculated test current phase angle. Verify correct operation of the 32QR element for the test voltage and current signals by using Equation 7.2 in the Negative-Sequence Directional Element Test Procedure of this section.

Step 1. Execute the **SHOWSET** command and verify the following relay settings: Z1MAG, Z1ANG, QUADZ, DIR2, XG2, RG2, 50L2, 50G2, k0M, k0A, T, Z2F, and 50QF. The example relay settings use the following settings: Z1MAG = 7.8 Ω; Z1ANG = 83.97°; QUADZ = 3; DIR2 = F; XG2 = 9.36 Ω; RG2 = 5.00 Ω; 50L2 = 0.90; 50G2 = 0.60; k0M = 0.726; k0A = -3.69; T = 0.00; Z2F = 0.77; 50QF = 0.5 A secondary.

Execute the **SET** command and change the following settings. Change GMHOZ to N, QUADZ to 3, XG1 = 6.24, XG2 = 9.36, XG3 = 1.87, RG1 = 2.5, RG2 = 5.0, and RG3 = 6.0. Changing the GMHOZ setting prevents the relay ground mho distance elements from interfering with the test.

Step 2. Select output contacts to indicate operation of the Z2G element. In this example we use the OUT7 output.

From Access Level 2, execute the **SET L n** command to configure Output 7 to close for assertion of the Z2G element.

```
=>>SET L 1 OUT7 <ENTER>
SELogic group 1
OUT7 =NA
? Z2G <ENTER>
OUT8 =32QR
? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. Type **Y <ENTER>** to accept those settings.

Connect output OUT7 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

Step 3. Connect the voltage sources to the A-phase, B-phase, and C-phase-to-neutral relay voltage inputs. Connect the current source to the A-phase relay current input. Refer to the voltage and current connections shown in Figure 7.6 as an example.

Step 4. Select the magnitude of the test signals, I_A and V_A .

Table 7.5 summarizes the test quantities for the Zone 2 A-G ground quadrilateral distance element based upon the example relay settings.

Table 7.5: Test Quantities for Zone 2 Ground Quadrilateral Distance Element: Reactive Reach

Test Voltages	Test Current
$V_A = 40.4 \angle 0^\circ V$	$I_{TEST} = 2.49 \angle -90.0^\circ A$
$V_B = 67.0 \angle -120^\circ V$	
$V_C = 67.0 \angle 120^\circ V$	

The following text describes a hand calculation method you may use to calculate relay distance element voltage and current test signals. If you do not wish to review this information, go to Step 5.

The relay ground distance elements operate based upon the magnitude of applied phase-ground impedance. The impedance calculation is supervised by the functions described. To effectively test the distance elements, select test signals that fulfill the impedance and supervisory requirements of the relay, but are within the ability of the test sources to produce accurately.

The reactive reach of the quadrilateral distance element under test is defined by the XG2 element setting. In this case XG2 = 9.36 secondary Ω . The impedance measured by the relay for a ground fault is determined by the faulted phase voltage, faulted phase current, and the residual current multiplied by the zero-sequence current compensation factor, k0. The SEL-321-5 Relay uses k01M and k01A settings to define the zero-sequence current compensation factor for Zone 1 ground distance elements and the k0M and k0A settings to define that factor for the remaining zones.

The reactance measured by the relay ground quadrilateral distance element for a Zone 2 fault is defined by the following equation:

$$X_{AG} = \frac{\text{Im}(V_A(I_R \cdot 1\angle T^\circ)^*)}{\text{Im}(1\angle Z1ANG(I_A + k0 \cdot I_R)(I_R \cdot 1\angle T^\circ)^*)} \quad \text{Equation 7.17}$$

Where:

$$k0 = k0M \angle k0A^\circ$$

T = Non-homogenous system compensation setting

For a fault on a radial system and when testing a ground distance element using a single current source, $I_A = I_R$. Equation 7.17 can be simplified:

$$X_{AG} = \frac{\text{Im}(V_A(I_A \cdot 1\angle T^\circ)^*)}{\text{Im}(1\angle Z1ANG(1+k0) \cdot I_A \cdot (I_A \cdot 1\angle T^\circ)^*)} \quad \text{Equation 7.18}$$

When $T = 0^\circ$, as it does in the example relay settings, Equation 7.18 can be further simplified using the following identity:

$$X_{AG} = \frac{\text{Im}(V_A(I_A)^*)}{\text{Im}(1\angle Z1ANG \cdot |I_A|^2 \cdot (1+k0))} \quad \text{Equation 7.19}$$

If we select a value for V_A , it then becomes possible to use Equation 7.19 to calculate the magnitude and angle of I_A required to test the Zone 2 ground quadrilateral distance element reactive reach.

For the example, select $V_A = 40.0 \angle 0^\circ$. To simplify the reactance calculation, select the angle of $I_A = -90^\circ$ with respect to V_A . For the Zone 2 element, $XG2 = 9.36 \Omega$, $\angle Z1ANG = 83.97^\circ$, and $k0 = 0.726 \angle -3.69^\circ$.

$$9.36 = \frac{\text{Im}(40.0 \angle 0^\circ \cdot |I_A| \angle -90^\circ)}{|I_A|^2 \cdot \text{Im}(1 \angle 83.97^\circ \cdot (1 + 0.726 \angle -3.69^\circ))}$$

The result of computing the imaginary portion of $V_A \cdot I_A^*$ when I_A lags V_A by 90° is:

$$\text{Im}(V_A \angle 0^\circ \cdot I_A \angle -90^\circ) = |V_A| \cdot |I_A|$$

Substituting this into the equation above yields:

$$9.36 = \frac{40.0 \cdot |I_A|}{|I_A|^2 \cdot (1.71)}$$

Solving for the magnitude of I_A yields:

$$|I_A| = \frac{40.0}{(9.39)(1.71)}$$

$$|I_A| = 2.49A$$

The Zone 2 ground distance element is forward-reaching in the example relay settings. Thus, it is supervised by the forward directional element 32QF, as well as the 50L2 and 50G2 phase and residual overcurrent elements. Applied phase current must exceed the 50L2 setting, applied residual current must exceed the 50G2 setting, and applied 3I2 must exceed the 50QF setting.

The 50L overcurrent elements operate based upon the magnitude of the phase current. Using the current connections shown in Figure 7.6, the magnitude of I_A is equal to the magnitude of the applied test current.

With a 50L2 setting of 0.90 A, 50L2 picks up when I_{TEST} is greater than 0.90 A.

The 50G overcurrent elements operate based upon the magnitude of the residual current. Using the current connections shown in Figure 7.6, the magnitude of I_R is equal to the magnitude of the applied test current.

With a 50G2 setting of 0.60 A, 50G2 picks up when I_{TEST} is greater than 0.60 A.

The 50QF negative-sequence overcurrent element operates based upon the magnitude of 3I2 applied. Using the current connections shown in Figure 7.6, calculate the magnitude of 3I2 applied based upon the magnitude of I_{TEST} .

$$I_2 = \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C)$$

$$3 \cdot I_2 = (I_A + a^2 \cdot I_B + a \cdot I_C)$$

$$I_A = I_{TEST} \text{ and } I_B = I_C = 0, \text{ so:}$$

$$3 \cdot I_2 = I_{TEST}$$

With a 50QF setting of 0.5 A, 50QF picks up when I_{TEST} is greater than 0.5 A.

We calculated $|I_A| = |I_{TEST}| = 2.49$ A, which satisfies the supervisory overcurrent conditions described above.

Select $V_B = 67\angle -120^\circ$ volts and $V_C = 67\angle 120^\circ$ V.

The ground distance elements are supervised by the negative-sequence directional element. Check the negative-sequence quantities applied and verify that the 32QF element should assert. Calculate the magnitude and angle of negative-sequence voltage and current applied for the test quantities listed above. Then calculate the negative-sequence impedance, Z2c, applied using Equation 7.2.

$$V_2 = \frac{1}{3} \cdot (V_A + a^2 \cdot V_B + a \cdot V_C)$$

$$I_2 = \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C)$$

$$Z2 = \frac{\operatorname{Re}[V_2 \cdot (1\angle Z1ANG^\circ \cdot I_2)^*]}{|I_2|^2}$$

$$Z2m = \frac{|V_2|}{|I_2|}$$

$$Z2FT = 1.25 \cdot Z2F - 0.25 \cdot Z2m$$

Taking the test signals from Table 7.5.

$$V_A = 40.4V\angle 0^\circ$$

$$V_B = 67.0V\angle -120^\circ$$

$$V_C = 67.0V\angle 120^\circ$$

$$V_2 = \frac{1}{3} \cdot (40.4\angle 0^\circ + 1\angle 240^\circ \cdot 67.0\angle -120^\circ + 1\angle 120^\circ \cdot 67.0\angle 120^\circ) V$$

$$V_2 = 9.0\angle 180^\circ V$$

$$I_A = 2.49A\angle -90.0^\circ$$

$$I_B = 0.0A\angle 0.0^\circ$$

$$I_C = 0.0A\angle 0.0^\circ$$

$$I_2 = \frac{1}{3} \cdot (2.49\angle -90.0^\circ) A$$

$$I_2 = 0.83\angle -90.0^\circ A$$

Using Equation 7.2 to calculate Z2c, the result is:

$$\begin{aligned}Z2c &= -10.84\Omega \\Z2m &= 10.84\Omega \\Z2FT &= 1.25 \cdot (0.77) - 0.25 \cdot (10.84) \\Z2FT &= -4.46\Omega\end{aligned}$$

The relay example Z2F setting is 0.77Ω . Z2c applied (-10.84Ω) is less than the Z2FT threshold (-4.46Ω), therefore, the 32QF element asserts when these signals are applied. If Z2c applied is greater than the Z2FT setting, select new test current and voltages using the steps outlined above.

- Step 5.** Turn on the voltage sources. Apply V_A , V_B , and V_C at the magnitudes and angles listed in Table 7.5. Turn on the current test source. Set the current angle to -90.0° . Slowly increase the magnitude of current applied until the Z2G element asserts, causing OUT7 to close. This occurs when current applied is approximately 2.49 A .

Note: As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

Ground Quadrilateral Distance Element Resistive Reach Test Using Three Voltage Sources and One Current Source

Note: This test refers directly to the Zone 2 ground quadrilateral distance element, but may be applied to any other forward-reaching ground quadrilateral distance element zone. To test reverse-reaching zones, simply add 180° to the calculated test current phase angle. Verify correct operation of the 32QR element for the test voltage and current signals by using Equation 7.2 in the Negative-Sequence Directional Element Test Procedure.

- Step 1.** Execute the **SHOWSET** command and verify the following relay settings: Z1MAG, Z1ANG, QUADZ, DIR2, XG2, RG2, 50L2, 50G2, k0M, k0A, T, Z2F, and 50QF. The example relay settings use the following settings: Z1MAG = 7.8Ω ; Z1ANG = 83.97° ; QUADZ = 3; DIR2 = F; XG2 = 9.36Ω ; RG2 = 5.00Ω ; 50L2 = 0.90; 50G2 = 0.60; k01M = 0.726; k01A = -3.69; T = 0.00; Z2F = 0.77Ω ; 50QF = 0.5 A secondary.

Execute the **SET** command and change the following settings. Change GMHOZ to N, QUADZ to 3, and ELOP from Y to N. Changing the GMHOZ setting prevents the relay ground mho distance elements from interfering with the test. Changing the ELOP setting prevents the Loss-of-Potential logic from blocking operation of the relay distance elements if the test signals fulfill Loss-of-Potential conditions.

- Step 2.** Select an output contact to indicate operation of the Z2G element. In this example use the OUT7 output.

From Access Level 2, execute the **SET L n** command to configure Output 7 to close for assertion of the Z2G element.

```
=>>SET L 1 OUT7 <ENTER>
SELogic group 1
OUT7 =NA
? Z2G <ENTER>
OUT8 =32QR
? END <ENTER>
```

After you type **END <ENTER>** to end the set procedure, the relay displays the current logic settings. Type **Y <ENTER>** to accept those settings.

Connect output OUT7 to the sense input of your test set, an ohmmeter, or some other contact sensing device.

- Step 3.** Connect the voltage sources to the A-phase, B-phase, and C-phase-to-neutral relay voltage inputs. Connect the current source to the A-phase relay current input. Refer to the voltage and current connections shown in Figure 7.6 as an example.
- Step 4.** Select the magnitude of the test signals, I_A and V_A .

Table 7.6 summarizes the test quantities for the Zone 2 A-G ground quadrilateral distance element based upon the example relay settings.

Table 7.6: Test Quantities for Zone 2 Ground Quadrilateral Distance Element: Resistive Reach

Test Voltages	Test Current
$V_A = 40.0 \angle 0^\circ V$	$I_{TEST} = 8.0 \angle 0.0^\circ A$
$V_B = 67.0 \angle -120^\circ V$	
$V_C = 67.0 \angle 120^\circ V$	

The following text describes a hand calculation method you may use to calculate relay distance element voltage and current test signals. If you do not wish to review this information, go to Step 5.

The relay ground distance elements operate based upon the magnitude of applied phase-ground impedance. The impedance calculation is supervised by the functions described. To effectively test the distance elements, select test signals that fulfill the impedance and supervisory requirements of the relay, but are within the ability of the test sources to produce accurately.

The resistive reach of the quadrilateral distance element under test is defined by the RG2 element setting. In this case RG2 = 5.00 secondary Ω . The impedance measured by the relay for a ground fault is determined by the faulted phase voltage, faulted phase current, and the residual current multiplied by the zero-sequence current compensation factor, k0. The SEL-321-5 Relay uses k01M and k01A settings to define the zero-sequence current compensation factor for all zones.

The reactance measured by the relay ground quadrilateral distance element for a Zone 2 fault is defined by the following equation:

$$R_{AG} = \frac{\text{Im}(V_A((I_A + k0 \cdot I_R) \cdot 1\angle Z1ANG)^*)}{\text{Im}[(\frac{3}{2} \cdot (I_{A2} + I_{A0})) (I_A + k0 \cdot I_R) \cdot 1\angle Z1ANG)^*]} \quad \text{Equation 7.20}$$

Where:

$k0 = k01M \angle k01A^\circ$ for Zone 1, 2, 3, and 4

I_{A2} = negative-sequence current flowing in A-phase for the fault

I_{A0} = zero-sequence current flowing in A-phase for the fault

For a fault on a radial system with no load and when testing a ground distance element using a single current source, $I_A = I_R$, $I_{A2} = I_A/3$, and $I_{A0} = I_A/3$. Equation 7.20 can be simplified:

$$R_{AG} = \frac{\text{Im}(V_A \cdot (I_A \cdot (1 + k0) \cdot 1\angle Z1ANG)^*)}{\text{Im}(I_A \cdot (I_A \cdot (1 + k0) \cdot 1\angle Z1ANG)^*)} \quad \text{Equation 7.21}$$

Select a value for V_A . Then it is possible to use Equation 7.21 to calculate the magnitude and angle of I_A required to test the Zone 2 ground quadrilateral distance element resistive reach.

For the example, select $V_A = 40.0 \angle 0^\circ$. To simplify the resistance calculation, select the angle of $I_A = 0^\circ$. For the Zone 2 element, $RG2 = 5.00 \Omega$, $\angle Z1ANG = 83.97^\circ$, and $k01 = 0.726 \angle -3.69^\circ$.

$$\begin{aligned} 5.00 &= \frac{\text{Im}(40.0 \angle 0^\circ (I_A \cdot (1 + 0.726 \angle -3.69^\circ) \cdot 1\angle 83.97^\circ)^*)}{\text{Im}(I_A \cdot (I_A \cdot (1 + 0.726 \angle -3.69^\circ) \cdot 1\angle 83.97^\circ)^*)} \\ 5.00 &= \frac{\text{Im}(40.0 \angle 0^\circ (I_A \cdot (1.725 \angle -1.55^\circ) \cdot 1\angle 83.97^\circ)^*)}{\text{Im}(I_A \cdot (I_A \cdot (1.725 \angle -1.55^\circ) \cdot 1\angle 83.97^\circ)^*)} \\ 5.00 &= \frac{\text{Im}(40.0 \angle 0^\circ (I_A \cdot (1.725 \angle 82.42^\circ))^*)}{\text{Im}(I_A \cdot (I_A \cdot (1.725 \angle 82.42^\circ))^*)} \end{aligned} \quad \text{Equation 7.22}$$

Because the angle of I_A equals 0° , simplify the equation above:

$$5.00 = \frac{40.0 \cdot |I_A| \cdot \text{Im}(1.725 \angle -82.42^\circ)}{|I_A|^2 \cdot \text{Im}(1.725 \angle -82.42^\circ)}$$

Cancelling the imaginary terms, and rearranging the equation to calculate $|I_A|$ yields:

$$\begin{aligned} |I_A| &= \frac{40.0}{5.0} \\ |I_A| &= 8.0A \end{aligned}$$

The Zone 2 ground distance element is forward-reaching in the example relay settings. Thus, it is supervised by the forward directional element 32QF, as well as the 50L2 and 50G2 phase and residual overcurrent elements. Applied phase current must exceed the 50L2 setting, applied residual current must exceed the 50G2 setting, and applied 3I2 must exceed the 50QF setting.

The 50L overcurrent elements operate based upon the magnitude of the phase current. Using the current connections shown in Figure 7.6, the magnitude of I_A is equal to the magnitude of the applied test current.

With a 50L2 setting of 0.90 A, 50L2 picks up when I_{TEST} is greater than 0.90 A.

The 50G overcurrent elements operate based upon the magnitude of the residual current. Using the current connections shown in Figure 7.6, the magnitude of I_R is equal to the magnitude of the applied test current.

With a 50G2 setting of 0.60 A, 50G2 picks up when I_{TEST} is greater than 0.60 A.

The 50QF negative-sequence overcurrent element operates based upon the magnitude of $3I_2$ applied. Using the current connections shown in Figure 7.6, calculate the magnitude of $3I_2$ applied based upon the magnitude of I_{TEST} .

$$\begin{aligned} I_2 &= \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C) \\ 3 \cdot I_2 &= (I_A + a^2 \cdot I_B + a \cdot I_C) \\ I_A &= I_{TEST} \text{ and } I_B = I_C = 0, \text{ so:} \\ 3 \cdot I_2 &= I_{TEST} \end{aligned}$$

With a 50QF setting of 0.5 A, 50QF picks up when I_{TEST} is greater than 0.5 A.

We calculated $|I_A| = |I_{TEST}| = 8.0$ A, which satisfies the supervisory overcurrent conditions described above.

Select $V_B = 67\angle -120^\circ$ V and $V_C = 67\angle 120^\circ$ V.

The ground distance elements are supervised by the negative-sequence directional element. Check the negative-sequence quantities applied and verify that the 32QF element should assert. Calculate the magnitude and angle of negative-sequence voltage and current applied for the test quantities listed above. Then calculate the negative-sequence impedance, Z2c, applied using Equation 7.2.

$$\begin{aligned} V_2 &= \frac{1}{3} \cdot (V_A + a^2 \cdot V_B + a \cdot V_C) \\ I_2 &= \frac{1}{3} \cdot (I_A + a^2 \cdot I_B + a \cdot I_C) \end{aligned}$$

$$Z2c = \frac{\operatorname{Re}[V_2 \cdot (1\angle Z1ANG^\circ \cdot I_2)^*]}{|I_2|^2}$$

$$Z2m = \frac{|V_2|}{|I_2|}$$

$$Z2FT = 1.25 \cdot Z2F - 0.25 \cdot Z2m$$

Taking the test signals from Table 7.6.

$$\begin{aligned} V_A &= 40.0V\angle 0^\circ \\ V_B &= 67.0V\angle -120^\circ \\ V_C &= 67.0V\angle 120^\circ \end{aligned}$$

$$\begin{aligned}V_2 &= \frac{1}{3} \cdot (40.0\angle 0^\circ + 1\angle 240^\circ \cdot 67.0\angle -120^\circ + 1\angle 120^\circ \cdot 67.0\angle 120^\circ) V \\V_2 &= 9.0\angle 180^\circ V\end{aligned}$$

$$\begin{aligned}I_A &= 8.0\angle 0.0^\circ \\I_B &= 0.0\angle 0.0^\circ \\I_C &= 0.0\angle 0.0^\circ\end{aligned}$$

$$\begin{aligned}I_2 &= \frac{1}{3} \cdot (8.0\angle 0.0^\circ) A \\I_2 &= 2.67\angle 0.0^\circ A\end{aligned}$$

Using Equation 7.2 to calculate Z2c, the result is:

$$\begin{aligned}Z2c &= -3.37\Omega \\Z2m &= 3.37\Omega \\Z2FT &= 1.25 \cdot (0.77) - 0.25 \cdot (3.37) \\Z2FT &= 0.12\Omega\end{aligned}$$

The relay example Z2F setting is 0.77Ω . Z2c applied (-3.37Ω) is less than the Z2FT threshold (0.12Ω), therefore, the 32QF element should assert when these signals are applied. If Z2c applied is greater than the Z2FT threshold, select new test current and voltages using the steps outlined above.

Step 5. Turn on the voltage sources. Apply V_A , V_B , and V_C at the magnitudes and angles listed in Table 7.6. Turn on the current test source. Set the current angle to 0.0° . Slowly increase the magnitude of current applied until the Z2G element asserts, causing OUT7 to close. This occurs when current applied is approximately 8.0 A.

Note: As you perform this test, other protection elements may assert, causing the relay to close other output contacts and assert relay targets. This is normal and is not a cause for concern.

TROUBLESHOOTING TEST RESULTS

The following information is intended to help you troubleshoot relay tests if the relay does not perform as you expected.

<u>Symptom:</u>	<u>What to check:</u>
Incorrect Targets	<ul style="list-style-type: none"> Check the relay event report. Determine the asserted elements at the instant the TRIP output was asserted. Verify the ac connections by plotting currents and voltages from event report data. Verify the MTU, MTCS, and MTO settings to ensure the appropriate elements are enabled to trip. Verify the TULO setting. If a trip occurs and does not unlatch following clearance of the fault, new faults do not generate new targets. You may need to turn off ac current applied to the relay, deassert 52A inputs, assert the External Trip Unlatch Input, (EXTUL), or press the Target Reset button.

<u>Symptom:</u>	<u>What to check:</u>
Incorrect Tripping	<ul style="list-style-type: none"> Check the current and voltage connections by applying small signals to the connected current and voltage inputs. Trigger an event report by using the TRIGGER command. Plot the magnitude and angle of measured currents and voltages. Check the MTU, MTCS, and MTO settings to determine which elements are enabled to trip. Check the output logic equation settings to determine which outputs are enabled to trip. Check the settings of elements that are enabled to trip. Check the settings of elements that supervise elements that are enabled to trip.
Incorrect Distance Element Characteristic Shape	<ul style="list-style-type: none"> Check the voltage and current connections by applying small signals to the connected current and voltage inputs. Trigger an event report by using the TRIGGER command. Plot the magnitude and angle of measured currents and voltages. Verify the distance element settings, including Zone 1 Extension logic settings. Verify the supervisory overcurrent element settings that apply to the element under test: 50PP overcurrent elements supervise the phase distance elements; 50G and 50L overcurrent elements supervise the ground mho and quadrilateral distance elements. Verify the negative-sequence directional element settings. 32QF supervises forward-reaching phase and ground distance elements. 32QR supervises reverse-reaching phase and ground distance elements. Verify the Loss-of-Potential (LOP) logic and element settings. If ELOP = Y, the relay blocks operation of the distance elements when LOP conditions are detected. LOP conditions are defined by the 50M, 59QL, 59PL, 50QF, and 50QR settings. The relay Single- and Three-Pole Open logic functions block certain phase and ground distance elements when those conditions are detected. Verify the 3POD and SPOD time delay settings and review event report data to determine if these functions are interfering with your test. The Load-Encroachment function blocks operation of the relay phase distance elements if measured positive-sequence impedance is within a defined load characteristic. Verify your Load-Encroachment logic settings and review event report data to determine if this function is interfering with your phase distance element test.

<u>Symptom:</u>	<u>What to check:</u>
Incorrect Contact Operation	<ul style="list-style-type: none"> • Check the logic equation settings to determine which elements are enabled to operate the contact. • Check the event report to determine which elements asserted during the event. • Check the connections and test signals to ensure that the appropriate signals were applied to cause the element under test to assert.

RELAY TROUBLESHOOTING

Inspection Procedure

Complete the following procedure before disturbing the system. After you finish the inspection, proceed to the Troubleshooting Procedure.

- Step 1.** Measure and record the power supply voltage at the power input terminals.
- Step 2.** Check to see that the power is on. Do not turn the relay off.
- Step 3.** Measure and record the voltage at all control inputs.
- Step 4.** Measure and record the state of all output relays.

Troubleshooting Procedure

All Front-Panel LEDs Dark

1. Relay power switch is in “OFF” position.
2. Input power not present.
3. Blown fuse.
4. Self-test failure.

Cannot See Characters on Relay LCD Screen

1. Front-panel connector cable is unhooked.
2. Relay is de-energized or turned off.
3. LCD contrast is out of adjustment. Use the steps below to adjust the contrast.

Press the **TARGET RESET** button to perform an LED lamp test. During the lamp test, the relay illuminates all 16 front-panel LEDs for about one second. The relay also turns on the LCD backlighting.

Locate the contrast adjust hole in the front panel below the **INST LED**.

Insert a small screwdriver in this hole to adjust the contrast. Turn clockwise to decrease contrast and counter-clockwise to increase contrast.

Relay Does Not Respond to Commands From Device Connected to Serial Port

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. System is processing event record. Wait several seconds.
4. System is attempting to transmit information, but cannot due to handshake line conflict. Check communications cabling.
5. 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. Auxiliary breaker contact inputs improperly wired.
2. Improper Trip Unlatch Logic Setting.
3. Output relay contacts welded closed.

No Prompting Message Issued to Terminal When Turned On

1. Terminal not connected to relay.
2. Terminal improperly connected to relay.
3. Incorrect terminal serial communications protocol (baud rate, parity, stop elements).
4. Main board failure.

System Does Not Respond to Faults

1. Relay improperly set.
2. Improper test source settings.
3. PT or CT input cable wiring error.
4. Analog input cable between transformer secondary and main board loose or defective.
5. Failed relay self-test.

Terminal Displays Meaningless Characters

1. Serial communications protocol (baud rate, parity, stop elements) set incorrectly.

RELAY CALIBRATION

The SEL-321-5 Relay is factory calibrated to a very high degree of accuracy. If you suspect that the relay is out of calibration, contact the factory. We can provide instructions for returning the relay for factory recalibration.

FIRMWARE UPGRADES

SEL may occasionally offer firmware upgrades to improve the performance of your relay.

The modifications require that you turn off the relay, remove its front panel, pull out the drawout unit, exchange the drawout unit with a new board sent from SEL, and reassemble the relay. The detailed instructions to perform the modifications are included with the firmware upgrade kit sent to the customer. If you do not wish to perform the modifications yourself, we can assist you. Simply return the relay to us. We will install the new board and return the unit to you within a few days.

TECHNICAL SUPPORT

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

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2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

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APPENDIX A: FIRMWARE VERSIONS IN THIS MANUAL

This manual covers SEL relays that contain firmware bearing the following part numbers and revision numbers (most recent firmware listed at top):

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

FID=SEL-321-5-R951-V516124pb-D960409

For a detailed explanation of the FID refer to *Section 4: Event Reporting*.

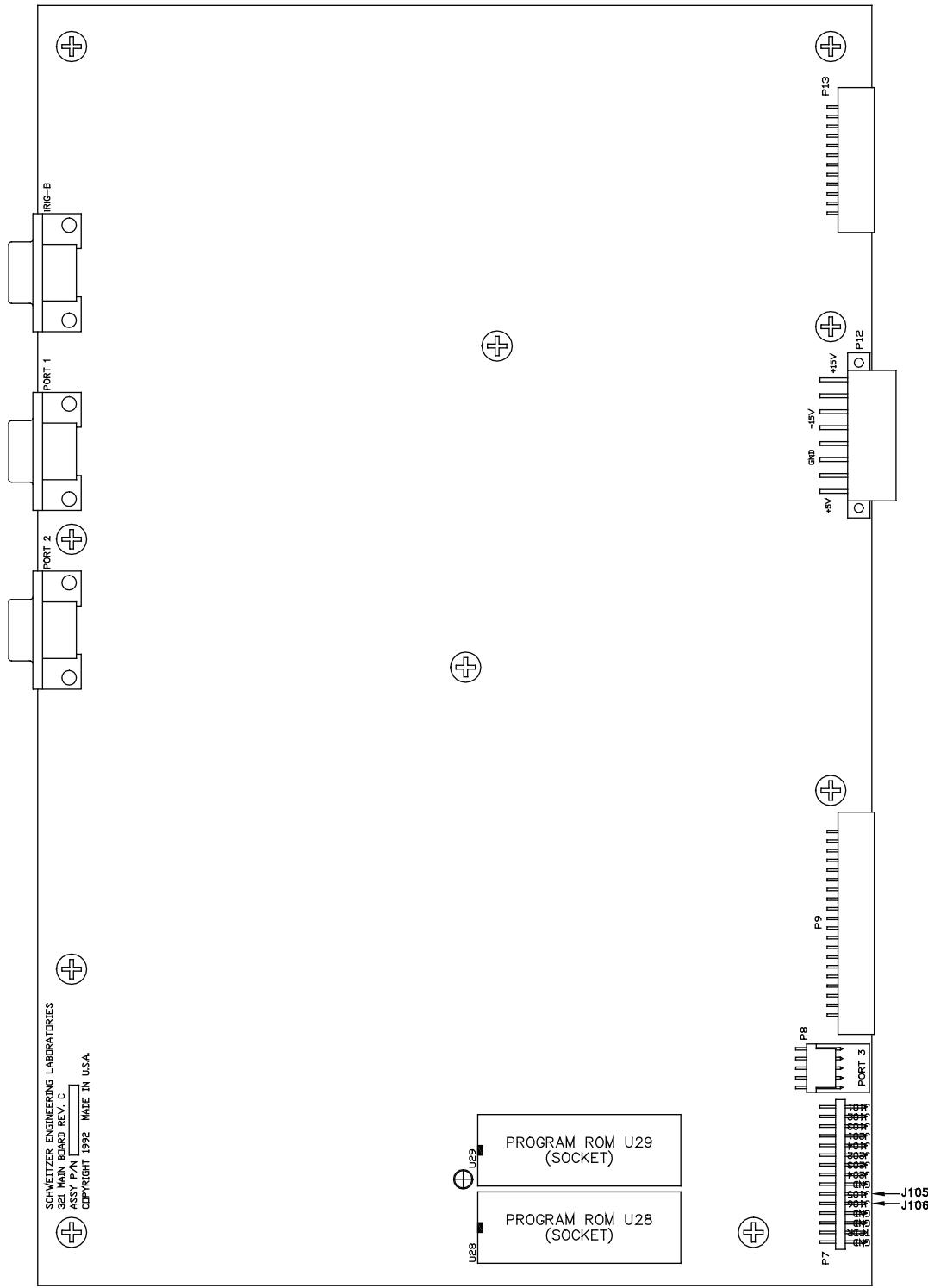
Firmware Part/Revision No.	SEL-321-5 Relay Base Version Description of Firmware
	Revision B and C Main Board and Low-Level Test Capability (ET3 or TT3):
SEL-321-5-R854-990415	- Added MIRRORED BITS™ protocol MB8. MB8 has two stop bits. - Prevent inadvertent cancellation of <i>Fast Operate</i> by a <i>Fast Meter</i> response. 50 Hz, 1 Amp, 1 I/O Board, ABC Rotation
SEL-321-5-R454-990415	50 Hz, 5 Amp, 1 I/O Board, ABC Rotation
SEL-321-5-R959-990415	50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation
SEL-321-5-R557-990415	50 Hz, 5 Amp, 2 I/O Boards, ABC Rotation
	This firmware differs from previous versions as follows: - Improved diagnostics. 50 Hz, 1 Amp, 1 I/O Board, ABC Rotation
SEL-321-5-R852-980806	50 Hz, 5 Amp, 1 I/O Board, ABC Rotation
SEL-321-5-R452-980806	50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation
SEL-321-5-R957-980806	50 Hz, 5 Amp, 2 I/O Boards, ABC Rotation
	This firmware differs from previous versions as follows: - Correct problem where relay incorrectly processed SELOGIC® control equations. 50 Hz, 1 Amp, 1 I/O Board, ABC Rotation
SEL-321-5-R851-980710	50 Hz, 5 Amp, 1 I/O Board, ABC Rotation
SEL-321-5-R451-980710	50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation
SEL-321-5-R956-980710	50 Hz, 5 Amp, 2 I/O Boards, ABC Rotation
SEL-321-5-R554-980710	50 Hz, 1 Amp, 1 I/O Board, ABC Rotation

Firmware Part/Revision No.	SEL-321-5 Relay Base Version Description of Firmware
	<p>Revision B and C Main Board and Low-Level Test Capability (ET3 or TT3):</p> <ul style="list-style-type: none"> - Include support of 8 output I/O board. - Does not check validity of hidden settings. - Adequately checks for event report being overwritten. - STFAIL bit cleared if no alarm conditions. - Fast Operate requests have higher priority than ASCII and do not affect time-out. - Added ERESTART setting. - New MIRRORED BITS protocol. - 51P, Remote-End-Just-Opened logic, and Pole Discordance logic removed. - Added single I/O board configuration. <p>50 Hz, 1 Amp, 1 I/O Board, ABC Rotation 50 Hz, 5 Amp, 1 I/O Board, ABC Rotation 50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation 50 Hz, 5 Amp, 2 I/O Boards, ABC Rotation</p>
SEL-321-5-R850-980605 SEL-321-5-R450-980605 SEL-321-5-R955-980605 SEL-321-5-R553-980605	
SEL-321-5-R954 SEL-321-5-R552	<ul style="list-style-type: none"> - Phase selection enable logic improvements. - Weak-infeed Echo Conversion to Trip improvements for 3-phase fault tripping. - Switch onto fault trip indication extension logic (3PSOTF). - Added separate trip duration timers for single-pole and three-pole weak infeed trips. - Added fault type indicators. - Changed power-up sequence such EN LED remains dark until relay is fully enabled. - Limited settings for PLAF, NLAF, PLAR, and NLAR to 900 sectors. <p>50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation 50 Hz, 5 Amp, 2 I/O Boards, ABC Rotation</p>

Firmware Part/Revision No.	SEL-321-5 Relay Base Version Description of Firmware
SEL-321-5-R953	<p>Revision B and C Main Board and Low-Level Test Capability (ET3 or TT3):</p> <ul style="list-style-type: none"> - Removed problem where entering an invalid command with several parameters (i.e., EVE 1 U M BAD), followed by SHOW L OUTn, where n is 12 - 15 or 29 - 32 could result in a vector halt. - Removed problem where powering up the relay with a port PROTOCOL setting set to R6 caused the default settings to be loaded. <p>50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation</p>
SEL-321-5-R952	<ul style="list-style-type: none"> - Relay-to-Relay integral communications-assisted protection security enhancement. <p>50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation</p>
SEL-321-5-R951	<p>Initial SEL-321-5 Relay Production Release:</p> <p>50 Hz, 1 Amp, 2 I/O Boards, ABC Rotation</p>

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APPENDIX B: SEL-321-5 MAIN BOARD JUMPER, CONNECTOR, AND SOCKET LOCATIONS



DWG: M0010

Figure B.1: SEL-321-5 Main Board Jumper, Connector, and Socket Locations

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APPENDIX C: APPLICATION GUIDELINES

This section contains the following application guides:

AG93-03 REJO Application Guidelines

AG93-10 SEL-321 Relay Load-Encroachment Function Setting Guideline

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REJO Application Guidelines

Jeff Roberts

When applied to the correct system, the Remote-End-Just-Opened (REJO) feature provides secure and reliable, pilotless-accelerated tripping times. Pilotless means without a communications channel. Do not apply this feature without performing prechecks to ensure its suitability for the intended application. This application guide outlines the prechecks required for applying the REJO feature found in the SEL-321, SEL-221F, and SEL-221-16 Relays.

REJO logic provides accelerated tripping for all unbalanced faults on the transmission line. This accelerated tripping is derived from the local terminal as it first identifies the remote terminal breaker opening. A fault is believed to be in-section if the remote breaker opens concurrently with the assertion of the local overreaching protective relay elements. Therefore, if the remote breaker opens, use this knowledge to give tripping permission to the local overreaching protective elements.

The following three conditions represent the criteria for establishing a REJO condition. All these criteria must be met before the relay declares a REJO condition:

Condition 1: Three-phase load current is established prior to the remote terminal breaker opening. The relay must first know the remote breaker is closed before it can detect its opening. The loss of three-phase current flow at the local terminal is a fundamental indicator that the remote terminal breaker opened.

The three-phase load condition is declared when all three phase currents exceed the threshold set for overcurrent elements used by the REJO logic. This condition is “memorized” for 2 cycles by an Instantaneous-Pickup/Time Delayed Dropout (TDDO) timer. The TDDO timer is a security feature that limits the time available for declaring a REJO condition.

Condition 2: At least one phase current must exceed the REJO current detector after the remote breaker opens. This differentiates between the remote breaker opening due to an internal unbalanced fault and normal opening to interrupt load current. In order for the REJO logic to operate, this condition must occur before the TDDO timer referred to in Condition 1 expires.

Condition 3: Conditions 1 and 2 are true for $\frac{1}{2}$ cycle. This condition is a safeguard against erroneous REJO declarations when the breaker on the next line section does not open its poles simultaneously.

When considering applying REJO to a system, scrutinize each of the following points:



INTERMEDIATE TAPPED LOAD

Is there a tapped load between the local terminal and the remote terminal? Recall, from Condition 1, that REJO logic requires the loss of three-phase current to detect the remote breaker opening. A tapped load can prevent the required dropout of REJO current detectors for faults past the tap. To avoid this, set the REJO fault detectors below the magnitude of three-phase current flow when both line terminal breakers are closed, but above the magnitude of three-phase load current drawn by the tapped load.

If you cannot set the REJO fault detector to satisfy these conditions, do not apply REJO to this particular application.

DISSIMILAR SOURCE IMPEDANCE RATIOS

Examine your fault study for conditions other than remote breaker opening that may establish REJO conditions. The concern here is that REJO logic may allow the local breaker to trip for faults outside the protected line section. You need only evaluate unbalanced faults that are detectable by the overreaching elements masked into the MPT logic mask.

Out-of-Section Fault Establishing REJO

The following describes the mechanism that forces the current magnitude in one phase below the REJO fault detector threshold. Four remote A-phase-to-ground fault cases are evaluated for the system shown in Figure 1. In each case, the fault is placed at the remote bus without fault resistance.

In actual practice, you should evaluate faults on the next adjoining line sections. For simplicity, however, these faults are placed at the remote bus:

1. Radial (remote terminal breaker open)
2. Two-terminal system with no load flow ($\delta = 0^\circ$)
3. Two-terminal system with load flow out ($\delta = +4.5^\circ$)
4. Two-terminal system with load flow in ($\delta = -4.5^\circ$)
(δ is the angular difference between Sources S and R)

The system shown in Figure 1 has the following source and line impedances:

<u>Source S</u>	<u>Line</u>	<u>Source R</u>
$ZS1 = 3.09 \angle 69.2^\circ$	$ZL1 = 1.95 \angle 81.2^\circ$	$ZR1 = 1.99 \angle 72.5^\circ$
$ZS0 = 3.09 \angle 69.2^\circ$	$ZL0 = 6.04 \angle 73.1^\circ$	$ZR0 = 5.73 \angle 77.9^\circ$

Where:

- $ZS1$ = Positive-sequence impedance of Source S
 $ZL1$ = Positive-sequence impedance of the transmission line
 $ZR1$ = Positive-sequence impedance of Source R
 $ZS0$ = Zero-sequence impedance of Source S
 $ZL0$ = Zero-sequence impedance of the transmission line
 $ZR0$ = Zero-sequence impedance of Source R

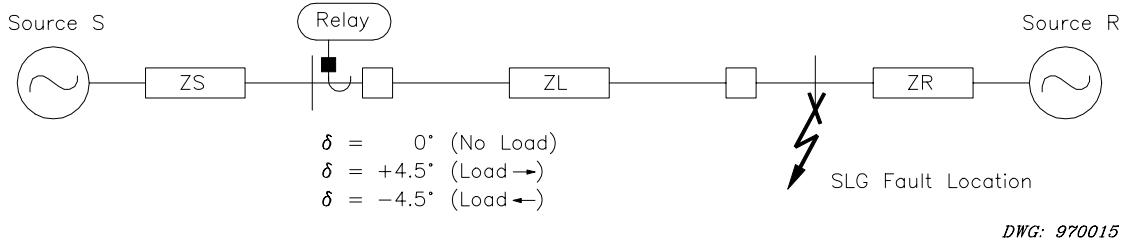


Figure 1: Two Terminal Single-Line Diagram

Figure 2 illustrates the positive-, negative-, and zero-sequence network connections for a single-line-ground (SLG) fault at the remote bus.

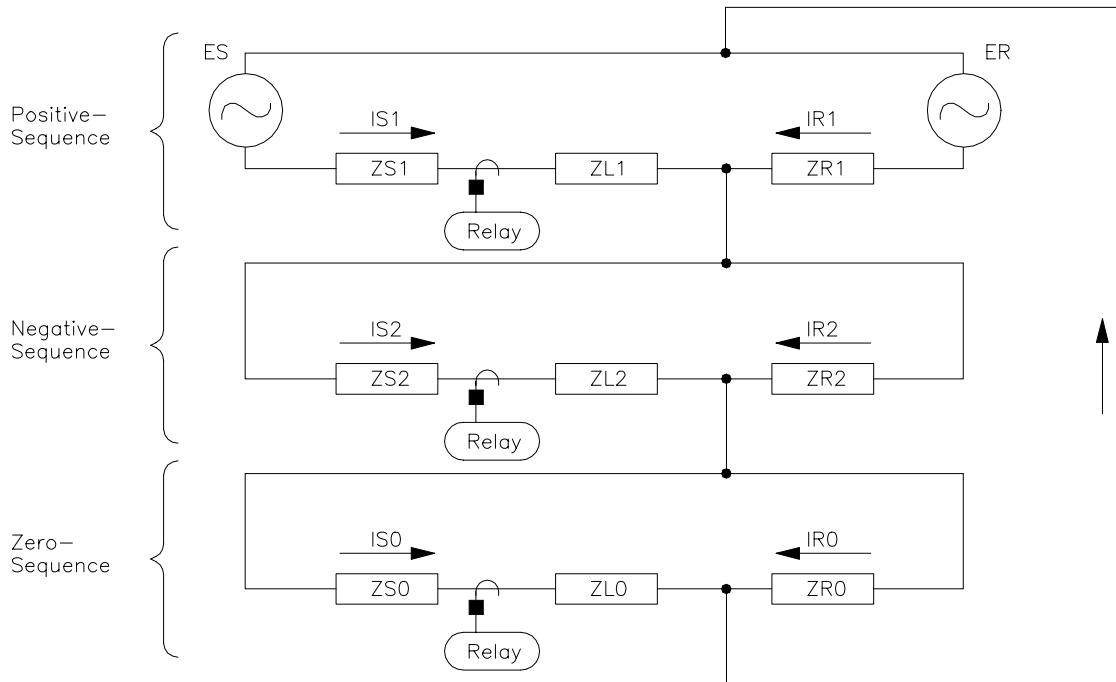


Figure 2: Sequence Network for Remote Ground Fault

The following case studies apply to the system established in Figure 1 and Figure 2.

Case 1: Radial Configuration (Remote Breaker Open)

For Case 1, Source R is infinite and contributes no current to the fault. This case is included to contrast single and multiple source sequence current distribution for the remote A-phase-to-ground fault. The following currents are presented to the relay for the remote A-phase-to-ground fault.

$$IS_1 = 3.66 \text{ A} \angle -73.11^\circ$$

$$IS_2 = 3.66 \text{ A} \angle -73.11^\circ$$

$$IS_0 = 3.66 \text{ A} \angle -73.11^\circ$$

Notice that all three sequence currents are in phase. This is due to the series connection of the networks with no sources of fault current except Source S.

From these sequence currents, determine each of the phase currents, given the following equations:

$$\begin{aligned} I_a &= IS1 + IS2 + IS0 \\ &= 3.66 A \angle -73.11^\circ + 3.66 A \angle -73.11^\circ + 3.66 A \angle -73.11^\circ \\ &= 10.98 \angle -73.11^\circ \end{aligned}$$

$$\begin{aligned} I_b &= a^2 \cdot IS1 + a \cdot IS2 + IS0 \\ &= 3.66 A \angle 166.89^\circ + 3.66 A \angle 46.89^\circ + 3.66 A \angle -73.11^\circ \\ &= 0 \end{aligned}$$

$$\begin{aligned} I_c &= a \cdot IS1 + a^2 \cdot IS2 + IS0 \\ &= 3.66 A \angle 46.89^\circ + 3.66 A \angle 166.89^\circ + 3.66 A \angle -73.11^\circ \\ &= 0 \end{aligned}$$

From this you can see that no current is present in the two noninvolved phases.

Case 2: Two-Terminal Configuration (No Load, $\delta = 0^\circ$)

For this case, the following currents are presented to the relay at Bus S for the remote A-phase-to-ground fault with Sources S and R contributing current to the fault.

$$\begin{aligned} IS1 &= 3.12 A \angle -75.42^\circ \\ IS2 &= 3.12 A \angle -75.41^\circ \\ IS0 &= 3.12 A \angle -71.04^\circ \end{aligned}$$

From these sequence currents, determine each of the phase currents, given the following equations:

$$\begin{aligned} I_a &= IS1 + IS2 + IS0 \\ &= 3.12 A \angle -7.41^\circ + 3.12 A \angle -75.41^\circ + 4.25 A \angle -71.04^\circ \\ &= 10.48 \angle -73.64^\circ \end{aligned}$$

$$\begin{aligned} I_b &= a^2 \cdot IS1 + a \cdot IS2 + IS0 \\ &= 3.12 A \angle 164.59^\circ + 3.12 A \angle 44.59^\circ + 4.25 A \angle -71.04^\circ \\ &= 1.16 \angle -59.25^\circ \end{aligned}$$

$$\begin{aligned} I_c &= a \cdot IS1 + a^2 \cdot IS2 + IS0 \\ &= 3.12 A \angle 44.59^\circ + 3.12 A \angle 164.59^\circ + 4.25 A \angle -71.04^\circ \\ &= 1.16 \angle -59.25^\circ \end{aligned}$$

The B-phase and C-phase have current present even though these phases are not involved with the fault. Also notice that the zero-sequence current (IS0) magnitude is greater than the positive- and negative-sequence currents, IS1 and IS2, respectively. This current unbalance is due to the unequal distribution of total fault current through the networks. The ZR1 and ZR2 ($1.99 \angle 72.5^\circ$) impedances are much less than $[ZS1 + ZL1]$ and $[ZS2 + ZL2]$ ($5.01 \angle 73.84^\circ$) impedances, respectively. This causes the majority of positive- and negative-sequence current to flow through ZR1 and ZR2. However, the zero-sequence impedance magnitudes of $[ZS0 + ZL0]$ (9.13

$\angle 71.78^\circ$ and $ZR0 (5.73 \angle 77.9^\circ)$ are much closer. This results in the magnitude of zero-sequence current flowing through $[ZS0 + ZL0]$ being greater than the current flowing through $[ZS1 + ZL1]$ or $[ZS2 + ZL2]$. Hence, the unequal sequence current distribution causes current to flow in B-phase and C-phase.

This unequal distribution of sequence current does not adversely affect the REJO logic because the relay sees a current increase in the two noninvolved phases. However, the next two cases illustrate how load does cause a difficulty for the REJO logic when applied to this same system.

Case 3: Two-Terminal Configuration (Load Out, $\delta = +4.5^\circ$)

For this case, load current is flowing from Bus S toward Bus R. The prefault load current magnitude is 0.78A.

The following currents are presented to the relay for the remote A-phase-to-ground fault.

$$\begin{aligned} IS1 &= 3.18 \text{ A} \angle -59.88^\circ \\ IS2 &= 3.12 \text{ A} \angle -74.13^\circ \\ IS0 &= 4.25 \text{ A} \angle -69.76^\circ \end{aligned}$$

From these sequence currents, determine each of the phase currents, given the following equations:

$$\begin{aligned} I_a &= IS1 + IS2 + IS0 \\ &= 3.18 \text{ A} \angle -59.88^\circ + 3.12 \text{ A} \angle -74.13^\circ + 4.25 \text{ A} \angle -69.76^\circ \\ &= 10.50 \angle -68.08^\circ \end{aligned}$$

$$\begin{aligned} I_b &= a^2 \cdot IS1 + a \cdot IS2 + IS0 \\ &= 3.18 \text{ A} \angle 180.12^\circ + 3.12 \text{ A} \angle 45.87^\circ + 4.25 \text{ A} \angle -69.76^\circ \\ &= 1.81 \angle -75.23^\circ \end{aligned}$$

$$\begin{aligned} I_c &= a \cdot IS1 + a^2 \cdot IS2 + IS0 \\ &= 3.18 \text{ A} \angle 60.12^\circ + 3.12 \text{ A} \angle 165.87^\circ + 4.25 \text{ A} \angle -69.76^\circ \\ &= 0.47 \angle -86.47^\circ \end{aligned}$$

For this fault, $*I_b*$ increases; more importantly, $*I_c*$ decreases. This decrease in I_c is attributable to load flow out and the effect on the $IS1$ current angle ($IS2$ and $IS0$ are not appreciably affected by load current flow in either direction). With $*I_c* = 0.47\text{A}$, the REJO current detector for C-phase drops out. The dropout of this phase current detector for an out-of-section fault satisfies Condition 1 described earlier. Condition 2 is satisfied by either A-phase or B-phase REJO current detectors. If the fault is truly out-of-section, the likelihood of Condition 3 being satisfied is very high, as the remote breaker cannot operate in less than $\frac{1}{2}$ cycle.

Therefore, if an overreaching protective element in the MPT logic mask or MTCS SELOGIC[®] Control Equation is asserted, the relay would trip by the incorrect REJO declaration.

Case 4: Two-Terminal Configuration (Load In, $\delta = -4.5^\circ$)

For this case, load current is flowing into Bus S from Bus R. The prefault load current magnitude is again 0.78A.

The following currents are presented to the relay for the remote A-phase-to-ground fault.

$$\begin{aligned}IS1 &= 3.23 \text{ A} \angle -90.73^\circ \\IS2 &= 3.12 \text{ A} \angle -76.69^\circ \\IS0 &= 4.25 \text{ A} \angle -72.32^\circ\end{aligned}$$

From these sequence currents, determine each of the phase currents, given the following equations:

$$\begin{aligned}I_a &= IS1 + IS2 + IS0 \\&= 3.23 \text{ A} \angle -90.73^\circ + 3.12 \text{ A} \angle -76.69^\circ + 4.25 \text{ A} \angle -72.32^\circ \\&= 10.50 \angle -79.20^\circ\end{aligned}$$

$$\begin{aligned}I_b &= a^2 \cdot IS1 + a \cdot IS2 + IS0 \\&= 3.23 \text{ A} \angle 149.27^\circ + 3.12 \text{ A} \angle 43.31^\circ + 4.25 \text{ A} \angle -72.32^\circ \\&= 0.83 \angle -18.24^\circ\end{aligned}$$

$$\begin{aligned}I_c &= a \cdot IS1 + a^2 \cdot IS2 + IS0 \\&= 3.23 \text{ A} \angle 29.27^\circ + 3.12 \text{ A} \angle 163.31^\circ + 4.25 \text{ A} \angle -72.32^\circ \\&= 1.93 \angle -54.57^\circ\end{aligned}$$

Notice for this fault $*I_c*$ increases, but $*I_b*$ decreases. This decrease in I_b is again attributable to load flow.

DISSIMILAR SOURCE RATIO GUIDELINE

If the current in one phase drops below the desired REJO fault detector level for an out-of-section fault prior to any breaker opening, do not apply REJO.

You may identify this type of system from your fault study even if your fault study does not model load. Model an out-of-section ground fault, which is detectable by the overreaching elements set in the MPT logic mask or MTCS SELLOGIC Control Equation. For this fault, if you notice appreciable current in the two noninvolved phases, consider the effects of load current by superimposing prefault current onto the fault current magnitudes. If the superposition results in one phase dropping below the desired REJO current threshold, do not apply REJO to this application.

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The SEL-321 Relay Load-Encroachment Function Setting Guidelines

John Kumm

INTRODUCTION

The SEL-321 Phase and Ground Distance Relay includes a Load-Encroachment function designed to prevent long reaching phase distance elements from tripping under heavy load conditions. The Load-Encroachment settings define an acceptable load region in the impedance plane. If the Load-Encroachment function is enabled, the relay blocks the three-phase distance elements when measured positive-sequence impedance is within the user-defined load region. Should a three-phase fault occur, the measured impedance quickly traverses out of the load region, allowing the relay to trip.

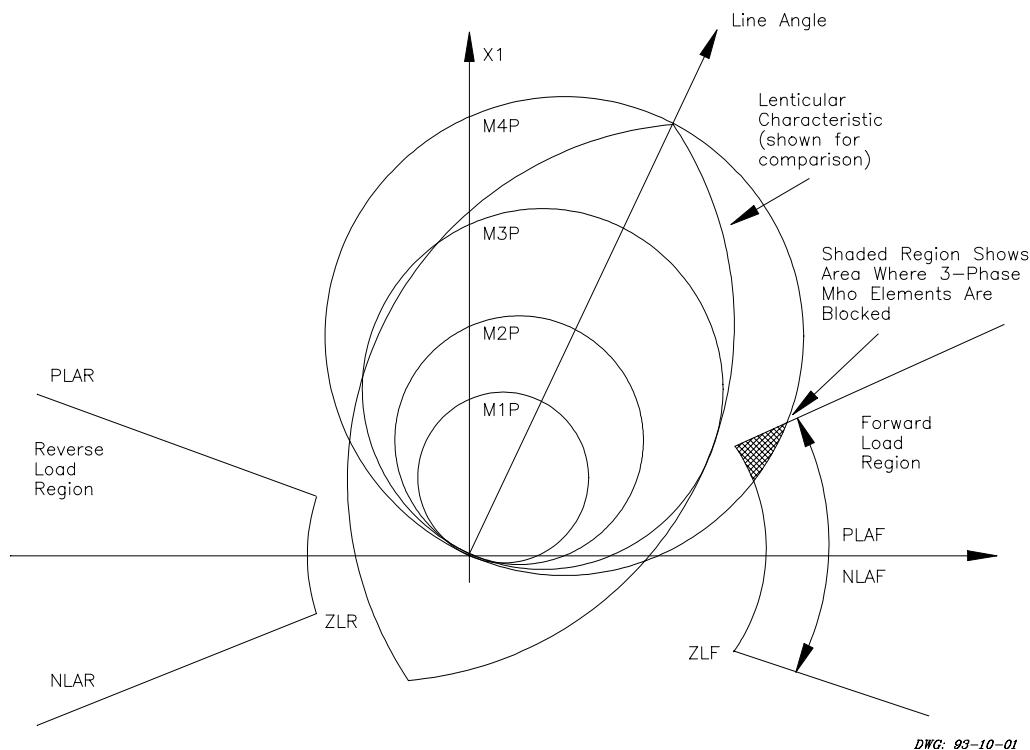


Figure 1 SEL-321 Load-Encroachment Characteristic

THE LOAD PROBLEM

The apparent impedance of transmission line load usually lies along the resistive axis of the impedance plane. As the load power factor decreases, the apparent impedance moves away from the resistive axis. Under heavy load and low power factor conditions, the load impedance may

actually move into the characteristic of an overreaching three-phase distance element. The distance relay trips improperly if the load impedance remains inside the distance element characteristic for longer than the element time delay.

A BETTER LOAD-ENCROACHMENT SOLUTION

In the past, a reduced phase distance element reach would be used to prevent the relay from tripping under high load conditions. Occasionally, modified distance element characteristics with restricted resistive reaches, such as the Lenticular Characteristic, would be used. This element allowed the required reach along the transmission line positive-sequence impedance angle. Both of these methods reduced the impedance plane area covered by the distance element.

The old setting criteria and modified detection methods attempted to avoid the load region. The SEL-321 allows you to define an acceptable load region and set your phase distance protection to protect the line.

The relay calculates the positive-sequence voltage (V_1) and current (I_1) from the measured phase quantities. It then calculates the magnitude and phase angle of the positive-sequence impedance (Z_1). If the measured positive-sequence impedance lies within either defined load region, the relay blocks the three-phase distance elements. Since load is largely a balanced condition, the positive-sequence impedance is a good load measure.

This function allows you to make phase distance element reach settings disregarding load. The load region rejects a minimal portion of the mho distance characteristic, as shown in Figure 1. Relay operation for phase-phase faults is not affected by the Load-Encroachment function.

Figure 2 shows the relay logic used by the Load-Encroachment function. When the Load-Encroachment function is enabled, the relay blocks operation of the three-phase distance elements when ZLOAD asserts.

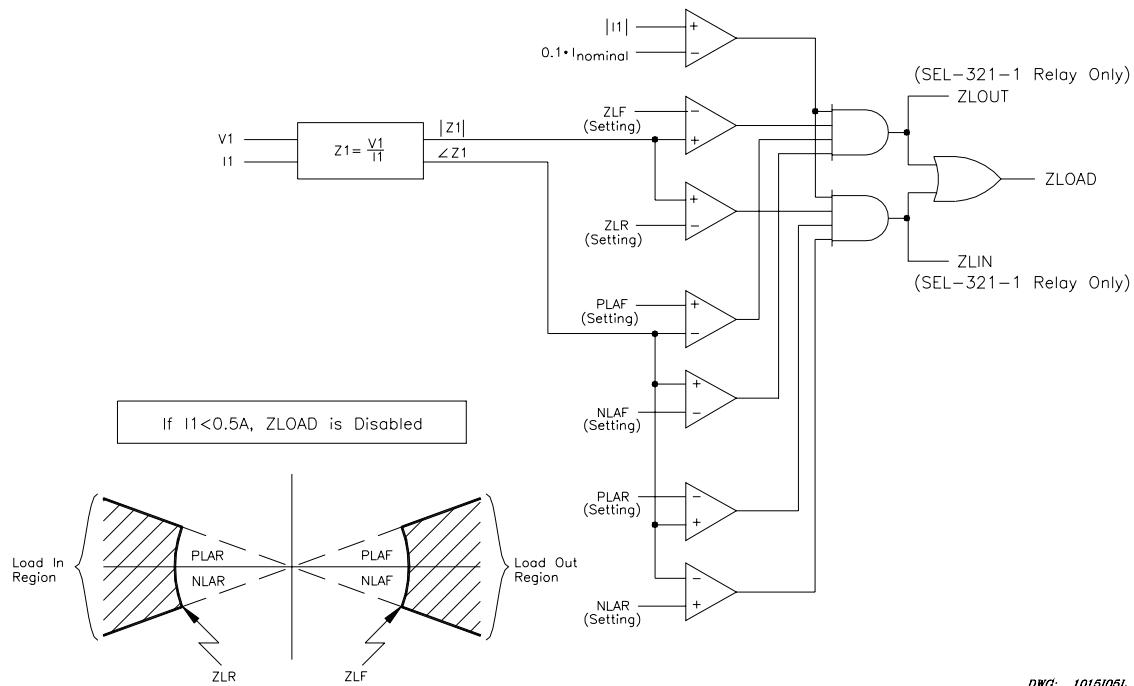


Figure 2 SEL-321 Load-Encroachment Logic

SETTING THE SEL-321 LOAD-ENCROACHMENT FUNCTION

The following settings define the SEL-321 Load-Encroachment function:

ELE	Enable Load Encroachment (Y/N)
ZLF	Forward Minimum Load Impedance [0.05–64 ohms sec]
ZLR	Reverse Minimum Load Impedance [0.05–64 ohms sec]
PLAF	Maximum Positive Load Angle Forward [+90° to –90°]
NLAF	Maximum Negative Load Angle Forward [+90° to –90°]
PLAR	Maximum Positive Load Angle Reverse [+90° to +270°]
NLAR	Maximum Negative Load Angle Reverse [+90° to +270°]

To enable the Load-Encroachment function, set ELE = Y. The remaining Load-Encroachment settings define the impedance plane boundaries of the load regions. The calculations to determine the Load-Encroachment element settings require the following information:

MVA _f	Forward Maximum Line Loading [MVA]
kV _f	Minimum Bus Line-Line Voltage, maximum forward load [kV]
MVA _r	Reverse Maximum Line Loading [MVA]
kV _r	Minimum Bus Line-Line Voltage, maximum reverse load [kV]
PF _f	Forward Minimum Power Factor
PF _r	Reverse Minimum Power Factor
CTR	Relay CT Ratio to 1 (for example, 1200:5 yields 240:1)
PTR	Relay PT Ratio to 1

Calculate the Load-Encroachment settings using the equations below.

$$ZLF = 0.9 \cdot \frac{kV_f^2 \cdot CTR}{MVA_f \cdot PTR} \text{ ohms secondary} \quad (1)$$

$$ZLR = 0.9 \cdot \frac{kV_r^2 \cdot CTR}{MVA_r \cdot PTR} \text{ ohms secondary} \quad (2)$$

Using a 0.9 multiplier in these equations provides a 10% margin between the minimum expected load impedance and the Load-Encroachment boundaries. To provide more margin, decrease this number.

$$PLAF = \arccos(PF_f) \text{ degrees} \quad (3)$$

$$NLAF = -\arccos(PF_f) \text{ degrees} \quad (4)$$

$$PLAR = 180^\circ - \arccos(PF_r) \text{ degrees} \quad (5)$$

$$NLAR = 180^\circ + \arccos(PF_r) \text{ degrees} \quad (6)$$

A LOAD-ENCROACHMENT SETTING EXAMPLE

Table 1 describes an example line where the Load-Encroachment function allows a longer over-reaching phase distance element setting.

Table 1 Example 230 kV Line Characteristics

Nominal Line Voltage	230 kV
Minimum Line Voltage	220 kV
Line Length	150 miles
Line Positive-Sequence Impedance, Z1L	50.4 \angle 85.3° ohms, primary
Maximum Line Loading	800 MVA (2000 amps, primary)
Minimum Power Factor	0.85
CT Ratio to 1	400
PT Ratio to 1	2000

Assuming 800 MVA is the maximum load in both the forward and reverse directions, we can use (1) to calculate the ZLF and ZLR relay settings.

$$ZLF = 0.9 \cdot \frac{220^2 \cdot 400}{800 \cdot 2000} \text{ ohms secondary}$$

$$ZLF = 10.89 \text{ ohms secondary}$$

Use (3), (4), (5), and (6) to calculate the load angle settings, assuming the absolute minimum power factor is 0.85.

$$\arccos \cdot (0.85) = 31.8^\circ$$

$$PLAF = 31.8^\circ$$

$$NLAF = -31.8^\circ$$

$$PLAR = 180^\circ - 31.8^\circ = 148.2^\circ$$

$$NLAR = 180^\circ + 31.8^\circ = 211.8^\circ$$

Table 2 summarizes the Load-Encroachment settings for the example line.

Table 2 Example Load-Encroachment Settings

ELE	Y
ZLF	10.89 Ω
ZLR	10.89 Ω
PLAF	31.8°
NLAF	-31.8°
PLAR	148.2°
NLAR	211.8°

Was the Load-Encroachment logic beneficial in this application? We used (7) to determine the maximum safe phase distance element reach setting if Load-Encroachment is not used.

$$Z21\% = \frac{ZLF \cdot PTR}{\cos(\angle Z1L - PLAF) \cdot |Z1L| \cdot CTR} \cdot 100\% \quad (7)$$

$$Z21\% = 182\%$$

Equation 7 shows that the maximum acceptable distance element reach setting along the line positive-sequence impedance angle would be 182% if Load-Encroachment logic were not used. When Load-Encroachment logic is enabled, we can select more useful Zone 2 and Zone 3 settings.

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* A G 9 3 - 1 0 *

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

The BASIC program in this note determines voltages and currents that 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).

<pre> 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 = RO+2*R1: Y = S0+2*S1 170 R3 = R1-RO: 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 </pre>	<pre> 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 </pre>
---	---

APPENDIX E: PC SOFTWARE

OVERVIEW

SEL provides many PC software solutions (applications) that support SEL devices. These software solutions are listed in Table E.1.

Visit selinc.com to obtain the latest versions of the software listed in Table E.1.

Note: PC software is updated more frequently than relay firmware. As a result, the descriptions in this section may differ slightly from the software. Select **Help** in the PC software for information.

Table E.1: SEL Software Solutions

Product Name	Description
SEL Compass®	This application provides an interface for web-based notification of product updates and automatic software updating.
ACSELERATOR QuickSet® SEL-5030 Software	QuickSet is a powerful setting, event analysis, and measurement tool that aids in applying and using the relay. See <i>ACSELERATOR QuickSet SEL-5030 Software Instruction Manual</i> for information about the various QuickSet applications. ^a
ACSELERATOR Architect® SEL-5032 Software	Use this application to design and commission SEL IEDs in IEC 61850 substations, create and map GOOSE messages, utilize predefined reports, create and edit data sets, and read in SCD, ICD, and CID files.
ACSELERATOR TEAM® SEL-5045 Software	The TEAM system provides custom data collection and movement of a wide variety of device information. The system provides tools for device communication, automatic collection of data, and creation of reports, warnings, and alarms. See <i>ACSELERATOR TEAM SEL-5045 Software Instruction Manual</i> for information about the various TEAM applications.
SEL-5601-2 SYNCHROWAVE® Event Software	Converts SEL Compressed ASCII and COMTRADE event report files to oscillography.
Cable Selector SEL-5801 Software	Selects the proper SEL cables for your application.

^a The SEL-321-5 does not support the freeform logic described in the QuickSet instruction manual.

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APPENDIX F: SPECIAL APPLICATION SETTINGS

Some settings have special values to actuate line specific features. These are documented in this appendix.

VALUE OF “S” FOR E51N, E51Q

With typical settings of “Y” or “N”, the time overcurrent accumulation is blocked for a single-pole open (SPO) condition. When E51N is set to “S”, SPO does not block the 51N elements. When E51Q is set to “S”, SPO does not block the 51Q elements.

VALUE OF “N1” OR “Y1” FOR ESPT SETTING

N1 activates special Scheme 1 Trip Logic if the SPTE contact enables single-pole tripping.

Y1 activates special Scheme 1 Trip Logic equations:

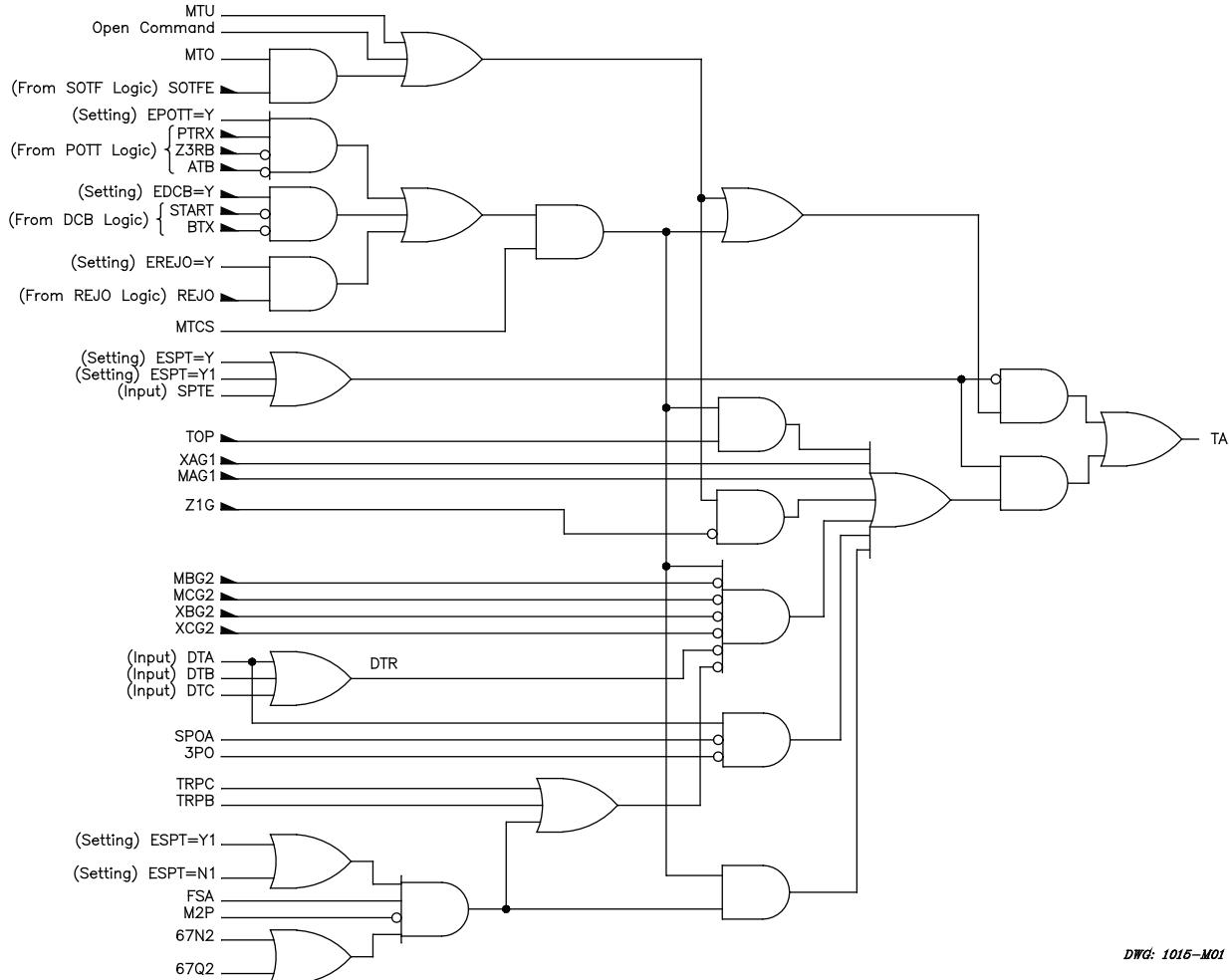


Figure F.1: Scheme 1 Trip Decision Logic for Phase A

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APPENDIX G: ADDITIONAL SEL-321-5 RELAY COMMUNICATIONS PROTOCOLS

This section contains the following application guides:

AG94-03 SEL Distributed Port Switch Protocol (LMD)

*AG95-03 SEL-321-1 Compressed ASCII Commands **

AG95-06 Fast Operate Command Processing

AG95-10 Configuration and Fast Meter Messages

*AG95-11 SEL-321-1/SEL-321-2 Configuration and Fast Meter Messages **

* These application guides apply to the SEL-321-1 Relay and the SEL-321-5 Relay.

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SEL Distributed Port Switch Protocol (LMD)

Tim Tibbals

The SEL Distributed Port Switch Protocol (LMD) enables multiple SEL relays to share a common communications channel. This protocol is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement.

SETTINGS

Use the front panel SET P command to activate the LMD protocol. Change the PROTOCOL port setting from the default SEL to LMD to reveal the following settings:

- ADDRESS:** Two character ASCII address. The range is "01" to "99". The default is "01".
- PREFIX:** One character to precede the address. This should be a character that does not occur in the course of other communications with the relay. Valid choices are one of the following: "@" "#" "\$" "%" "&". The default is "@".
- SETTLE TIME:** Time in seconds that transmission is delayed after the request to send (RTS line) asserts. This delay accommodates transmitters with a slow rise time.

OPERATION

1. The relay ignores all input from this port until it detects the prefix character and the two-byte address.
2. Then, it asserts the RTS line, which you can use to key a serial data transmitter. The relay enables echo and message transmission. If the port had received an XOFF character, the relay performs as if it received an XON. The relay then issues the Access Level 0 prompt.
3. Until the relay connection terminates, you can use the standard commands that are available when PROTOCOL is set to SEL.



4. The QUIT command terminates the connection. If no ASCII (not *Fast Meter* or *Fast Operate*) data are sent to the relay before the port timeup period, it automatically terminates the connection. Receipt of a valid prefix character terminates the connection.
5. Terminating the connection aborts in-progress transmissions.
6. Enter the sequence CTRL-X QUIT <CR> before entering the prefix character if all relays in the multidrop network do not have the same prefix setting.

Note: You can use the front panel SET command to change the port settings to return to SEL protocol.

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SEL-321-1 Relay Compressed ASCII Commands

Tim Tibbals

COMPRESSED ASCII COMMANDS

This application guide describes commands that are not described in *Section 3: Communications* of the SEL-321/321-1 Relay Instruction Manual. These commands allow an external device to obtain data from the SEL-321-1 Relay in a format that directly imports into spreadsheet or database programs and which can be validated with a checksum. The compressed ASCII configuration message can be entered at any command access level. All other compressed ASCII commands can be entered at the command access level indicated in the configuration message.

Commands you type appear in bold/uppercase. In this application guide, ASCII control codes are shown with the following conventions:

- <STX> Start of Transmission Code
- <ETX> End of Transmission Code
- <CR> Carriage Return (Enter) Code

Each compressed ASCII response is formatted as follows:

Leading <STX> Character

One or more lines of printable ASCII characters, each terminated by a comma, the checksum described below, and <CR>.

Four ASCII characters which are the hexadecimal representation of the two-byte binary checksum. The checksum is the sum of the first byte that is not an <STX>, through the comma preceding the checksum.

The <ETX> code.



CASCI

The compressed ASCII configuration message provides data for an external computer to extract data from other compressed ASCII commands. Obtain the configuration message for the compressed ASCII commands available for this relay:

CAS <CR>

The relay sends:

```
<STX>"CAS",10,"01D4" <CR>
"CME",1,"01A2" <CR>
"21H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IA","IB","IC",
"LAB","IBC","ICA","VA","VB","VC","VAB","VBC","VCA","P","Q","1B04" <CR>
"1D","T","I","I","I","I","I","I","I","I","I","I","I","F","F","F",
"F","F","F","F","OFFA" <CR>
"CST",1,"01B7" <CR>
"28H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IA","IB","IC","VA",
"VB","VC","MOF","+5V_PS","+5V_REG",-5V_REG","+12V_REG",-12V_REG",
"+15V_PS",-15V_PS,"TEMP","RAM","ROM","A/D","CR_RAM","EEPROM",
"SETTINGS","30E4" <CR>
"1D","T","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"6S","6S","6S","6S","6S","6S","6S","6S","6S","6S","6S","6S","6S",
"6S","6S","6S","6S","6S","6S","6S","6S","6S","6S","6S","6S","1A61" <CR>
"CHI",1,"01A1" <CR>
"12H","REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","EVENT",
"LOC","GRP","TARGETS","15A1" <CR>
"40D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"45S","0A74" <CR>
"CTA",1,"01A5" <CR>
"8h","6S","6S","6S","6S","6S","6S","6S","6S","08D8" <CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"06AD" <CR>
"CEV",1,"01AB" <CR>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BB9" <CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"05F4" <CR>
"11H","IR","IA","IB","IC","VA","VB","VC","MID","RLY_BITS","OUT","IN","0EDF" <CR>
"44D","I","I","I","I","F","F","F","1S","16S","5S","5S","0A30" <CR>
"CEV L",1,"0217" <CR>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BB9" <CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"05F4" <CR>
"11H","IR","IA","IB","IC","VA","VB","VC","MID","RLY_BITS","OUT","IN","0EDF" <CR>
"176D","I","I","I","I","F","F","F","F","1S","16S","5S","5S","0A66" <CR>
"CEV C",1,"020E <CR>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BB9" <CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"05F4" <CR>
"11H","IR","IA","IB","IC","VA","VB","VC","MID","RLY_BITS","OUT","IN","0EDF" <CR>
"176D","I","I","I","I","F","F","F","F","1S","16S","5S","5S","0A66" <CR>
"CEV M",1,"0218" <CR>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BB9" <CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"05F4" <CR>
"11H","IR","IA","IB","IC","VA","VB","VC","MID","RLY_BITS","TMB","RMB","0F14" <CR>
"44D","I","T","I","I","F","F","F","F","1S","16S","5S","5S","0A30" <CR>
"CEV L M",1,"0284" <CR>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BB9" <CR>
"1D","I","I","I","I","I","I","I","I","I","I","I","I","I","I","I",
"05F4"
```

```

"11H","IR","IA","IB","IC","VA","VB","VC","MID","RLY_BITS","TMB","RMB","0F14"
"176D","I","I","I","F","F","F","1S","16S","5S","5S","0A66"
"CEV C M",1,"027B"
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BB9"
"1D","I","I","I","I","I","I","05F4"
"11H","IR","IA","IB","IC","VA","VB","VC","MID","RLY_BITS","TMB","RMB","0F14"
"176D","I","I","I","F","F","F","1S","16S","5S","5S","0A66"
<ETX>

```

- where **#H** identifies a header line to precede one or more data lines, '#' is the number of subsequent ASCII names. For example, "21H" identifies a header line with 21 ASCII labels.
- #h** identifies a header line to precede one or more data lines, '#' is the number of subsequent format fields. For example, "8h" identifies a header line with 8 format fields.
- #D** identifies a data format line, '#' is the maximum number of subsequent data lines, each format field contains one of the following type designators:
- | | |
|----|--|
| I | Integer data |
| F | Floating point data |
| mS | String of maximum m characters (e.g., 10S for a 10 character string) |

A compressed ASCII command may require multiple header and data configuration lines.

If a compressed ASCII request is made for data that are not available, (e.g., the history buffer is empty or invalid event request), the relay responds with the following message:

<STX>"No Data Available", "0668"<CR><ETX>

CMETER Command

Display meter data in compressed ASCII format by sending:

CME <CR>

The relay sends:

```

<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IA","IB","IC",
"LAB","IBC","ICA","VA","VB","VC","VAB","VBC","VCA","P","Q","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,yyyy" <CR><ETX>

```

- where xxxx are the data values corresponding to the first line labels and
 yyyy is the 4-byte hex ASCII representation of the checksum.

CSTATUS Command

Display status data in compressed ASCII format by sending:

CST <CR>

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","IA","IB","IC","VA",
"VB","VC","MOF","+5V_PS","+5V_REG",-5V_REG","+12V_REG",-12V_REG",
"+15V_PS",-15V_PS","TEMP","RAM","ROM","A/D","CR_RAM","EEPROM",
"SETTINGS","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"xxxx","xxxx","xxxx","xxxx","xxxx",
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx",
"xxxx","xxxx","xxxx","xxxx","xxxx" <CR><ETX>
```

where xxxx are the data values corresponding to the first line labels and
yyyy is the 4-byte hex ASCII representation of the checksum.

CHISTORY Command

Display history data in compressed ASCII format by sending:

CHI <CR>

The relay sends:

```
<STX>"REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC",
"EVENT","LOC","GRP","TARGETS","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"xxxx",xxxx,xxxx,"xxxx",yyyy <CR>
<ETX>
```

(the second line is then repeated for each record)

where xxxx are the data values corresponding to the first line labels and
yyyy is the 4-byte hex ASCII representation of the checksum.

CTARGET Command

Display target data in compressed ASCII format by sending:

CTA n <CR>

where n is one of the target numbers accepted by the TAR command. If n is omitted, 1 is used.

The relay sends:

```
<STX>"lll","lll","lll","lll","lll","lll","lll","lll","yyyy" <CR>
x,x,x,x,x,x,x,"yyyy" <CR><ETX>
```

where lll are the labels for the given target,
x is 0 or 1 corresponding to the first line labels, and
yyyy is the 4-byte hex ASCII representation of the checksum.

CEVENT Command

Display event report in compressed ASCII format by sending:

CEV n m <CR>

where n is the number of the event report, as used in the EVE command; and m is the format selector, as used in the EVE command.

The relay sends:

```
<STX>"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,yyyy" <CR>
"IR","IA","IB","IC","VA","VB","VC,"MID","RLY_BITS","OUT","IN","yyyy" <CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,z,"xxxx","xxxx","xxxx","yyyy" <CR>
<ETX>
```

(the fourth line is then repeated for each record)

where xxxx are the data values corresponding to the first, third, and fifth line labels.

yyyy is the 4-byte hex ASCII representation of the checksum.

z is ">" for mid-fault record and empty for all others.

MID refers to the mid-fault record indication.

RLY_BITS refers to the relay element data.

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SEL APPLICATION GUIDE

Volume II

AG95-06

FAST OPERATE COMMAND PROCESSING

Tim Tibbals

APPLIES TO:

SEL-321-1

OVERVIEW

This Application Guide describes special messages that are not included in the Communications Section of SEL relay instruction manuals. The instruction manuals describe the messages that human operators use to set, control, and extract data. The messages in this Application Guide are used by devices with embedded processing capability to communicate with an SEL relay.

The fast operate message is a binary data stream that an external device uses to perform a trip, close, set remote bit, or clear remote bit operation. The relay accepts binary fast operate messages independent of activity with ASCII commands. For example, when the external device requests an event report with the EVE command, the relay responds with the long event report. If the external device sends a fast operate command while the report is in progress, the relay processes the fast operate command without interrupting the event report.

MESSAGE

Fast Operate Command Transmitted by External Device

The external device sends the following message to perform a fast open/close:

1. 2 bytes Command bytes A5E3 (hexadecimal), outside the range of normal ASCII printable characters
2. 1 byte Message length: 6 bytes
3. 1 byte Operate Code: 31 (hex) for OPEN, 12 (hex) for CLOSE
4. 1 byte Operate Validation: 4  Operate code+1
5. 1 byte Checksum calculated from the addition of all the above bytes.
- 6 bytes Total message length

The external device sends the following message to perform a fast set/clear remote bit:

1. 2 bytes Command bytes A5E0 (hexadecimal), outside the range of normal ASCII printable characters
2. 1 byte Message length: 6 bytes
3. 1 byte Operate Code: 00 - 0F (hex) clear remote bit or 20 - 2F (hex) set remote bit, for RB1 - RB16, respectively
4. 1 byte Operate Validation: $4 \oplus$ Operate code+1
5. 1 byte Checksum calculated from the addition of all the above bytes.
- 6 bytes Total message length

PROCESSING

The relay does not echo the A5, EO, E3, or the subsequent 4 bytes. The relay will perform the operation if all of the following conditions are true:

The operate code is a valid operate code for this relay.

$1 + (\text{Operate Code } \oplus 4)$ = the operate validation.

The Checksum byte equals the calculated checksum.

The FAST_OP port setting is set to Y.

The OPEN/CLOSE command enable jumper is in place for fast open/close operation.

The TDURD setting is not zero for the fast open operation.

The relay is enabled.

For all fast operate commands except CLOSE, there is less than an 8 msec maximum delay from receipt of the checksum until the SEL Relay asserts the coil of an output relay assigned to the associated Relay Word bit. For a fast CLOSE operation, there is less than a 24 msec maximum delay from receipt of the checksum until the SEL Relay asserts the coil of the assigned output relay.

The external device can monitor whether or not the operation takes place by decoding the output bits in an extended fast meter packet. The relay does not send an explicit acknowledgement or feedback message. Tripping the breaker triggers an event report.

COMMUNICATIONS SECURITY

The message contains the operate code and operate validation to incorporate the security of select and configuration steps in one message. The six-byte string contains a unique data pattern for each operation; it is extremely unlikely that this six-byte sequence could be replicated by communications noise.

COMMUNICATIONS SPEED

On serial communications Ports 1 and 2 the relay accepts binary fast operate messages at speeds up to and including 9600 bits per second. On serial communications Port 3 the relay accepts binary fast operate messages at speeds up to and including 4800 bits per second.

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Configuration and Fast Meter Messages

Tim Tibbals and David Wood

OVERVIEW

This application guide describes special messages that are not included in the Communications Section of SEL relay instruction manuals. The instruction manuals describe the messages that human operators use to set, control, and extract data. Devices with embedded processing capability use the messages in this application guide to communicate with an SEL relay. This application guide describes the generic commands and messages for SEL relays that provide configuration messages.

SEL relays have two separate data streams that share the same serial port. The human data communications with the relay consist of ASCII character commands and reports that are intelligible to humans using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

Definition and Configuration

SEL relays designed prior to 1994 utilize a single binary message that matches one of six type definitions. In early 1994, SEL defined messages that provide data to avoid special software development in external devices to accommodate the features of each new product:

- Relay Definition Block: This message includes the protocols supported by the relay and, for each Fast Meter message available from this relay, provides the command to use to retrieve its Fast Meter configuration block. For each bit in a relay status byte that normally indicates action by the external device, this relay definition block includes the message that the device should send when the bit asserts.
- Fast Meter Configuration Block: This message defines the contents of a Fast Meter message. It includes scaling information for each analog channel and the locations in the message to find analog and digital data. For each set of calculations, this message block includes the information to perform the calculation. The ASCII text name for each analog channel is included so the external system can connect an ASCII legend with each analog input.
- Compressed ASCII commands provide the text names for the digital points in a Fast Meter and the name of each datum in the binary short event report. For example, the external system can use these text labels as “tags” in a station digital point display.

Binary Data Stream Acquisition

After the external device retrieves the configuration information, the device can acquire data using Fast Meter request commands. Each response includes the information to calculate instantaneous metering values and a status flag byte. In a typical application, the device requests the regular Fast Meter packet every second to retrieve a snapshot of line quantities. The device checks the status flag byte to determine if a special message sequence is needed. Other messages provide peak or demand metering data.

Binary Data Stream Message List

<u>Request to Relay (Hex)</u>	<u>Response From Relay</u>
A5C0	The relay definition block.
A5C1	A configuration block for regular Fast Meter command if available.
A5C2	A configuration block for demand Fast Meter if available.
A5C3	A configuration block for peak demand Fast Meter if available.
A5CE	A configuration block for Fast Operate if available.
A5CF	Alternate configuration block for Fast Operate if available.
A5DC	One of the old standard Fast Meter blocks if available.
A5DA	One of the old extended Fast Meter blocks if available.
A5D1	Regular Fast Meter defined by configuration block.
A5D2	Demand Fast Meter defined by configuration block.
A5D3	Peak demand Fast Meter defined by configuration block.
A5E0	Fast Operate command for remote bit operation.
A5E3	Fast Operate command for breaker operation.
A5E5	Fast Operate OPEN Command.
A5E6	Fast Operate CLOSE Command.
A5E7	Fast Operate SET Command.
A5E8	Fast Operate CLEAR Command.
A5E9	Fast Operate PULSE Command.
A5B2	Oldest unacknowledged event report packet.
A5B5	Acknowledge event report most recently sent.
A5B9	Clear status bits: power-up, setting change.
A560	Most recent event report packet.
A561–A56C	A561 is previous event report, 6C is 12th oldest event report.
A56D–A59F	Reserved for relays that save up to 64 event reports.

ASCII Data Stream Messages Used for Configuration (see Binary Command Descriptions)

<u>Request to Relay (ASCII)</u>	<u>Response From Relay</u>
ID <CR>	ASCII FID and TRMID Strings. <CR> indicates the carriage return character code.
ENA <CR>	ASCII Names of Short Event Packet Data.
DNA <CR>	ASCII Names of Digital I/O.
BNA <CR>	ASCII Names of Status Bits.

Recommended Message Usage

An external device can support existing and new SEL products by using the following sequence of commands:

1. On initial connection, the device sends the two-byte sequence A5C0 (hexadecimal) to request a definition block. If the relay responds with a definition block, skip to Step 2, below. If the relay does not respond, the device cannot retrieve definition and configuration information using the information in this application guide. In this case, the device sends A5DA to request an old extended Fast Meter command. If the relay does not respond, the device sends A5DC to request an old regular Fast Meter command. If a Fast Meter packet is sent by the relay in response to the A5DA or A5DC command, the device can request and analyze data following the description in the separate application guide for each of the older style Fast Meter commands. If the relay does not send a Fast Meter message in response to A5DC or A5DA, meter information can only be obtained with the ASCII MET command.
2. For each Fast Meter command included in the definition block, the device sends the code to retrieve the corresponding Fast Meter configuration block. The device sends the ENA command to retrieve and store the ASCII names for the short event report data, the DNA command to retrieve and store the ASCII names for the digital I/O points, the BNA command to retrieve status names, and the ID command to get the FID and TRMID strings.
3. Every second, the device sends A5D1 (hex) and in response receives a Fast Meter message from the relay. The device converts, scales, and stores the analog channel data. The device analyzes the status byte using the status flag information from the definition block. The status byte includes a bit that is set if there are any unacknowledged event reports. If this bit is set, the device requests the oldest unacknowledged event report by sending A5B2 (hex). The relay responds with a short event packet. If this packet has a valid checksum, the device acknowledges it by sending A5B5 (hex).

If the Power-Up or Self-Test bits are set, the device requests a STATUS message.

4. The device may use other binary and ASCII commands to support other relay data retrieval and control functions.

BINARY COMMAND DESCRIPTIONS

Definitions Used in Binary Command Descriptions

Length:	Number of total bytes in message (includes command, length).
Checksum:	1 byte arithmetic sum of all bytes in message, starting with the initial command byte and through the last byte preceding the checksum.
Index:	Element number selecting one member of an array. First element is number zero.
Offset:	Number of bytes to add to start of message to calculate address of item in message.

Relay Definition Block

In response to an A5C0 request, the relay sends the following message:

Bytes	Usage	
2	Command A5C0	
1	Length: Number of bytes in message.	
1	The number of protocol(s) supported.	
1	The number of Fast Meter messages supported by the relay.	
1	The number of status flag commands.	
Per Fast Meter command, repeat:		
2	Fast Meter configuration command	
2	Fast Meter command	
Per status flag command, repeat:		
2	Status bit	
6	Command affected by the flag bit	ASCII string including <CR> or binary command string. Pad unused trailing bytes with null (0) bytes.
Per protocol, repeat:		
1	Protocol Specific Data	Usage depends on protocol, below:
1	Protocol Type	0 = SEL standard Protocol data byte is a bit-wise OR of the following: 0x1 if Fast Operate supported; send A5CE to request a Fast Operate configuration block. 0x2 if Fast Message supported; send A546 with function code 0x00 to request a Fast Message configuration block. 1 = SEL Limited Multidrop (LMD) data byte is 0 if no Fast Operate. 0x1 if Fast Operate supported; send A5CE to request a Fast Operate configuration block. 0x2 if Fast Message supported; send A546 with function code 0x00 to request a Fast Message configuration block. 2 = Modbus® data byte always 0. 3 = SY/MAX® data byte always 0. 4 = R SEL relay-to-relay data byte always 0. 5 = DNP3 data byte always 0. 6 = R6 SEL relay-to-relay data byte always 0.
1	Optional pad byte	
1	Checksum	

Fast Meter configuration block commands may be associated with a status flag command. If the given status bit is set, the data associated with the configuration block needs to be updated by requesting a new configuration message.

Event Report Commands

A5B2	Oldest unacknowledged event report packet.
A5B5	Acknowledge event report most recently sent.
A560	Most recent event report.
A561–A59F	Older event reports.

In response to an A5B2 request, the relay sends the following message if there are any unacknowledged event reports:

Bytes	Usage
2	Command (A5B2)
1	Length
1	Active group at time of event report trigger, 0 for relays without multiple groups.
8	Time: byte each for month, day, last 2 digits of year, hour, min, sec, word for ms
8	EVENT as defined in HIS or EVE (ASCII).
Per fault optional variable, repeat (names in order of ENA command after event):	
4	Fault variable value (float)
1	Optional pad byte
1	Checksum

Typically, an external device sends A5B5 to acknowledge this message.

To recover a specific event report, send A560 for the most recent event, A561 for the previous one up to the oldest possible event report, or A59F, whichever is less.

If an A5B2 request is made and there are no unacknowledged event reports, or if A560–A59F are used to request a report that does not exist, all data except command, length, and checksum are 0.

Fast Operate Configuration Block

In response to an A5CE request, the relay sends the configuration block for the Fast Operate message.

Bytes	Usage
2	Command A5CE
1	Length: Number of bytes in message
1	Number of circuit breakers supported
2	Number of remote bits supported
1	Remote bit pulse support: 0 not supported; 1 supported
1	Reserved for future use.
Per Fast Operate breaker command, repeat:	
1	Fast Operate open breaker code
1	Fast Operate close breaker code

Per Fast Operate Remote Bit command, repeat:

- 1 Fast Operate clear remote bit code
- 1 Fast Operate set remote bit code
- 1 Fast Operate pulse remote bit code. (Present only if remote bit pulse supported.)
- 1 Optional pad byte
- 1 Checksum

Fast Operate Command

Fast Operate commands take the following form:

Bytes	Usage
2	Command A5E3 for breaker operation; A5E0 for remote bit operation.
1	Message Length: always 6
1	Operate Code: from Fast Operate configuration block
1	Operate Validation: $(4 \cdot \text{Operate Code}) + 1$
1	Checksum

For a Fast Operate command to succeed, the following must be true:

- Operate Code is valid for relay.
- Operate Validation = $(4 \cdot \text{Operate Code}) + 1$
- Checksum byte is correct.
- Fast Operate commands are enabled in relay settings.
- OPEN/CLOSE command enable jumper installed in relay for fast breaker operations.
- The relay is enabled.

See the relay specific application guide for operation speeds and baud rate limits.

Alternate Fast Operate Configuration Block

Devices with a large number of possible operations use this configuration block. In response to an A5CF request, the device sends the following configuration block for the Fast Operate messages.

Bytes	Usage
2	Command A5CF
1	Length: always 12
1	Number of ports
1	Number of breakers per port
1	Number of remote bits per port
1	Fast Operate open breaker code: E5
1	Fast Operate close breaker code: E6
1	Fast Operate clear remote bit code: E8
1	Fast Operate set remote bit code: E7
1	Fast Operate pulse remote bit code: E9 if supported, 0 if not supported
1	Checksum

Alternate Fast Operate Commands

Fast Operate commands defined in an A5CF configuration block take the following form:

Bytes	Usage
2	Command: A5E5, A5E6, A5E7, A5E8, or A5E9
1	Message length: always 8
2	Operate Code
2	Operate Validation: $(4 \cdot \text{Operate Code}) + 1$
1	Checksum

The conditions for these Fast Operate commands to succeed are the same as for the other Fast Operate commands discussed above.

Fast Meter Configuration Block

In response to an A5C1 request, the relay sends the configuration block for the regular Fast Meter message. The relay sends messages with the same format for demand (A5C2) and peak (A5C3) configuration blocks.

Bytes	Usage	
2	Command (A5C1)	Two-byte hex code
1	Length: Number of bytes in message	If this number is -1, the old format is used, which is a 1-byte type code.
1	Number of status flag bytes	0 = in FM, 1 = in config message. Non-zero if scale factors are in configuration message.
1	Scale factor location	1 = each sample is magnitude.
1	Number of scale factors	2 = imaginary, real components, in that order.
1	Number of analog input channels	4 = 1st, 2nd, 5th, 6th quarter-cycle of data, in that order.
1	Number of samples per channel	
1	Number of digital banks	
1	Number of calculation blocks, below	
2	First analog channel offset	Byte offset from start of Fast Meter message.
2	Time stamp offset	Byte offset from start of Fast Meter message. -1 = no message time stamp. Time format: byte each for month, day, last 2 digits of year, hour, min, sec, word for ms.
2	First digital channel offset	Byte offset from start of Fast Meter message. -1 = no digital channels.

Per analog channel, repeat:		
6	Analog channel name	ASCII characters; pad unused bytes with null (0).
1	Analog channel type	0 = 2-byte integer, 1 = 4-byte IEEE FPS, 2 = 8-byte IEEE FPS, 3 = 8-byte time stamp.
1	Scale factor type	Time format: byte each for month, day, last 2 digits of year, hour, min, sec, word for ms. -1 = no scale factor. 0 = 2-byte integer, 1 = 4-byte IEEE FPS, 2 = 8-byte IEEE FPS, 3 = 8-byte time stamp.
2	Analog channel scale factor offset	Time format: byte each for month, day, last 2 digits of year, hour, min, sec, word for ms. Set to 0 if unused.
Per calculation block, repeat:		
1	Line configuration	Sum of one value from each of the following groups: Group 1—Rotation 0 - ABC rotation 1 - ACB rotation Group 2—Voltage connection 0 - Y-connected 2 - Δ -connected in sequence V_{AB} , V_{BC} , V_{CA} 4 - Δ -connected in sequence V_{AC} , V_{BA} , V_{CB} Group 3—Current connection 0 - Y-connected 8 - Δ -connected in sequence I_{AB} , I_{BC} , I_{CA} 16 - Δ -connected in sequence I_{AC} , I_{BA} , I_{CB} 0 standard power calculations 1 2-1/2 element Δ power calculations 2 voltages only 3 currents only 4 single-phase I_A and V_A only 5 standard power calculations with two sets of currents 6 2-1/2 element Δ power calculations with two sets of currents Scale factor offset to D_{sa} used to deskew calculations. If offset is -1, no skew correction for the calculation (scale factor in 4-byte IEEE FPS). Scale factor offset for R_s (scale factor in 4-byte IEEE FPS).
1	Calculation type	
2	Skew correction offset	
2	R_s offset	

2	X_S offset	Scale factor offset for X_S (scale factor in 4-byte IEEE FPS). If R_S or X_S is -1, no voltage compensation in calculations.
1	I_A index	For calculation types 0, 1, 3, and 4: index of I_A channel from start of analog data record. For calculation types 5 and 6: index of calculation block containing the first set of currents.
1	I_B index	For calculation type 2: unused (FF). For calculation types 0, 1, and 3: index of I_B channel from start of analog data record. For calculation types 5 and 6: index of calculation block containing the second set of currents.
1	I_C index	For calculation types 2 and 4: unused (FF). For calculation types 0, 1, and 3: index of I_C channel from start of analog data record. For calculation types 2, 4, 5, and 6: unused (FF).
1	V_A or V_{AB} index	V_A index (Y) or V_{AB} index (Δ)
1	V_B or V_{BC} index	V_B index (Y) or V_{BC} index (Δ)
1	V_C or V_{CA} index	V_C index (Y) or V_{CA} index (Δ)

If scale factor location is 1, for each scale factor, repeat:

2 or 4 or 8	Scale factor	2 bytes for type 0 4 bytes for type 1 8 bytes for type 2
1	Optional pad byte	
1	Checksum	

Fast Meter Messages

The external device transmits one of the requests shown below. In response, the relay transmits a packet of Fast Meter information. The external device uses the information from the corresponding Fast Meter Configuration Block to interpret each type of Fast Meter message.

Request to <u>Relay (Hex)</u>	Fast Meter Response <u>From Relay</u>	Corresponding Configuration <u>Request (Hex)</u>
A5D1	Regular	A5C1
A5D2	Demand	A5C2
A5D3	Peak	A5C3
A5DC	Old Standard	
A5DA	Old Extended	

Separate application guides document the contents of each Fast Meter response for each relay. Status Flag Bytes are described in the Status Flag Byte(s) section. Scale Factors are located in either the Configuration Message or the Fast Meter Message, as indicated in the scale factor location byte.

Each Fast Meter request causes the relay to send a message with the following format.

Bytes	Usage	
2	Command code (e.g., A5D1 hex)	
1	Length	
N	Status flag bytes as defined in config message.	
1	Optional pad byte	
Defined by Config Block		Area of message defined by configuration block. Within the analog portion, all of the analogs for the first sample will come first (in the order in which they are defined), then for the second sample, and so on through all of the samples.
1	Optional pad byte	
1	Checksum	Includes analog data, time stamp. Can include digital data, scale factors.

Analog Data Example

The analog data block of the Fast Meter message is defined by the number of analog input channels (NUM_CHAN) and number of samples (NUM_SAMPLES) in the configuration block. One common data block has 6 integer analog channels and 4 samples per channel. The data are sent with one row per sample time, of all channels.

12 bytes	Analog meter data: one 12-byte record for each of 4 quarter-cycles: Aqc ₁ : 6 Integers in the order I _A ,I _B ,I _C ,V _A ,V _B ,V _C for first quarter-cycle.
12 bytes	Aqc ₂ : 6 Integers in the order I _A ,I _B ,I _C ,V _A ,V _B ,V _C for second quarter-cycle.
12 bytes	Aqc ₃ : 6 Integers in the order I _A ,I _B ,I _C ,V _A ,V _B ,V _C for fifth quarter-cycle.
12 bytes	Aqc ₄ : 6 Integers in the order I _A ,I _B ,I _C ,V _A ,V _B ,V _C for sixth quarter-cycle.

Status Flag Byte(s) and Clear Status Bits Command

The A5B9 command clears the bits indicated in each example below. These bits are cleared on a port-specific basis; clearing them on one port will not clear them for other ports.

For example, the status byte for the SEL-321 Phase and Ground Distance Relay and the SEL-587 Current Differential Relay includes:

Bit	Usage
0	Power-Up Set on power-up, cleared by clear status bits command message (A5B9).
1	Event Trigger Set by triggering an event, cleared by acknowledging all events.
2	Self-Test Warning Set if self-test warning, clear if all diagnostics passed.
3	Self-Test Failure Set if self-test failure, clear if all diagnostics passed.
4	Group or Setting Changes Set if settings changed, cleared by the clear status bits command message (A5B9).

Analog Channel Scaling

Whenever an external device reads Fast Meter data, it must first scale the received quantities. If there is only one sample per channel, this is simply a matter of multiplying the sample by the scale factor to get the magnitude:

X	Analog channel data
Scale	Analog channel scale factor
Mag(X)	$X \cdot \text{Scale}$

If there is more than one sample per channel, the real and imaginary parts of the data are found by averaging the even and odd samples, respectively, and then scaling:

X _N	Nth sample of analog channel data
----------------	-----------------------------------

$$\text{Re}(X) = \text{Scale} \cdot (X_2 + X_4 + \dots) / (\text{Num Samples}/2)$$

$$\text{Im}(X) = \text{Scale} \cdot (X_1 + X_3 + \dots) / (\text{Num Samples}/2)$$

Whenever a channel is referenced in a calculation block, it may require additional scaling. If there is a deskew angle, use it to correct the angles of the currents as follows:

I _X	One of the current channels referenced in calculation block
----------------	---

I _{Xpre}	Current channel before deskewing
-------------------	----------------------------------

I _{Xpost}	Current channel after deskewing
--------------------	---------------------------------

MTA	Skew correction angle (in degrees); default is 90 degrees
-----	---

$$\text{Re}(I_{Xpost}) = \text{Re}(I_{Xpre}) \cdot \cos(90^\circ - \text{MTA}) - \text{Im}(I_{Xpre}) \cdot \sin(90^\circ - \text{MTA})$$

$$\text{Im}(I_{Xpost}) = \text{Im}(I_{Xpre}) \cdot \cos(90^\circ - \text{MTA}) + \text{Re}(I_{Xpre}) \cdot \sin(90^\circ - \text{MTA})$$

If R_S and X_S scaling is used, any voltages referenced in calculation block must be corrected as follows:

I _X	Current channel
----------------	-----------------

V _X	Corresponding voltage channel
----------------	-------------------------------

V _{xpre}	Voltage channel before correction
-------------------	-----------------------------------

V _{xpost}	Voltage channel after correction
--------------------	----------------------------------

$$\text{Re}(V_{Xpost}) = \text{Re}(V_{Xpre}) - [R_S \cdot \text{Re}(I_{pre}) - X_S \cdot \text{Im}(I_{pre})]$$

$$\text{Im}(V_{Xpost}) = \text{Im}(V_{Xpre}) - [R_S \cdot \text{Im}(I_{pre}) + X_S \cdot \text{Re}(I_{pre})]$$

Note: R_S and X_S scaling will never occur on a delta relay.

When two sets of currents are involved (calculation block types 5 and 6), the currents for each of the three phases must be summed together before being used in subsequent calculations:

$$\text{Re}(I_A) = \text{Re}(I_{A0}) + \text{Re}(I_{A1})$$

$$\text{IM}(I_A) = \text{Im}(I_{A0}) + \text{Im}(I_{A1})$$

$$\text{Re}(I_B) = \text{Re}(I_{B0}) + \text{Re}(I_{B1})$$

$$\text{IM}(I_B) = \text{Im}(I_{B0}) + \text{Im}(I_{B1})$$

$$\text{Re}(I_C) = \text{Re}(I_{C0}) + \text{Re}(I_{C1})$$

$$\text{IM}(I_C) = \text{Im}(I_{C0}) + \text{Im}(I_{C1})$$

To find the magnitude and phase of any of these vectors, simply make the following conversion:

$$\text{Mag}(X) = \sqrt{\{\text{Re}(X)\}^2 + \{\text{Im}(X)\}^2}$$

$$\text{Ang}(X) = \begin{cases} \text{arc tan} [\text{Im}(X)] / [\text{Re}(X)] & \text{Re}\{X\} \geq 0 \\ -\text{arc tan} [\text{Im}(X)] / [\text{Re}(X)] & \text{Re}\{X\} < 0 \end{cases}$$

Phase Estimates From Delta Quantities

If a relay is delta-connected, it is possible to estimate phase quantities from the measured values by assuming the zero-sequence component is 0 ($X_A + X_B + X_C = 0$). If you have delta-connected currents, this will be necessary in order to estimate the power.

$$X_{AB} = -X_{BA} \text{ AB delta quantity}$$

$$X_{BC} = -X_{CB} \text{ BC delta quantity}$$

$$X_{CA} = -X_{AC} \text{ CA delta quantity}$$

$$X_A \quad \text{A-phase estimate}$$

$$X_B \quad \text{B-phase estimate}$$

$$X_C \quad \text{C-phase estimate}$$

$$\text{Re}(X_A) = [\text{Re}(X_{AB}) - \text{Re}(X_{CA})]/3$$

$$\text{Im}(X_A) = [\text{Im}(X_{AB}) - \text{Im}(X_{CA})]/3$$

$$\text{Re}(X_B) = [\text{Re}(X_{BC}) - \text{Re}(X_{AB})]/3$$

$$\text{Im}(X_B) = [\text{Im}(X_{BC}) - \text{Im}(X_{AB})]/3$$

$$\text{Re}(X_C) = [\text{Re}(X_{CA}) - \text{Re}(X_{BC})]/3$$

$$\text{Im}(X_C) = [\text{Im}(X_{CA}) - \text{Im}(X_{BC})]/3$$

Power Calculations

When calculation blocks of types 0, 1, 5, or 6 are present, power can be calculated from the data. The standard power calculation (types 0 and 5) simply involves finding the power in each phase and then summing these powers:

$$I_X \quad \text{Fully scaled current data}$$

$$V_X \quad \text{Fully scaled voltage data}$$

$$P_X \quad \text{Phase real power}$$

$$Q_X \quad \text{Phase reactive power}$$

$$P \quad \text{Total real power}$$

$$Q \quad \text{Total reactive power}$$

$$P_X = \text{Re}(V_X) \text{Re}(I_X) + \text{Im}(V_X) \text{Im}(I_X)$$

$$Q_X = \text{Im}(V_X) \text{Re}(I_X) - \text{Re}(V_X) \text{Im}(I_X)$$

$$P = P_A + P_B + P_C$$

$$Q = Q_A + Q_B + Q_C$$

Delta power calculations (types 1 and 6) cannot be performed on a per channel basis, but the total power can be calculated as follows:

I_0 Zero-sequence current

$$\text{Re}(I_0) = [\text{Re}(I_A) + \text{Re}(I_B) + \text{Re}(I_C)]/3$$

$$\text{Im}(I_0) = [\text{Im}(I_A) + \text{Im}(I_B) + \text{Im}(I_C)]/3$$

$$\begin{aligned} P &= \text{Re}(V_{AB}) \cdot [\text{Re}(I_A) - \text{Re}(I_0)] + \text{Im}(V_{AB}) \cdot [\text{Im}(I_A) - \text{Im}(I_0)] \\ &\quad - \text{Re}(V_{BC}) \cdot [\text{Re}(I_C) - \text{Re}(I_0)] - \text{Im}(V_{BC}) \cdot [\text{Im}(I_C) - \text{Im}(I_0)] \end{aligned}$$

$$\begin{aligned} Q &= \text{Im}(V_{AB}) \cdot [\text{Re}(I_A) - \text{Re}(I_0)] - \text{Re}(V_{AB}) \cdot [\text{Im}(I_A) - \text{Im}(I_0)] \\ &\quad - \text{Im}(V_{BC}) \cdot [\text{Re}(I_C) - \text{Re}(I_0)] + \text{Re}(V_{BC}) \cdot [\text{Im}(I_C) - \text{Im}(I_0)] \end{aligned}$$

Note: If the first voltage difference is V_{AC} instead of V_{AB} , use $-V_{BA}$ for V_{AB} and $-V_{CB}$ for V_{BC} .

Other Calculations

When a calculation block associates channels, these associations can be used to calculate delta quantities from phase quantities and to calculate sequence components. Delta quantities can be found from phase quantities by taking simple differences:

X_X A channel voltage or current

X_Y Another channel voltage or current

X_{XY} The delta quantity between these channels

$$\text{Re}(X_{XY}) = \text{Re}(X_X) - \text{Re}(X_Y)$$

$$\text{Im}(X_{XY}) = \text{Im}(X_X) - \text{Im}(X_Y)$$

The sequence components for an ABC rotation relay are:

$$\text{Re}(X_0) = [\text{Re}(X_A) + \text{Re}(X_B) + \text{Re}(X_C)]/3$$

$$\text{Im}(X_0) = [\text{Im}(X_A) + \text{Im}(X_B) + \text{Im}(X_C)]/3$$

$$\text{Re}(X_1) = \{\text{Re}(X_A) - 1/2 [\text{Re}(X_B) + \text{Re}(X_C)] - \sqrt{3}/2 [\text{Im}(X_B) - \text{Im}(X_C)]\}/3$$

$$\text{Im}(X_1) = \{\text{Im}(X_A) - 1/2 [\text{Im}(X_B) + \text{Im}(X_C)] + \sqrt{3}/2 [\text{Re}(X_B) - \text{Re}(X_C)]\}/3$$

$$\text{Re}(X_2) = \{\text{Re}(X_A) - 1/2 [\text{Re}(X_B) + \text{Re}(X_C)] + \sqrt{3}/2 [\text{Im}(X_B) - \text{Im}(X_C)]\}/3$$

$$\text{Im}(X_2) = \{\text{Im}(X_A) - 1/2 [\text{Im}(X_B) + \text{Im}(X_C)] - \sqrt{3}/2 [\text{Re}(X_B) - \text{Re}(X_C)]\}/3$$

For an ACB relay, the positive-sequence (X_1) and negative-sequence (X_2) component calculations must be reversed.

On a delta-connected relay, the positive- and negative-sequence components can be calculated:

$$\text{Re}(X_1) = [\text{Re}(X_{AB}) + 1/2 \text{Re}(X_{BC}) - \sqrt{3}/2 \text{Im}(X_{BC})]/3$$

$$\text{Im}(X_1) = [\text{Im}(X_{AB}) + 1/2 \text{Im}(X_{BC}) + \sqrt{3}/2 \text{Re}(X_{BC})]/3$$

$$\text{Re}(X_2) = [\text{Re}(X_{AB}) + 1/2 \text{Re}(X_{BC}) + \sqrt{3}/2 \text{Im}(X_{BC})]/3$$

$$\text{Im}(X_2) = [\text{Im}(X_{AB}) + 1/2 \text{Im}(X_{BC}) - \sqrt{3}/2 \text{Re}(X_{BC})]/3$$

For an ACB relay, X_1 and X_2 are reversed. If the first delta connection is X_{AC} instead of X_{AB} , replace X_{AB} with $-X_{BA}$ and X_{BC} with $-X_{CB}$.

ASCII DATA STREAM MESSAGE DESCRIPTIONS

BNA

Obtain the names of the bits in the Fast Meter status flag byte(s) by sending:

BNA <CR>

The relay sends:

<STX> followed by one line for each status flag byte in the Fast Meter data block:
 "xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","yyyy" <CR><ETX>

where:

xxxxx is each name in ASCII. An "*" character indicates an unused bit position. The first name is associated with the MSB and last name with the LSB of each byte.
 yyyy is the 4-byte hex ASCII representation of the checksum.

DNA

Obtain the digital names by sending:

DNA <CR>

The relay sends:

<STX> followed by one line for each bank of eight digital elements:
 "xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","yyyy" <CR><ETX>

where:

xxxxx is each name in ASCII. "*" indicates an unused bit position. The first name is associated with the MSB and last name with the LSB of each bank.
 yyyy is the 4-byte hex ASCII representation of the checksum.

ENA

Retrieve the short event report data names by sending:

ENA <CR>

The relay sends:

<STX> "GROUP","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR>
 "EVENT","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","yyyy" <CR><ETX>

where:

xxxxx are the names that are specific to the relay.
 yyyy is the 4-byte hex ASCII representation of the checksum.

ID

Obtain the Firmware ID string and Terminal ID setting by sending:

ID <CR>

The relay sends:

```
<STX>"FID STRING ENCLOSED IN QUOTES","yyyy" <CR>
"ID SETTING ENCLOSED IN QUOTES","yyyy" <CR>
<ETX>
```

where:

The ID settings line is repeated for relays with multiple ID settings.

yyyy is the 4-byte ASCII hex representation of the checksum for the message.

In some relays, the ID command has a third line, which contains a device code. This code is used by the SEL-2020 Communications Processor to identify the relay to Modbus users. This three-line response format is:

```
<STX>"FID STRING ENCLOSED IN QUOTES","yyyy" <CR>
"ID SETTING ENCLOSED IN QUOTES","yyyy" <CR>
xxxx,"yyyy" <CR>
```

<ETX>

where:

The ID settings line is repeated for relays with multiple ID settings.

yyyy is the 4-byte ASCII hex representation of the checksum for the message.

xxxx is the device code.

FACTORY ASSISTANCE

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* A G 9 5 - 1 0 *



SEL-321-1/SEL-321-2 Configuration and Fast Meter Messages

Tim Tibbals

The companion to this application guide, AG95-10, "Configuration and Fast Meter Messages," describes the commands to retrieve configuration information from SEL relays. This application guide describes the specific message content for the SEL-321-1/SEL-321-2 Relays.

RESPONSE TO THE DEFINITION COMMAND (A5C0) FROM SEL-321-1/SEL-321-2

A5C0	Command
49	Length
03	Support three protocols
01	Support one Fast Meter message
07	Seven status flag commands
A5C1	Fast Meter configuration command
A5D1	Fast Meter command
0001	Event triggered flag bit
A5B200000000	Oldest unacknowledged short event report (hex)
0002	Self-test warning bit
7374610D0000(STA<CR>)	Check status (ASCII characters, <CR>, binary zeros)
0003	Self-test failure bit
7374610D0000(STA<CR>)	Check status (ASCII characters, <CR>, binary zeros)
0004	Setting change bit
A5C100000000	Fast Meter configuration can be affected by settings
0004	Setting change bit
73686F0D0000(SHO<CR>)	Check settings (ASCII characters, <CR>, binary zeros)
0004	Setting change bit
73686F206C0D(SHO L<CR>)	Check logic settings (ASCII characters, <CR>)
0004	Setting change bit
73686F20670D(SHO G<CR>)	Check global settings (ASCII characters, <CR>)
0000	The protocol supported: standard SEL, no Fast Operate
0001	The protocol supported: LMD, no Fast Operate
0004	The protocol supported: R, no Fast Operate
checksum	Checksum



RESPONSE TO THE FAST METER CONFIGURATION COMMAND (A5C1) FROM SEL-321-1/SEL-321-2

A5C1	Fast Meter command
63 (HEX)	Length
01	One status flag byte
01	Scale factors in configuration message
02	Two scale factors
06	Six analog input channels
04	Four samples per channel
1B (HEX)	27 digital banks (if 2 I/O boards, then there are 30 digital banks and the code is 1C)
1	One calculation
0004	Analog channel offset
0034	Time stamp offset
003C	Digital offset
696100000000(ia)	Analog channel name
00 (integer)	Analog channel type. 0 - integer, 1 - float
01 (float)	Scale factor type. 0 - integer, 1 - float
005A (HEX, offset)	Use first scale factor
696200000000(ib)	
00	
01	
005A (HEX, offset)	
696300000000(ic)	
00	
01	
005A (HEX, offset)	
766100000000(va)	
00	
01	
005E (HEX, offset)	Use second scale factor
766200000000(vb)	
00	
01	
005E (HEX, offset)	
766300000000(vc)	
00	
01	
005E (HEX, offset)	
00	Y-connected, ABC rotation (if ACB rotation, will be 01)
00	Standard power calculations
FFFF(-1)	No skew adjustment
FFFF(-1)	
FFFF(-1)	
00	No voltage compensation
01	Channel index I _a
02	I _b
03	I _c
	V _a

04	V_b
05	V_c
scale factor 1 (4 bytes)	
scale factor 2 (4 bytes)	
checksum	

STATUS FLAG BYTE

The status byte for SEL-321 includes:

BIT	USAGE	
0	Power-Up	Set on power-up, cleared by status acknowledge message.
1	Event Trigger	Set if triggering event report, cleared by acknowledging all events.
2	Self-Test Warning	Set if self-test warning, clear if all diagnostics pass.
3	Self-Test Failure	
4	Group or Setting Changes	Set if settings changed, cleared by the status acknowledge message.

RESPONSE TO THE FAST OPERATE CONFIGURATION COMMAND (A5CE) FROM SEL-321-1/SEL-321-2

A5CE	Command
2B	Length
01	Support one circuit breaker
0010	Support 16 remote bits
0000	
31	Operate code, open breaker
12	Operate code, close breaker
00	Operate code, clear remote bit RB1
20	Operate code, set remote bit RB1
01	Operate code, clear remote bit RB2
21	Operate code, set remote bit RB2
02	Operate code, clear remote bit RB3
22	Operate code, set remote bit RB3
03	Operate code, clear remote bit RB4
23	Operate code, set remote bit RB4
04	Operate code, clear remote bit RB5
24	Operate code, set remote bit RB5
05	Operate code, clear remote bit RB6
25	Operate code, set remote bit RB6
06	Operate code, clear remote bit RB7
26	Operate code, set remote bit RB7
07	Operate code, clear remote bit RB8

27	Operate code, set remote bit RB8
08	Operate code, clear remote bit RB9
28	Operate code, set remote bit RB9
09	Operate code, clear remote bit RB10
29	Operate code, set remote bit RB10
0A	Operate code, clear remote bit RB11
2A	Operate code, set remote bit RB11
0B	Operate code, clear remote bit RB12
2B	Operate code, set remote bit RB12
0C	Operate code, clear remote bit RB13
2C	Operate code, set remote bit RB13
0D	Operate code, clear remote bit RB14
2D	Operate code, set remote bit RB14
0E	Operate code, clear remote bit RB15
2E	Operate code, set remote bit RB15
0F	Operate code, clear remote bit RB16
2F	Operate code, set remote bit RB16
checksum	Checksum

RESPONSE TO THE FAST METER REQUEST (A5D1) FROM SEL-321-1/SEL-321-2

1. 2 bytes Command codes A5D1 (hex), outside the range of normal ASCII printable characters.
2. 1 byte Message length, 58 (hex) (if 2 I/O boards, then message length is 5B [hex]).
3. 1 byte 1 Status byte.
4. 48 bytes The first and third half-cycles of two cycles of data saved by the relay. The data are presented in quarter-cycle sets of integer data in the following order: Ia, Ib, Ic, Va, Vb, Vc.
5. 8 bytes Time stamp.
6. 27 bytes The 27 digital banks (target rows 0–19, 26, 27, 40–45). If 2 I/O boards, then 30 bytes (target rows 0–19, 26, 27, 40–48).
7. 1 byte 88 bytes Checksum calculated by addition of all the above bytes. Total message length (if 2 I/O boards, then 91 bytes).

RESPONSE TO THE OLDEST UNACKNOWLEDGED EVENT REPORT REQUEST (A5B2) FROM SEL-321-1/SEL-321-2

1. 2 bytes Command codes A5B2 (hex), outside the range of normal ASCII printable characters.
2. 1 byte Message length, 19 (hex).

- | | | |
|----|---------------------------|---|
| 3. | 1 byte | Active group at time of event report trigger. |
| 4. | 8 bytes | Time: byte each for month, day, last two digits of year, hour, min, sec, word for msec. |
| 5. | 8 bytes | EVENT as defined in HIS or EVE. |
| 6. | 4 bytes | Fault location in floating point format. |
| 7. | <u>1 byte</u>
25 bytes | Checksum calculated by addition of all the above bytes.
Total message length. |

RESPONSE TO THE BNA COMMAND FROM SEL-321-1/SEL-321-2

<STX>"*","*","*", "STSET", "STFAIL", "STWARN", "STEVE", "STPWR", "0C5A"<CR>
<ETX>

RESPONSE TO THE DNA COMMAND FROM SEL-321-1/SEL-321-2

<STX> followed by one line for each bank of eight digital elements:
 "xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","xxxxx","yyyy" <CR>
<ETX>

where xxxx is each name in ASCII. "*" indicates an unused bit position.
 yyyy is the 4-byte hex ASCII representation of the checksum.

RESPONSE TO THE ENA COMMAND FROM SEL-321-1/SEL-321-2

<STX>"GROUP","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0CC7"<CR>
 "EVENT", "LOC", "0340"<CR>
<ETX>

RESPONSE TO THE ID COMMAND FROM SEL-321-1/SEL-321-2

<STX>"FID STRING ENCLOSED IN QUOTES","yyyy" <CR>
 "ID SETTING ENCLOSED IN QUOTES","yyyy" <CR>
 xxxx,"yyyy" <CR>
<ETX>

where yyyy is the 4-byte hex ASCII representation of the checksum for the message.
 xxxx is the device code used by the SEL-2020 to identify the relay to Modbus® users.

FACTORY ASSISTANCE

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APPENDIX H: MIRRORED BITS COMMUNICATIONS

OVERVIEW

MIRRORED BITS® is a direct relay-to-relay digital communications protocol that allows protective relays to exchange information quickly and securely, and with minimal expense. The information exchanged can facilitate remote control, remote sensing, or communications-assisted protection schemes such as POTT, DCB, etc. In this document the bits received are called RMB1 through RMB8. Bits transmitted are called TMB1 through TMB8.

SETTINGS

```
protocol (SEL,LMD,MB,MB8)          PROTOCOL= MB    ?
baud rate (300-9600)              SPEED = 9600    ?
enable hardware handshaking (Y,N,MBT) RTS_CTS= N    ?
Mirrored Bits Receive bad pickup (1- 10000 sec) RBA0PU= 60    ?
Mirrored Bits Channel bad pickup (1- 10000 10E-6) CBADPU= 1000    ?
Mirrored Bits transmit identifier(1 - 4)      TX_ID = 1    ?
Mirrored Bits receive identifier(1 - 4)       RX_ID = 2    ?
Mirrored Bits receive default state (string of 1s, 0s or Xs)
     87654321
RXDFLT=00000X11
?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB1PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB1DO= 1    ?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB2PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB2DO= 1    ?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB3PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB3DO= 1    ?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB4PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB4DO= 1    ?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB5PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB5DO= 1    ?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB6PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB6DO= 1    ?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB7PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB7DO= 1    ?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)   RMB8PU= 1    ?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)   RMB8DO= 1    ?
```

```
protocol (SEL,LMD,MB,MB8)          PROTOCOL= MB    ?
```

Set PROTOCOL = MB or MB8 to enable the MIRRORED BITS protocol.

```
baud rate (300-9600)              SPEED = 9600    ?
```

Use the SPEED setting to control the rate at which the MIRRORED BITS messages are transmitted, in power system cycles. The following table indicates the worst case message per cycle rate.

SPEED	SEL-321-5	SEL-351
9600	1 message per 1/2 cycle	1 message per 1/2 cycle
4800	1 message per 1 cycle	1 message per 1 cycle

```
enable hardware handshaking (Y,N,MBT)      RTS_CTS= N      ?
```

Use the MBT option if you are using a Pulsar MBT 9600 baud modem. With this option set, the relay will transmit a message every 3/8 power system cycle and the relay will deassert the RTS signal on the EIA-232 connector. Also, the relay will monitor the CTS signal on the EIA-232 connector, which the modem will deassert if the channel has too many errors. The modem uses the relay's RTS signal to determine whether the new or old MIRRORED BITS protocol is in use.

```
Mirrored Bits Receive bad pickup (1- 10000 sec)    RBADPU= 60      ?
```

Use the RBADPU setting to determine how long a channel error must last before the relay element RBAD is asserted. RBAD is instantaneously deasserted when the channel error is corrected.

```
Mirrored Bits Channel bad pickup (1- 10000 10E-6)    CBADPU= 1000 ?
```

Use the CBADPU setting to determine the ratio of channel downtime to the total channel time before the relay element CBAD is asserted. The times used in the calculation are those that are available in the COMM records. See the **COMM** command in the SEL-321-5 or SEL-351 manuals for a description of the COMM records.

```
Mirrored Bits transmit identifier (1 - 4)      TX_ID = 1      ?  
Mirrored Bits receive identifier (1 - 4)      RX_ID = 2      ?
```

Set the RX_ID of the local relay to match the TX_ID of the remote relay. For example, in the three-terminal case, where Relay A transmits to Relay B, Relay B transmits to Relay C, and Relay C transmits to Relay A:

Relay	TX_ID	RX_ID
A	1	3
B	2	1
C	3	2

```
Mirrored Bits receive default state (string of 1s, 0s or Xs)  
87654321  
RXDFLT=00000X11  
?
```

Use the RXDFLT setting to determine the default state the MIRRORED BITS should use in place of received data if an error condition is detected. The setting is a mask of 1s, 0s and/or Xs, for RMB1–RMB8, where X represents the most recently received valid value.

Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB1PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB1DO= 1	?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB2PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB2DO= 1	?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB3PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB3DO= 1	?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB4PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB4DO= 1	?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB5PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB5DO= 1	?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB6PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB6DO= 1	?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB7PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB7DO= 1	?
Mirrored Bits RMB_ Debounce PU time (1-8 msgs)	RMB8PU= 1	?
Mirrored Bits RMB_ Debounce DO time (1-8 msgs)	RMB8DO= 1	?

Supervise the transfer of received data (or default data) to RMB1–RMB8 with the MIRRORED BITS pickup and dropout security counters. Set the pickup and dropout counters individually for each bit.

For example, any received MIRRORED BIT that is used for direct transfer tripping should have at least a two received message pickup delay.

OPERATION

Message Transmission

All messages are transmitted without idle bits between characters. Idle bits are allowed between messages.

- At 4800 baud, one message is transmitted each power system cycle.
- At 9600 baud, one message is transmitted each 1/2 power system cycle.

Message Decoding and Integrity Checks

The relay will deassert a relay element bit, ROK for any of the following reasons:

- Relay disabled.
- MIRRORED BITS not enabled.
- Received data parity, framing, or overrun errors.
- Receive data redundancy error.
- Receive message identification error.
- No message received in the time three messages have been sent.

While ROK is not asserted, the relay will:

- Enter the synchronization process described below.
- Prevent new data from being transferred to the pickup/dropout security counters. Instead, the relay will send the default values (RXDFLT) to the security counter inputs:

1
0
The last valid value

The relay will assert ROK only after successful synchronization as described below and two consecutive messages pass all of the checks described above.

The user can combine ROK with other relay bits in SELOGIC® control equations.

After ROK is reasserted, received data may be delayed while passing through the security counters described below.

Transfer of received data to RMB1–RMB8 is supervised by the eight user-programmable pickup/dropout security counters (RMB1PU–RMB8DO) settable from 1 (allow every occurrence to pass) to 8 (require eight consecutive occurrences to pass). The pickup and dropout security count settings are separate.

Note: Pickup/dropout security counters operate identically to pickup/dropout timers, except they are set in counts of received messages instead of time.

Synchronization

When a node detects a communications error, it deasserts ROK and transmits an attention message, which includes its TX_ID setting.

When a node receives an attention message, it checks to see if its own TX_ID is included.

If its own TX_ID is included and at least one other TX_ID is included, the node discards the attention message and transmits data.

If its own TX_ID is not included, the node deasserts ROK, includes its TX_ID in the attention message, and transmits the new attention message.

If its own TX_ID is the only TX_ID included, the node assumes the message is corrupted unless the loop back mode has been enabled. If loop back is not enabled, the node deasserts ROK and transmits the attention message with its TX_ID included. If loop back is enabled, the node discards the attention message and transmits data.

Note: In summary, when a node detects an error, it transmits attention until it receives an attention with its own TX_ID included. If three or four relays are connected in a ring topology, then the attention message will go all the way around the loop, and will eventually be received by the originating node. It will then be discarded, and data transmission will resume. This method of synchronization allows the nodes to reliably determine which character is the first character of the message. It also forces a mis-synchronized relay to become re-synchronized. This method takes down the entire loop for a receive error at any node in the loop, an exchange of availability for security.

Loopback Testing

Physically loopback the MIRRORED BITS communication channel external to the relay. Then use the **LOOP** command to enable loopback testing.

While in loopback mode, ROK is deasserted, and the relay element LBOK will assert and deassert based on the ROK checks listed above.

The **TAR** command, front-panel targets, and/or the **COMM** command may be used to monitor the loopback test.

Refer to the SEL-321-5 or SEL-351 manuals for additional information on these commands.

Channel Monitoring

Based on the results of data checks described above, the relay will collect information regarding the 255 most recent communications errors. Each record will contain at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout (See *Message Decoding and Integrity Checks*)

Use the **COMM** command to generate a long or summary report of the communications errors.

Note: There is only a single record for each outage, but an outage can evolve. For example the initial cause could be a data disagreement, but the outage can be perpetuated by framing errors. If the channel is presently down, the COMM record will only show the initial cause, but the COMM summary will display the present cause of failure.

When the duration of an outage exceeds the setting RBADPU, the relay will assert the relay element, RBAD.

Note: RBAD is typically combined with other alarm conditions using SELOGIC control equations.

When channel unavailability exceeds the setting CBADPU, the relay will assert the relay element, CBAD.

Note: CBAD is typically combined with other alarm conditions using SELOGIC control equations.

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APPENDIX I: SEL-321-5 RELAY FACTORY SETTINGS

At the factory setting access level, special internal settings are used for special applications. SEL recommends that you contact the factory before making any adjustments to the factory settings. A “SHO F” with the default settings is shown below:

```
====>
==>>SHO F <ENTER>
FIDEN1= 0      FIDEN2= 2      LOPDO = 0.00    UBOSBF= 4.00   DEM   = Y
IOBRD1= 16     IOBRD2= 16
FQITVL= 1      FQLPDY= 3      FQVPU = 10      FQDBND= 2      FQADJ = 2
Z1ADJ = 0.75   OP_DEN= 1.00   MBND   = 3.00    Z3XPU = 2      SOTF3D= 10
TDUR3D= 12.00  TDUR1D= 6.00
====>
```

FIDS ENABLE IR/IBETA RATIO ADJUSTMENT

FIDEN1 AND FIDEN2

The FIDS enable (FIDEN) settings are used to adjust the FIDS comparison of IR to the maximum phase-to-phase current. The default of FIDEN1 = 0, FIDEN2 = 2 yields a ratio of .1111 for IR/I_MAX.PP. Other ratios can be obtained by using the settings from Table G.1.

Table I.1: FIDS Enable Settings

FIDEN1 FIDEN2	0	1	2	3	4	5	6	7
0 0.166667	0.090909	0.047619	0.02439	0.012346	0.006211	0.003115	0.00156	
1 0.142857	0.083333	0.045455	0.02381	0.012195	0.006173	0.003106	0.001558	
2 0.111111	0.071429	0.041667	0.022727	0.011905	0.006098	0.003086	0.001553	
3 0.076923	0.055556	0.035714	0.020833	0.011364	0.005952	0.003049	0.001543	
4 0.047619	0.038462	0.027778	0.017857	0.010417	0.005682	0.002976	0.001524	
5 0.027027	0.02381	0.019231	0.013889	0.008929	0.005208	0.002841	0.001488	
6 0.014493	0.013514	0.011905	0.009615	0.006944	0.004464	0.002604	0.00142	
7 0.007519	0.007246	0.006757	0.005952	0.004808	0.003472	0.002232	0.001302	
8 0.003831	0.003759	0.003623	0.003378	0.002976	0.002404	0.001736	0.001116	

LOSS-OF-POTENTIAL DROPOUT DELAY

LOPDO

The LOPDO timer adds a dropout delay on the resetting of a Loss-of-Potential (LOP) condition. Refer to Figure 2.39 in *Section 2: Specifications*.

OUT-OF-STEP ANGLE CHANGE UNBLOCK RATE

UBOSBF

The UBOSBF is a multiplier used to determine the Out-of-Step unblocking delay (UBOSBD) for detection of three-phase faults that occur during an Out-of-Step condition. Refer to Figure 2.20 in *Section 2: Specifications*.

THREE-PHASE DIRECTIONAL AND NEGATIVE-SEQUENCE DIRECTIONAL ELEMENT MATCH

DEM

The DEM enable provides a secondary direction check for the phase distance elements. The added directional check is required when a ground fault that occurs during an Out-of-Step condition.

OUTPUTS ON I/O BOARDS

IOBRD1 and IOBRD2

The number of digital outputs on the first I/O board is specified in IOBRD1. If it is a tall chassis, the number of digital outputs on the second I/O board is specified in IOBRD2. The default for either is 16.

FREQUENCY TRACKING VALUES

Name	Default	Usage
FQITVL	6	Number of PIT ISRs between frequency calculations. One PIT ISR is approximately 15.6 ms.
FQLPDY	3	Number of PIT ISRs delayed after LOP condition clears before frequency adjustment can start.
FQVPU	10	Volts secondary to allow frequency adjustment.
FQDBND	2	Number of TCR1 ticks deadband. Each TCR1 tick is 238 nanoseconds. The frequency is $1/(counts \cdot 238\text{ ns} \cdot 16)$, so at 60 Hz each tick represents approximately 0.02 Hz difference.
FQADJ	2	Number of TCR1 ticks to adjust TCR1 each frequency adjustment.

ZONE 1 ADJUSTMENT

Z1ADJ

Z1ADJ is a scalar adjustment of the Zone 1 reach. The number of security counts for the Zone 1 element is increased when the measure impedance is greater than Z1ADJ*(Zone 1 setting) but less than the Zone 1 setting.

OPEN POLE DIRECTIONAL ELEMENT THRESHOLD

OP_DEN

OP_DEN defines the minimum sensitivity of the open pole directional element.

MULTIPLIER TO BOUND THE DISTANCE ELEMENT SENSITIVITY

MBND

MBND is a multiplier that establishes a maximum threshold for which the distance elements shall operate during the open pole time. The boundary is defined by MBND*Z1L, where Z1L is the positive-sequence impedance setting in the relay.

ZONE 3 REVERSE BLOCKING PICKUP (DIRECTIONAL COMPARISON BLOCKING LOGIC)

Z3XPU

The Z3XPU timer determines the pickup delay for the reverse blocking elements in the Directional Comparison Blocking logic. Refer to Figure 2.34 in *Section 2: Specifications*.

SWITCH-ONTO-FAULT EXTENSION

SOTF3D

The Switch-Onto-Fault Extension timer extends the switch-onto-fault output if the fault occurs near the end of the SOTFD delay. Refer to Figure 2.38 in *Section 2: Specifications*.

THREE-POLE TRIP DURATION EXTENSION TIMER

TDURD3D

The three-pole trip duration extension timer extends the minimum trip duration time when the three-pole trip is generated due to a weak-infeed condition. Refer to Figure 2.50 in *Section 2: Specifications*.

SINGLE-POLE TRIP DURATION EXTENSION TIMER

TDURD1D

The single-pole trip duration extension timer extends the minimum trip duration time when a single-pole trip is generated due to a weak-infeed condition. Refer to Figure 2.50 in **Section 2: Specifications**.

FACTORY SETTING PROCEDURE

Use the **CALIBRATION** command to enter factory setting access, Calibration Access Level. A password is required to access this level. The default password for this level is set to CLARKE at the factory; use the **PASSWORD** command from the Calibration Access Level to change this password.

The following display indicates successful access:

```
=>CALIBRATION <ENTER>
Password: ? CLARKE <ENTER>

EXAMPLE: BUS B, BREAKER 3      Date: 02/01/93      Time: 15:11:14.607
Calibration Access Established
==>>
```

You may use any Level 1, Level 2, or Level B command from the “==>>” prompt. The relay pulses the ALARM contact closed for one second after any Level C access attempt (unless an alarm condition exists).

Use the **SET F** command to access the factory settings.

APPENDIX J:INTERFACE BOARD SPECIFICATIONS

INTRODUCTION

The SEL-321-5 Relay is available with one or two interface boards for application flexibility. The number of inputs, number of outputs, operating speeds, interrupt capabilities, and operation configuration vary depending on the interface boards. This appendix describes the interface boards and shows partial rear-panel diagrams for each.

Note: The interface boards are not interchangeable with each other on a two I/O board relay.

Table J.1: Interface Board Types

Screw Terminal			
I/O Board	Inputs	Outputs	
Interface 1*	8	16	Standard Shared-Terminal
Interface 2**	8	12	Standard Independent
Interface 5	8	8	Fast High Current Interrupting

* Interface Board 1 is listed as option 7 on the SEL-321-5 ordering information sheet.

** Interface Board 2 is listed as option 9 on the SEL-321-5 ordering information sheet.

INTERFACE BOARD 1 (16 OUTPUTS, 8 INPUTS)—SCREW TERMINAL

Optoisolated Inputs

All eight control inputs are dry optoisolated inputs and are not polarity-dependent. The nominal rated control voltage of 24, 48, 125, or 250 Vdc must be specified when ordering. To assert an input, apply control voltage to the terminals assigned to that input. Each input is individually isolated, and a terminal pair is brought out for each input. There are no internal connections between inputs. The inputs will assert within 2 ms and draw approximately 4 mA of current at nominal voltage. For further information, see **General Specifications** in **Section 2**.

Output Contacts

30 A make

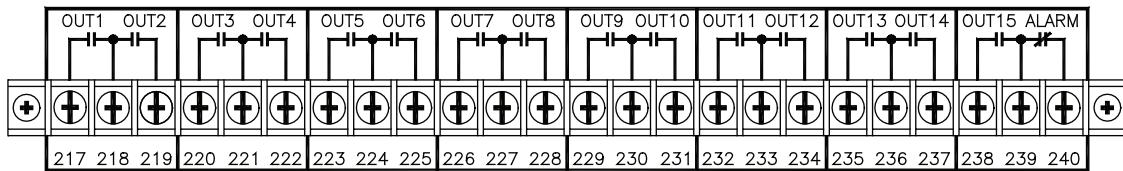
6 A carry

Not rated for interrupting duty

Closing (pickup for “a” contacts, dropout for “b” contacts): 1/4-cycle or less

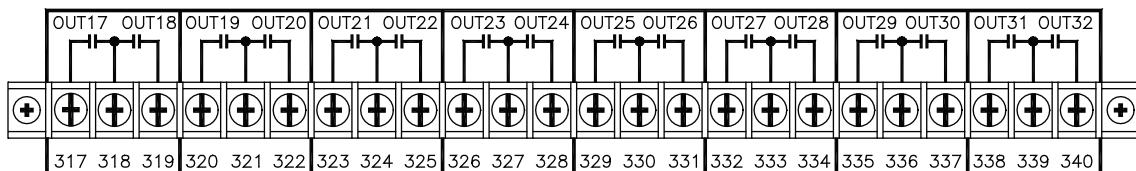
Opening (dropout for “a” contacts, pickup for “b” contacts): 1/4-cycle or less

Interface board 1 provides 16 contact outputs. These 16 **standard** dry output contacts **share** a common terminal for each pair of contacts, but are not polarity-dependent. The rear of the relay will be similar to the following figures:



DWG: M0011

Figure J.1: Interface Board 1 Output Contacts (Board Position 1)



DWG: M0012

Figure J.2: Interface Board 1 Output Contacts (Board Position 2)

Configure the output contacts as “a” contacts or “b” contacts with solder jumpers. Figure J.3 shows the locations of the jumpers and explains the jumper positions. Contacts are factory-configured as “a” contacts (except the alarm contact which is “b”).

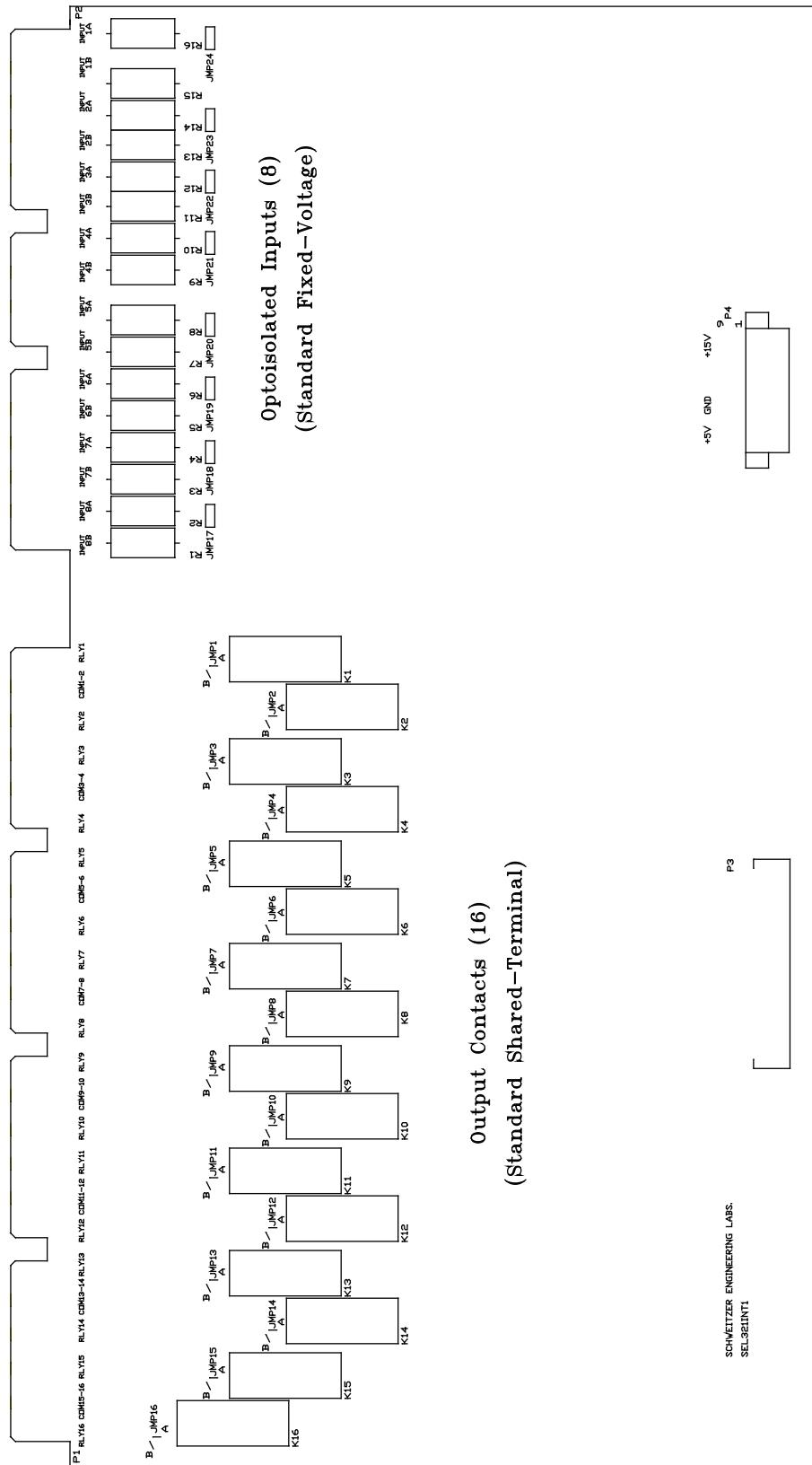


Figure J.3: Interface Board 1 Component Layout (Screw Terminal)

INTERFACE BOARD 2 (12 OUTPUTS, 8 INPUTS)—SCREW TERMINAL

Optoisolated Inputs

All eight control inputs are dry optoisolated inputs, and are not polarity-dependent. The nominal rated control voltage of 24, 48, 125, or 250 Vdc must be specified when ordering. To assert an input, apply control voltage to the terminals assigned to that input. Each input is individually isolated, and a terminal pair is brought out for each input. There are no internal connections between inputs. The inputs will assert within 2 ms and draw approximately 4 mA of current at nominal voltage. For further information, see **General Specifications** in **Section 2**.

Output Contacts

30 A make

6 A carry

Not rated for interrupting duty

Closing (pickup for “a” contacts, dropout for “b” contacts): 1/4-cycle or less

Opening (dropout for “a” contacts, pickup for “b” contacts): 1/4-cycle or less

Interface board 2 provides 12 output contacts. These 12 **standard** dry output contacts have **independent** terminals for each pair of contacts and are not polarity-dependent. The rear of the relay will be similar to the following figures:

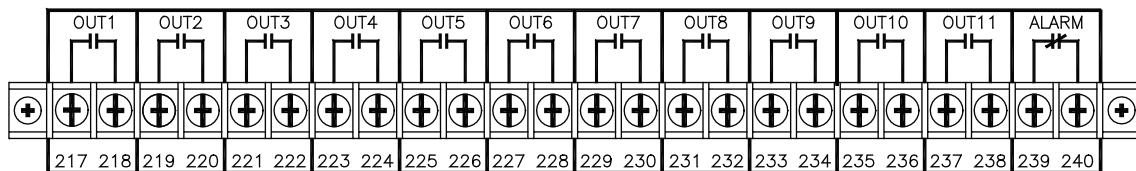


Figure J.4: Interface Board 2 Output Contacts (Board Position 1)

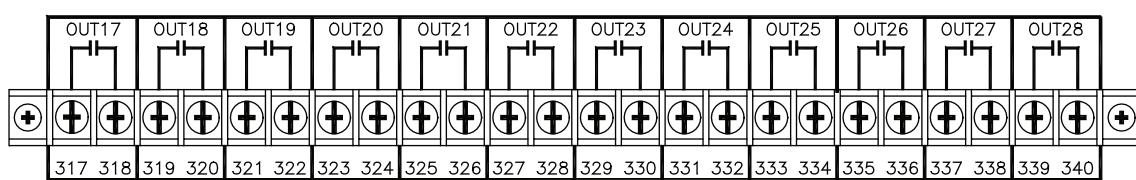


Figure J.5: Interface Board 2 Output Contacts (Board Position 2)

Configure the output contacts as “a” contacts or “b” contacts with solder jumpers. Figure J.6 shows the locations of the jumpers and explains the jumper positions. Contacts are factory-configured as “a” contacts (except the alarm contact which is “b”).

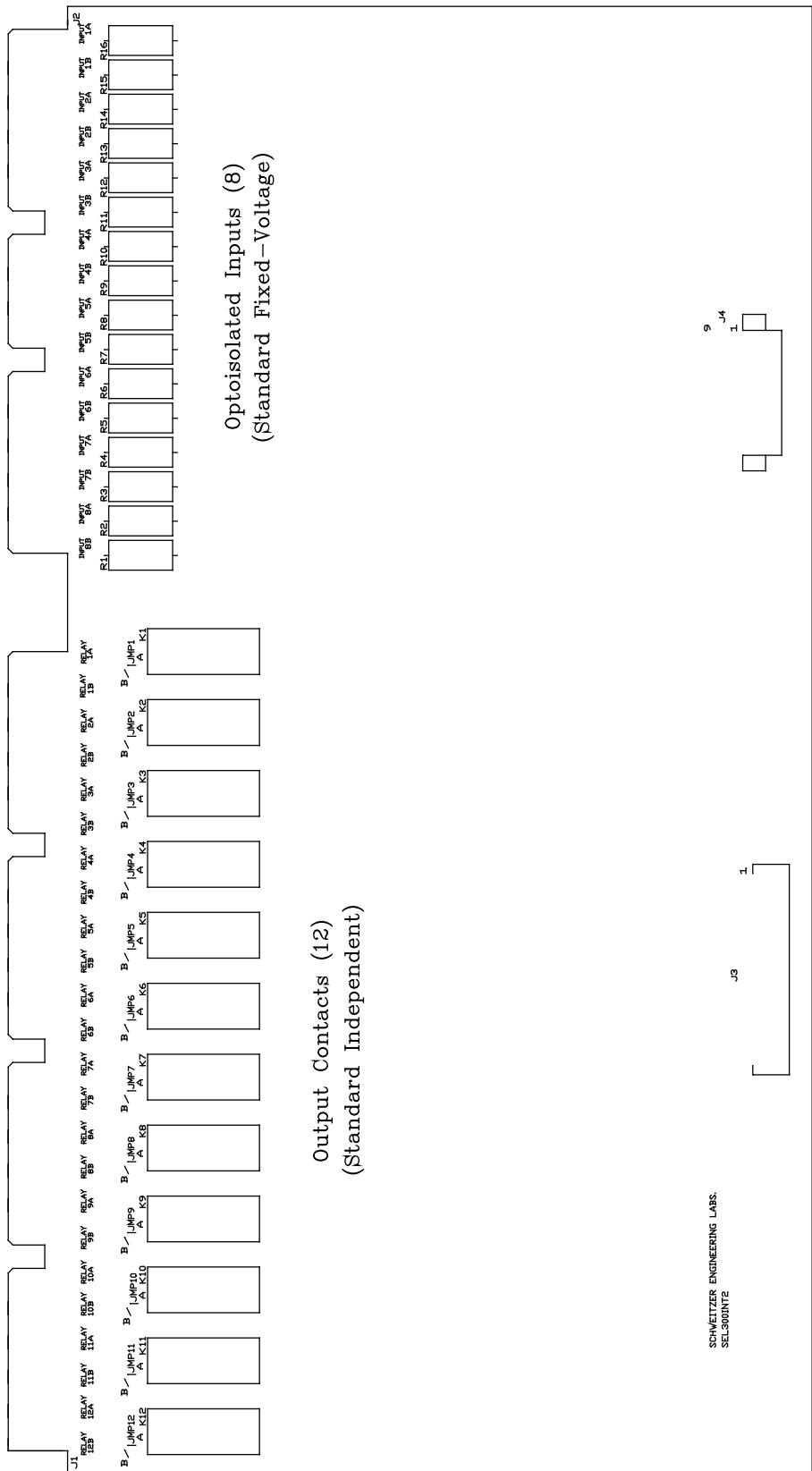


Figure J.6: Interface Board 2 Component Layout (Screw Terminal)

INTERFACE BOARD 5 (8 OUTPUTS, 8 INPUTS)—SCREW TERMINAL

Optoisolated Inputs

All eight control inputs are standard, fixed-voltage, dry optoisolated inputs, and are not polarity-dependent. The nominal rated control voltage of 24, 48, 125, or 250 Vdc must be specified when ordering. To assert an input, apply control voltage to the terminals assigned to that input. Each input is individually isolated, and a terminal pair is brought out for each input. There are no internal connections between inputs. The inputs will assert within 2 ms and draw approximately 4 mA of current at nominal voltage. For further information, see **General Specifications** in *Section 2*.

Output Contacts

30 A make

6 A carry

10 A interrupt for $L/R < 0.04$ seconds at 125 Vdc

10 A interrupt for $L/R < 0.02$ seconds at 250 Vdc

Closing (open-to-close for both “a” or “b” contacts): 200 μ s

Opening (close-to-open for both “a” or “b” contacts): typically 1/2-cycle

Interface board 5 provides eight output contacts. These eight **Fast High Current Interrupting** dry output contacts can interrupt 10 A of inductive current with an $L/R < 0.04$ seconds. At 250 Vdc, they will interrupt 10 A of inductive current for an $L/R < 0.02$ seconds. They operate (open-to-close for both “a” or “b” contacts) in less than 10 μ s (.00001 seconds). Due to relay capabilities the outputs of the SEL-321-5 Relay are specified at 200 μ s (.0002 seconds).

The output contacts may be configured as either “a” or “b” contacts with solder jumpers. Figure J.10 shows the locations of the jumpers and explain the jumper positions. Contacts are factory-configured as “a” contacts (except the alarm contact which is “b”).

Short transient inrush current may flow when a switch that is in series with the contact is closed, and the Interface 5 contact is open. This transient will not energize the circuit used in typical applications. Trip and Close coils and standard auxiliary relays will not pick up; however, an extremely sensitive digital input or light-duty, high-speed auxiliary may pick up for this condition. The transient occurs when the capacitance of the output contact circuitry is charged. A third terminal for each contact provides a path for charging the capacitance when the circuit is open. See Figure J.7 and Figure J.8.

Figure J.9 shows some possible connections for this third terminal that will eliminate the possibility of transients when closing a switch. Circuit load is not shown. In general, the third terminal must be connected to the dc rail that is on the same side as the open switch condition. If an open switch may exist on either side of the output contact, only one condition may be considered. Two open switches (one on each side of the contact) defeat the charge circuit.

The Interface 5 contact outputs are **not** polarity-dependent.

The rear of the relay will be similar to the following drawings:

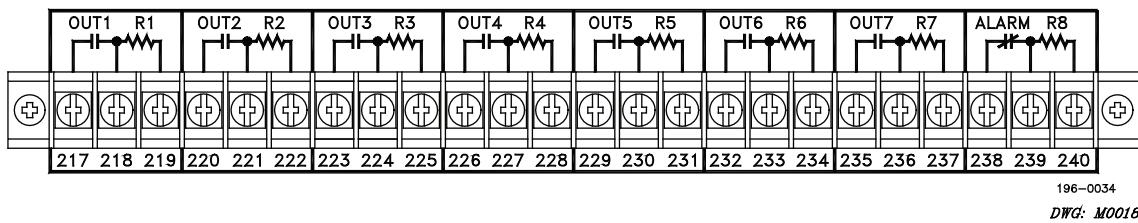


Figure J.7: Interface Board 5 Output Contacts (Board Position 1)

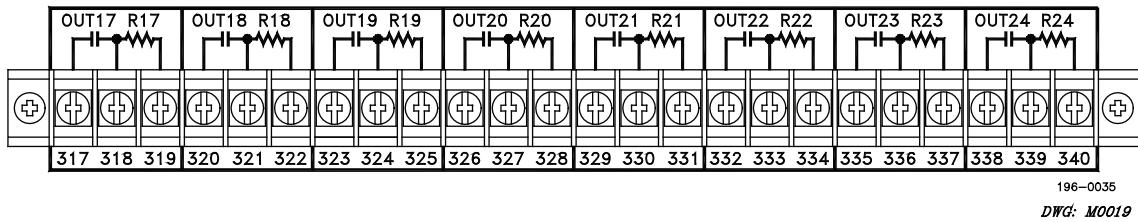


Figure J.8: Interface Board 5 Output Contacts (Board Position 2)

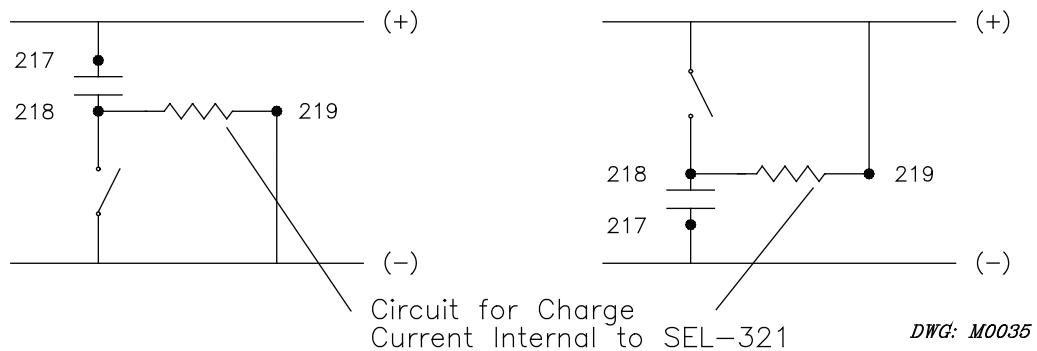


Figure J.9: Possible Connections for Fast High Current Interrupting Output Contacts (Circuit Load Not Shown, Third Terminal Connection is Optional)

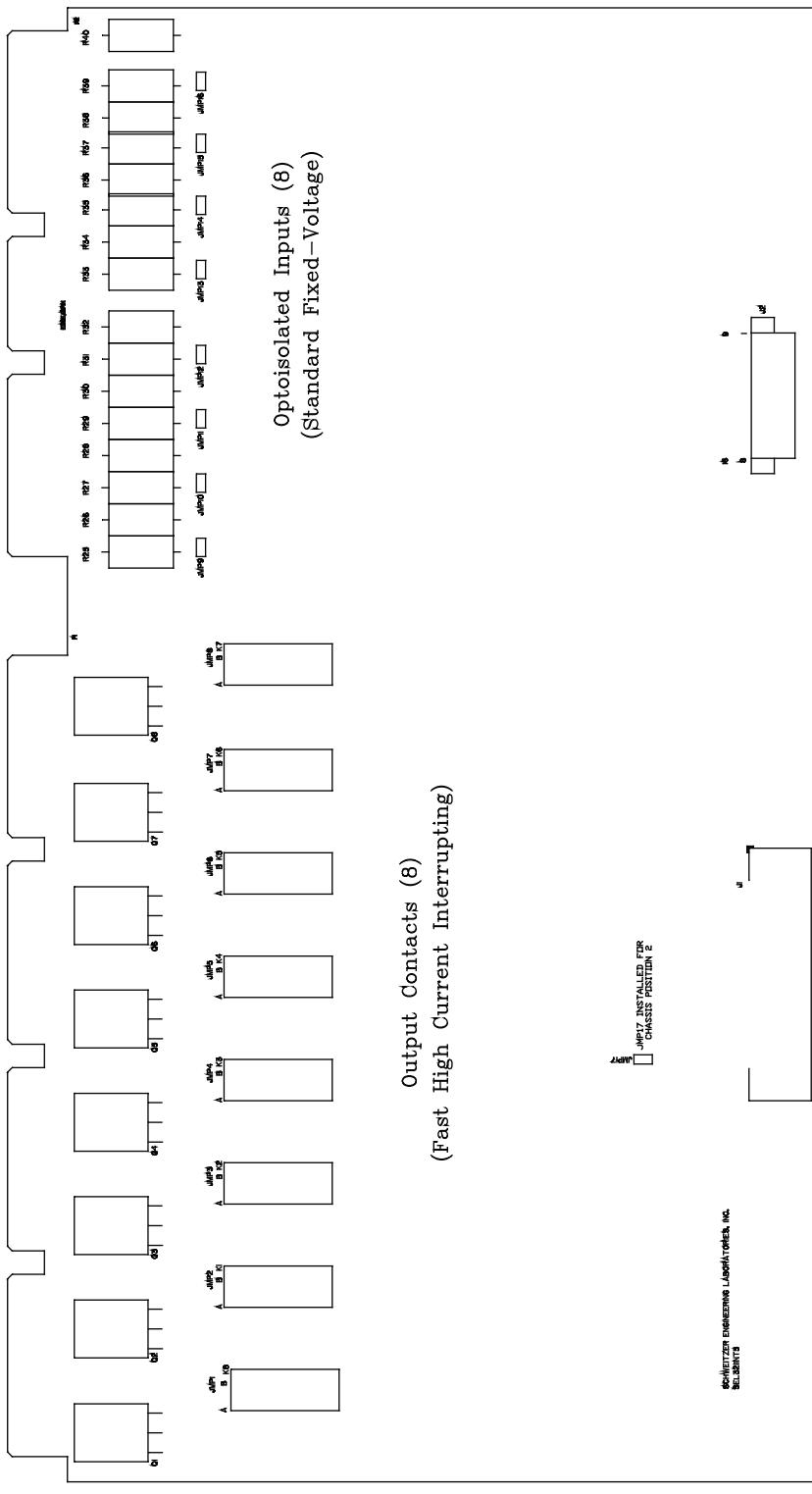


Figure J.10: Interface Board 5 Component Layout (Screw Terminal)

Output Contacts K1 – K8 Operation		I/O Board Position Selection
Solder Jumper Position		
A	Contact closes when asserted	First I/O board position selected
B	Contact opens when asserted	Second I/O board position selected

JMP17 shorting block removed	JMP17 shorting block installed
Dwg: M0029	

* Note: Revision A is jumper configurable for K8 only (alarm).
The other output contacts are type "a" only.

SEL-321-5 TARGET INFORMATION

SEL-321-5 Relay

TAR	Status Indicators							
0	INST	TIME	COMM	SOTF	ZONE1	ZONE2	ZONE3	ZONE4
1	EN	A	B	C	G	Q	51	50
2	Z4G	Z3G	Z2G	Z1G	M4P	M3P	M2P	M1P
3	Z4GT	Z3GT	Z2GT	LOP	M4PT	M3PT	M2PT	OPA
4	67Q4	67Q3	67Q2	67Q1	67N4	67N3	67N2	67N1
5	67Q4T	67Q3T	67Q2T	OST	67N4T	67N3T	67N2T	OSB
6	PD1	3P27	27L	50H	50MF	51NT	51QT	51PT
7	ZLOAD	SOTFE	TCM	CC	3PO	SPO	REJO	PD2
8	3P50R	51NP	51QP	51PP	50G	50PP	50M	50L
9	50Q4	50Q3	50Q2	50Q1	50N4	50N3	50N2	50N1
10	50ABC	X6ABC	X5ABC	3PT	TPC	TPB	TPA	32QF
11	3P59	59L	59N	59PR	59PB	59NL	59PL	50Q
12	BTX	GDS	STOP	START	FIDEN	FSC	FSB	FSA
13	32QR	KEY3	KEY1	EKEY	Z3RB	ATB	ECTT	KEY
14	XAG4	XAG3	XAG2	XAG1	MAG4	MAG3	MAG2	MAG1
15	XBG4	XBG3	XBG2	XBG1	MBG4	MBG3	MBG2	MBG1
16	XCG4	XCG3	XCG2	XCG1	MCG4	MCG3	MCG2	MCG1
17	MBC4	MBC3	MBC2	MBC1	MAB4	MAB3	MAB2	MAB1
18	SPOC	SPOB	SPOA	*	MCA4	MCA3	MCA2	MCA1
19	50HH	OSTI	50CA	50BC	50AB	*	*	*
20	Z1X	27C	27B	27A	USOSB	ROK	3PSOTF	TOP
21	LP1	SS3	SS2	SS1	EXT	DT	BT	PT
22	EXTUL	PARC	PARB	PARA	SPTE	PTXFR	LP2	LOG
23	LP3	CLOSE	52AC2	52AC1	52AB2	52AB1	52AA2	52AA1
24	LP5	LP4	TCMC2	TCMC1	TCMB2	TCMB1	TCMA2	TCMA1
25	DTA	DTB	DTC	LP6	LP7	LP8	LP9	LP10
26	RB8	RB7	RB6	RB5	RB4	RB3	RB2	RB1
27	RB16	RB15	RB14	RB13	RB12	RB11	RB10	RB9
28	ZT	Z	YT	Y	XT	X	W	V
29	RAG4	RAG3	RAG2	RAG1	MER	MTO	MTU	MTCS
30	RCG4	RCG3	RCG2	RCG1	RGB4	RGB3	RGB2	RGB1
31	50AL4	50AL3	50AL2	50AL1	VPOLV	N3PT	L3PT	PTRX
32	50CL4	50CL3	50CL2	50CL1	50BL4	50BL3	50BL2	50BL1
33	50G4	50G3	50G2	50G1	50CL	50BL	50AL	CBAD
34	OSB4	OSB3	OSB2	OSB1	50PP4	50PP3	50PP2	50PP1
35	TS	TC	TB	TA	ZLOUT	ZLIN	ILOP	50P
36	SPT_EN	OSBC	OSBB	OSBA	LBOK	52AC	52AB	52AA
37	50AB4	50AB3	50AB2	50AB1	ATPC	ATPB	ATPA	50PPL
38	50CA4	50CA3	50CA2	50CA1	50BC4	50BC3	50BC2	50BC1
39	RBAD	51NR	51QR	51PR	FTG	FTA	FTB	FTC

SEL-321-5 TARGET INFORMATION

SEL-321-5 Relay—One I/O Board Version

TAR	Status Indicators							
40	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8
41	OUT9	OUT10	OUT11	OUT12	OUT13	OUT14	OUT15	!ALARM
42	TMB8	TMB7	TMB6	TMB5	TMB4	TMB3	TMB2	TMB1
43	MIRBRK	MIRFRA	MIRPAR	MIROVR	MIRIN	MIRSYC	MIRDAT	MIRDIS
44	IN8	IN7	IN6	IN5	IN4	IN3	IN2	IN1
45	RMB8	RMB7	RMB6	RMB5	RMB4	RMB3	RMB2	RMB1

SEL-321-5 Relay—Two I/O Board Version

TAR	Status Indicators							
40	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8
41	OUT9	OUT10	OUT11	OUT12	OUT13	OUT14	OUT15	!ALARM
42	OUT17	OUT18	OUT19	OUT20	OUT21	OUT22	OUT23	OUT24
43	OUT25	OUT26	OUT27	OUT28	OUT29	OUT30	OUT31	OUT32
44	TMB8	TMB7	TMB6	TMB5	TMB4	TMB3	TMB2	TMB1
45	MIRBRK	MIRFRA	MIRPAR	MIROVR	MIRIN	MIRSYC	MIRDAT	MIRDIS
46	IN8	IN7	IN6	IN5	IN4	IN3	IN2	IN1
47	IN16	IN15	IN14	IN13	IN12	IN11	IN10	IN9
48	RMB8	RMB7	RMB6	RMB5	RMB4	RMB3	RMB2	RMB1

SEL-321-5 RELAY 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 for one second.

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 for one second.

BREAKER Answer password prompt (if password protection is enabled) to enter breaker control Access Level B. Allows execution of OPEN, CLOSE, GROUP *n*, and Access Level 1 commands.

COMM Displays MIRRORED BITS® communications summary data.

COMM C Clears MIRRORED BITS communications data.

COMM L Displays MIRRORED BITS communications data.

DATE Shows or sets date. DATE 2/3/92 sets date to Feb. 3, 1992. IRIG-B time code input overrides existing month and day settings. DATE pulses ALARM contacts when year entered differs from year stored.

EVENT Shows event record. EVE 1 shows newest event; EVE 12 shows oldest. Default report is 1/4-cycle standard, EVE *n* L = 1/16-cycle standard, EVE *n* R = 1/16-cycle unfiltered, EVE *n* C = 1/16-cycle SEL-5601-2 SYNCHROWAVE® Event Software Report, EVE *n* U = 1/16-cycle unfiltered.

GROUP Shows setting group to use in lieu of active group.

HISTORY Shows DATE, TIME, ZONE/TYPE, LOCATION (distance), GROUP, and front-panel targets for the last 40 events.

IRIG Force immediate attempt to synchronize internal relay clock to time code input. Reports ID, Date, Time, or Error Message.

METER Displays meter data.

QUIT Returns control to Access Level 0; returns target display to Relay Targets TAR O. Displays ID, Date, and Time.

SHOWSET *n* Shows active group settings for Group *n*. Shows active relay group settings if *n* omitted.

SHOWSET C Shows calibration settings.

SHOWSET G Shows Global settings.

SHOWSET L Displays active logic settings. Append group number (1–6) to display the logic settings of that group.

SHOWSET P	Shows the settings of the active port. Append port number (1–3) to display the settings of that port.
STATUS	Shows self-test status.
TIME	Shows or sets time. TIME 13/32/00 sets clock to 1:32:00 p.m. IRIG-B synchronization overrides this setting.
TRIGGER	Triggers an event report.

Access Level B

CLOSE	Asserts the CLOSE condition.
GROUP	Specifies currently selected group. Use GROUP <i>n</i> to change selected group to <i>n</i> .
OPEN	Asserts trip condition.

Access Level 2

COPY <i>m n</i>	Copies settings and logic from setting Group <i>m</i> to Group <i>n</i> .
LOOP	Enables MIRRORED BITS loopback mode for testing communications.
LOOP R	Disables MIRRORED BITS loopback.
PASSWORD	Shows or sets passwords. Command pulses ALARM contacts closed momentarily after password entry. PAS 1 OTTER sets Access Level 1 password to OTTER. PAS 2 TAIL sets Access Level 2 password to TAIL.
PULSE <i>n t</i>	Closes an output contact for testing and control purposes.
RDMEM <i>m</i>	Use to download contents of selected memory areas. <i>m</i> = RAM, EEPROM or ALL.
SET <i>n</i>	Use to enter group settings. If <i>n</i> argument omitted, edits active group.
SET G	Use to enter new Global settings.
SET L	Use SET L <i>n</i> to edit the logic settings of Group <i>n</i> . Selects active logic group to edit.
SET P	Use SET P <i>n</i> to edit the settings of Port <i>n</i> . Changes settings of the active port.
TARGET	Shows target values, and defines target group for display. TAR <i>n</i> displays target row <i>n</i> . TAR R command resets front-panel targets to TAR 1.

SEL-321-5 TARGET INFORMATION

SEL-321-5 Relay

TAR	Status Indicators							
0	INST	TIME	COMM	SOTF	ZONE1	ZONE2	ZONE3	ZONE4
1	EN	A	B	C	G	Q	51	50
2	Z4G	Z3G	Z2G	Z1G	M4P	M3P	M2P	M1P
3	Z4GT	Z3GT	Z2GT	LOP	M4PT	M3PT	M2PT	OPA
4	67Q4	67Q3	67Q2	67Q1	67N4	67N3	67N2	67N1
5	67Q4T	67Q3T	67Q2T	OST	67N4T	67N3T	67N2T	OSB
6	PD1	3P27	27L	50H	50MF	51NT	51QT	51PT
7	ZLOAD	SOTFE	TCM	CC	3PO	SPO	REJO	PD2
8	3P50R	51NP	51QP	51PP	50G	50PP	50M	50L
9	50Q4	50Q3	50Q2	50Q1	50N4	50N3	50N2	50N1
10	50ABC	X6ABC	X5ABC	3PT	TPC	TPB	TPA	32QF
11	3P59	59L	59N	59PR	59PB	59NL	59PL	50Q
12	BTX	GDS	STOP	START	FIDEN	FSC	FSB	FSA
13	32QR	KEY3	KEY1	EKEY	Z3RB	ATB	ECTT	KEY
14	XAG4	XAG3	XAG2	XAG1	MAG4	MAG3	MAG2	MAG1
15	XBG4	XBG3	XBG2	XBG1	MBG4	MBG3	MBG2	MBG1
16	XCG4	XCG3	XCG2	XCG1	MCG4	MCG3	MCG2	MCG1
17	MBC4	MBC3	MBC2	MBC1	MAB4	MAB3	MAB2	MAB1
18	SPOC	SPOB	SPOA	*	MCA4	MCA3	MCA2	MCA1
19	50HH	OSTI	50CA	50BC	50AB	*	*	*
20	Z1X	27C	27B	27A	USOSB	ROK	3PSOTF	TOP
21	LP1	SS3	SS2	SS1	EXT	DT	BT	PT
22	EXTUL	PARC	PARB	PARA	SPTE	PTXFR	LP2	LOG
23	LP3	CLOSE	52AC2	52AC1	52AB2	52AB1	52AA2	52AA1
24	LP5	LP4	TCMC2	TCMC1	TCMB2	TCMB1	TCMA2	TCMA1
25	DTA	DTB	DTC	LP6	LP7	LP8	LP9	LP10
26	RB8	RB7	RB6	RB5	RB4	RB3	RB2	RB1
27	RB16	RB15	RB14	RB13	RB12	RB11	RB10	RB9
28	ZT	Z	YT	Y	XT	X	W	V
29	RAG4	RAG3	RAG2	RAG1	MER	MTO	MTU	MTCS
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33	50G4	50G3	50G2	50G1	50CL	50BL	50AL	CBAD
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SEL-321-5 TARGET INFORMATION

SEL-321-5 Relay—One I/O Board Version

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